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CICLO XIX

ENTREPRENEURIAL BEHAVIOUR OF RESEARCHERS IN A BASIC RESEARCH CENTER: THE EXAMPLE OF CERN

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Introduction

In the last decades, in the wake of increasing attention to technology transfer, Europe followed the American lead paying more and more attention to university-industry links. Debates on technology transfer are on-going in academic journals and conferences. National and European policies are also increasingly attentive towards the necessity of transferring technology. Research centers as well as university are developing their own policies on technology transfer. However, for technology to be successfully transferred, the single researchers must be an active part of the process.

It is in this light that this work wants to explore whether researchers show an entrepreneurial behaviour either at the personal and/or at the organization level and what are the factors related to such behaviour. A researcher is here defined as having an "entrepreneurial behaviour" not exclusively by creating his own firm, but also by being active towards technology transfer and partnership with industry in many different ways. The focal point is what might move the researcher to become involved in technology transfer at large, and not what practical actions he undertakes nor what the results of his actions are.

Time and resources constraints were essential in bounding the empirical part of the research to only one research centre, where ideally the whole set of European research centers might have been subject to the study. From here the choice of CERN, the biggest international research center in Europe, but the technology transfer (TT) capabilities of which are not unique to it. Hence, the theoretical framework developed in this study may be used for successive studies in analogous research institutions, allowing for a generalization of the methodology developed and for comparison of results.

Thus, the contribution this work wishes to give is a better understanding of the understudied individual level within a public research centre. In fact, if the organization's TT policy is matched by an increasing interest of the researchers towards entrepreneurial activities, it is possible to highlight some of the factors that induced this interest to grow. Whereas, if the organization's policy is not matched by any significant change, it is possible to indicate which factors and incentives do not seem to bear responses at the level of the individual researcher and to react accordingly.

The research questions this study wants to answer to are:

- Do the researchers show an interest towards an entrepreneurial behaviour either at the individual level or at the organization level?
- Do they see scientific research and entrepreneurialism as essentially complementary or substitutive activities?
- Are there incentives that (can) play a role in encouraging CERN researchers to become (more) entrepreneurial and thus engage in technology transfer activities?

Chapter 1 presents an analysis of the literature that forms the natural background for this study. Most of the times, in technology transfer analyses, research centers are treated together with, and with no distinction from, universities; and the individual researcher's role is often neglected to concentrate on the institutional level. However, some authors notice that scientists may participate to TT, because of the prospect of financial gains, for both themselves and their research group (e.g. Trune and Goslin 1998; Mejia 1998). On the other side, the idea that TT and scientists' entrepreneurialism, as ways to create additional funds, are motivated by shrinking budgets alone has found some opposition, justified by the fact that income from TT to industry is very modest compared to governmental funds (Mowery and Rosenberg 1989).

An interesting proposition is that researchers' support of entrepreneurial activities can partly be explained by a restructuring of the evaluative norms for scientific performance (Etzkowitz 1998, 2001; Lee 1996). This shift in evaluative norms allows individual scientists to aim at two goals simultaneously: scientific excellence and profit making.

Other background literature comes from the sociology of science: from the analysis of the reward system based upon reputation effects (Merton 1968) to recent studies where knowledge is identified as commodity upon which to capitalize, (Etzkowitz 1998); and from De Solla Price's (1963) pioneering work on the concept of 'network' to recent works on the 'networks dynamics' (e.g. Callon 1994; Gibbons *et al.* 1994; Ziman 1994; David *et al.* 1997). From the economics of science comes the classical concept of scientific knowledge as a public good (Nelson 1959; Arrow 1962); from the new economics of science, comes the focus on research networks and on the choice between disclosure and secrecy (Dasgupta and David 1994, 1987). From the science policy literature comes the post-World War II rationale, as expressed by Bush (1945), that governments should "pour" money into research because of the infallibility of the linear model; as well as more complex models of the interactions between basic research, applied research, society and the market, emphasizing feedbacks among the different actors and activities (Geuna *et al.* 2003).

Chapter 2 is dedicated to the presentation of CERN and its technology transfer policy and infrastructure. Literature about the organization is briefly considered, mainly from the historical perspective (Pestre and Krige 1988), but also from the economical point of some authors, who have interpreted TT from CERN mainly in terms of its frontier-technology needs, which require industry to develop new technologies to satisfy CERN's requirements (Hameri and Vuola 1996; Hameri 1996).

Documents however are mainly to be found at CERN, especially the reports focusing on its technology transfer policy. This policy concentrates on patents, licenses, copyrights, etc., but it also highlights the importance to support staff to be pro-active about commercial exploitation of research results. Within the organization, technology transfer is recognized to happen though different means: people, purchasing, collaboration agreements with industry (Barbalat 1997), R&D special projects (CERN 2000), IPRs, consultancy and services, start-ups and spin-offs (CERN 1999, 2002b, 2003, 2006g).

Chapter 3 is composed of two parts, the theoretical framework and the research procedures.

The first part is itself divided into two sections, the first of which proposes some organizational concepts that should be considered when analyzing a basic research center. A European research center organization is constrained by a series of factors: its constituting mission as set in its founding constitution; fixed funds coming from member countries; the accountability to European research policy; the public accountability; and the researchers' goals and objectives. It will be proposed that a European research center such as CERN should remain a knowledge seeker organization, where, mediated by public and EU accountability, technology transfer is a complementary activity, which has to be mediated by the eventual entrepreneurialism of the researchers. It will also be proposed that the technology transfer policy actually in place at public research centers in Europe allow for a reading of the TT process as a peculiar form of the classical sharecropping process in agriculture. In fact, the sharecropping arrangement allows for both the landlord and the worker to gain from the outcome (although the worker usually also receives a fix wage) by sharing risks and allowing for incentives for the worker (Stiglitz 1974). Both the organizational model of a knowledge-seeker institution and that of sharecropping give relevance to the figure of the researcher. In both of them, the researcher is an active part in what happens both in the institution and in the TT process.

A theoretical framework will then be proposed to explain what factors can be expected to influence entrepreneurial behaviour (EB) of the researchers. Whereas the two factors identified as 'Recognition by peers' and 'Networks' represent a connection between the individual researcher and the community in which s/he is embedded, the factors identified as 'Prior knowledge', 'Field of research' and 'Personal character' represent the more characteristic aspects of each person as an individual. Finally, the 'Incentives' factor wants to identify a connection between the researcher and the specific organization into which s/he works and to which s/he is under contract.

The second part of chapter 3 is a presentation of the methods and procedures adopted for this study and a description of the main characteristics of the receivers of the questionnaire take the final section of the chapter.

Chapter 4 presents the results of the statistical analysis conducted on the responses to the questionnaire. The theoretical framework supposed a linear correlation between the identified factors influencing entrepreneurial behaviour and the expression of interest and attitudes towards EB by the single researcher both at the level of CERN and at the level of the researcher him/herself.
Hypotheses were confirmed, both at the individual level and at the organization level, that the desired entrepreneurial behaviour is correlated to general networks, general incentives, to prior experience in consulting and to applied research as main field of activity. Such correlations could not be confirmed in the case of recognition by peers, of CERN networks and of CERN incentives.
While aware of a technology transfer policy and infrastructure, researchers claim there were no significant changes in their relationships with industry, although the existence of financial incentives would push them to engage in TT-related activities. High shares of respondents also agree that the Lab should commercialize its research and/or technologies, set up incubators and mostly encourage its staff to provide consulting services to the industrial sector. Finally, academic career was recognized as the most attractive, followed by corporate, public sector and entrepreneurial career.

From the results obtained it is possible to draw some interpretations that are presented in Chapter 5. The starting point is that researchers do show to be interested in entrepreneurial behaviour both at the individual and at the organizational level. Although different factors influence in different ways such interest towards collaboration with industry, the fact that CERN specific factors, such as CERN incentives and CERN networks, do not show significant correlations, allows to inductively form interpretations abstracted from the Laboratory itself.

A proposition is made that it could be the case to start thinking of research organizations as "entrepreneurial organizations", much in the same way as Etzkowitz suggestion of "entrepreneurial university" (Etzkowitz 2001). At the same time, a partial revival of the linear model might be considered for the specific case of basic research centers. At the intermediate level, some relations connecting outputs from research and TT activities with costs in terms of personnel costs are proposed, for the case of fixed-terms contracts. And as a consequence of the new contract scheme at the Lab in case of TT outcomes, an information asymmetry problem arises, which should be considered within the sharecropping arrangement. At the individual level, interpretations regarding the CERN specific population of researchers are made.

To synthetize, the unit of analysis is the individual researcher; the time period concerned is that subsequent to the formal introduction of a technology transfer service; survey-based methodology is adopted; the institutional context is CERN; the broader context is that of technology transfer at non-university basic research institutes; the background literature is mainly, but not only, that of technology transfer; and the factors identified as correlated to entrepreneurial behaviour can be of use for further studies of similar institutions.

Chapter 1 – Literature review

Introduction

This chapter wants to give a panoramic view over the aspects of the literature that are at the base of the model that will be presented in the following chapters. For this reason, the following discussion is not, and does not want to be, an exhaustive and all-inclusive analysis of the literature. On the contrary, here the focus is on the main topics that should be mastered as a base for the research done in this thesis.

The chapter is organized according to the following structure:

- "The macro-level: knowledge governance" treats of the literature that deals with the entire system of knowledge governance, it looks in general at how knowledge is produced and used, without making distinctions about specific institutions and knowledge producers/users;
- "The intermediate-level: institutions producing knowledge" treats specifically of how research institutions producing knowledge deal with this knowledge, focusing on technology transfer;
- "The micro-level: knowledge producers and users" presents the relevant literature concerning the people that produce knowledge (the scientists) and the people that use it for business goals (the entrepreneurs).

Throughout the following analysis and the oncoming chapters it should be kept in mind that the knowledge discussed in the thesis is basic research. This is the research done to gain an understanding of the basic laws that govern the physical world around us in any field of knowledge (from astrophysics to computers, to medicine, to geology, etc.). This kind of research can be motivated by curiosity, by a need to better understand the basic laws in order to increase efficiency, or by any other reason.

The core of this thesis focuses on basic knowledge produced by a public international institution. As a consequence, basic research produced by industry *per se* is kept into account and recognized as an important share of the overall knowledge produced, but it is foreign to the focus of the thesis and insomuch it is only marginally discussed.

1. The macro-level: knowledge system

1.1 Knowledge as a public good

In the "classical" economics of science, scientific knowledge – here interpreted mainly as basic research – is seen as a public good, because of its characteristics of non-excludability and non-rivalry, and therefore the problem of non-appropriability (Nelson 1959; Arrow 1962). Non-excludability means that once the knowledge is available, others can not be stopped from using it, and non-rivalry means that the use of knowledge by others does not detract from the knowledge of the producers. It follows that knowledge is subject to the problem of non-appropriability because the producer of the knowledge cannot appropriate (or better maximize) the profits deriving from the production of that knowledge. Moreover, scientific knowledge is a durable good, as it is not consumed by use, and its production is uncertain, as it is not generally possible to exactly predict results and their usefulness. From here, the "market failure" approach: the private sector is not interested in producing knowledge that it cannot appropriate enough. Scientific knowledge is then a public good, which the government must fund in order to overcome "the reluctance of firms to fund their own research to a socially optimal extent because of their inability to appropriate all the benefits" (Salter and Martin 2001, p.511).

Connected to the relative positions of science and technology is a debate that has been going on for years in the economics of science: the debate of science and technology push vs. demand pull.

The demand pull party affirms that in a great number of cases research was motivated by "the recognition of a costly problem to be solved or a potentially profitable opportunity to be sized" (Schmookler 1966 cited in Bridgstock and Burch 1998).

The science and technology push party says that science is produced irrespective of economic interests: scientists research what is intrinsically interesting (e.g. Price 1963). Once in a while a discovery is made that is useful to industry, which then uses applied research to turn it into a remunerative product or process.

The science push position is basically that of the linear model of innovation, which derives by the seminal report "Science: the endless frontier" by Vannevar Bush. The post World War II rationale expressed by Bush (1945) maintained that governments should "pour" money into research because of the infallibility of the linear model.

The linear model describes a process that leads from basic science to profits in three stages, as Abetti puts it (Abetti 2002):

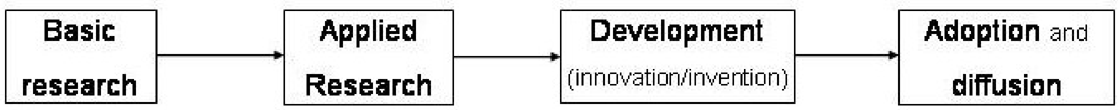
1) scientific research stage: give to the best scientists well-equipped laboratories and money and let them decide their own research, and then wait for their inevitable discoveries;

2) technology and invention stage: finance creative inventors who will translate the scientific discoveries into technology, developing new products and processes;

3) management stage: business managers insert the new products and processes in markets, creating profits that will be used to finance new research.

More in detail, the linear model can be thought as a process that starts with basic research, continues in applied research, then applied research results are developed in innovations or in inventions, which are then adopted by firms and diffused on the market (Figure 1.1).

Figure 1.1 – The linear model



Source: Geuna (2001)

In the years, authors proposed different reasons for rejecting the linear model, as shown by the few examples that follow.[1]

There have been cases where technological breakthroughs were made first and the scientific base was understood afterwards (Bernal 1971 cited in Pavitt 2000). According to Abetti (Abetti 2002), the linear model failed because it did not take into account innovation (in contrast to invention) and entrepreneurs (in contrast to business managers). Other critics to the linear model are: a) the description of the evolution of scientific and technological knowledge is oversimplified; b) the depiction of basic and applied science as two separated activities, with the former bearing no connections with the economy; c) new technological opportunities for producers are often the result of small incremental advances and not necessarily of research breakthroughs; d) current and future economic conditions influence the allocation of resources to the various research activities (David 1992).

One of the consequences of the dismissal of the linear model is that it reduced the privilege attached to internalist agendas – why should what scientists think, be more highly valued than what users of scientific knowledge think is important. Bush answered this with his ‘Gresham’s law’ statement that the isolation of science prevented short-term orientation and opportunism from crowding out ‘pure science’ (Steinmueller 1994). In a world where science is not an ivory tower anymore, this claim cannot be sustained. However – as shown by the case of CERN analyzed in this thesis – high-energy (particle) physics is a discipline in which it can be hypothesized that problem domains have no current overlap with practical purposes, but the means for exploring these domains are very likely to have overlaps. Hence, there is no reverse causation from practical pursuits to the pursuit of string theory for example, but if there are specific tests of string theory hypotheses to be made, then the problems domains relevant for making tools for performing these tests are likely to overlap with practical problems domains[2].

[1] For a detailed critics to the linear model see (Kline and Rosenberg 1986).

[2] In fact, CERN develops for its research unique and most advanced technological facilities and equipments. These are a kind of applied research not restricted by cost or market requirements. Their adoption and diffusion on the market is possible and has happened through a) incremental changes in developing new products on their base; or b) innovation due to combination of different disciplines inputs; or c) creating revolutionary means for society at large (e.g. the Web).

A partial revival of the linear model, integrated by a reshaped reward system allowing scientists to get credit also for entrepreneurial activities, may then form a theoretical basis on which to conduct the research.

1.2 Knowledge as a quasi-private good

Time and research have proven that the linear model is not entirely apt to explain reality. As stated by Antonelli "The first major shift in the economics of knowledge takes place when the notion of knowledge as a public good is challenged and knowledge is regarded as a quasi-private good with higher levels of natural appropriability and exclusivity" (Antonelli 2005).

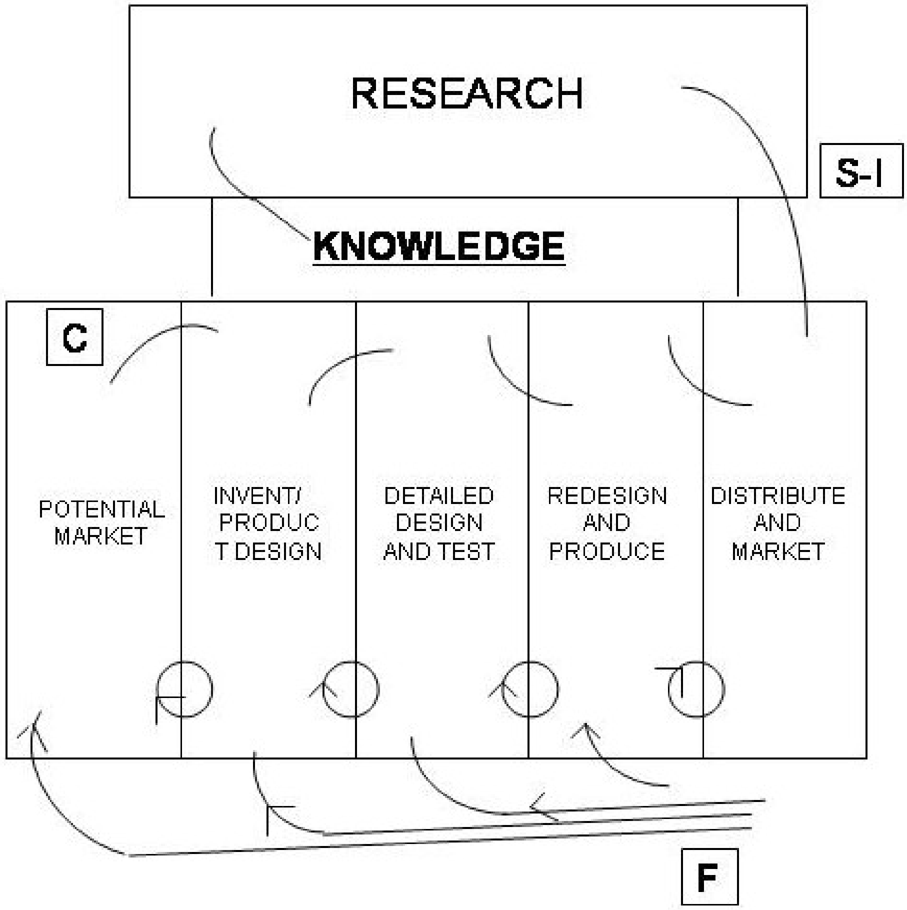
A more complex model of the interactions between basic research, applied research, society and the market was developed; emphasizing feedbacks among the different actors and activities (Figure 1.2). As synthesized by Dasgupta and David:

> "It would seem that as we look to the future there is more and more reason to treat research, both scientific and technological, as one continuous process of iteration between phases of generalization and application" (Dasgupta and David 1987, p. 525).

In parallel to the new understanding of the science and innovation interaction, many governments have taken a different approach on basic research, based on concentration and selectivity of research funds and a higher level of accountability and cost reduction. This change was due to some global factors: increasing competition, constraints on public expenditure, and the growing importance of scientific competencies (Martin 2001).[3]

[3] "An alternative way of interpreting these changes is (the shift from Mode I to) the Mode II thesis" (Martin 2001, p. 6).

Figure 1.2 - The circular model



Source: Geuna (2001)

In contrast to the view of scientific knowledge as "on the shelf, costly available to all comers" (Rosenberg 1990, p.165), the evolutionary approach suggests that it is necessary to consider how much knowledge is embodied in the researcher. Therefore scientific knowledge is not completely a public good because only those who have the necessary background can understand it; and to acquire the necessary background, investments must be made (Callon 1994).

As noted by Salter and Martin (Salter and Martin 2001), the evolutionary approach generated two lines of enquiry in the economics of science. One assumes that publicly funded research is still important in producing knowledge, here defined as information, given the different approach of private and public production of knowledge towards its dissemination: respectively secrecy vs.

disclosure approach (e.g. Dasgupta and David 1994). The other line of enquiry says that the information view does not fully describe knowledge, as part of the knowledge is embodied in people. Knowledge in part is tacit, as it cannot be transferred from one person to another by words (Pavitt 1991; Rosenberg 1990). In this second approach networks of researchers play an important role.[4]

1.3 Knowledge as a collective process

As explained by Antonelli: "The new approach is based upon the re-discovery through the 1990s of external knowledge as an essential intermediary input in the production process of new knowledge" (Antonelli 2005, p. 60). Basically, the production of new knowledge results from the interdependence (i.e. transaction and interaction) of many different agents, who are engaged in complementary research activities in the same geographic region and who are connected in network relations.[5]

The "new growth economics" takes into account R&D spill-overs as a factor of economic growth (Griliches 1992; Romer 1994). This relationship between science and economic growth is mainly studied in three lines of enquiry: 1) relationship between published knowledge and growth; 2) innovations are analyzed to study the scientific antecedents of the innovation and the time lags involved; 3) relationship between innovative activity of firms and research activities of universities (and other firms) (Stephan 1996).

All the three lines of enquiry find that spill-overs do exist, but while the former two focus on the time lag aspect, the third one is interested in the geographical aspect of spill-over effects. The rationale behind the third line of enquiry is that of tacit knowledge: the availability to the firm of close contacts with university

[4] For a compendium on the Economics of Science with informative views on sociology and policy of science see (Stephan and Audretsch 2000).

[5] For a detailed and summarized explanation on the topic of knowledge as a collective process see (Antonelli 2005). Here we focus only on the two aspects relevant to this thesis: spill-overs and networks.

researchers and of a pool of trained personnel as some of the explaining factors for economic growth through localized R&D spill-overs (Zucker *et al.* 1998; Mansfield 1995). As shown by Cohen and Levinthal 1989, in-house R&D efforts are important because they allow the firm to create new knowledge, but also because it enhances their 'absorptive capacity', i.e. their capability to assimilate, understand and exploit external knowledge (Cohen and Levinthal 1989).

Spill-overs are but a form of technology transfer in its broad definition and are valued by firms, universities and governments:

> "Firms also look to universities as a source of technology as well as trained personnel. Local and regional government also view local universities in a new light as a potential source of contribution to the economy through the formation of start-up firms" (Etzkowitz 1994, p. 11)

1.3.1 Networks

Connected to the concept of knowledge as a collective process, is the idea of networks. In the sociology of science, De Solla Price's pioneering work established the concept of 'networks', which he defined as "invisible colleges", informal groupings of around 100 scientists (Price 1963). More recent works on the 'networks dynamics' (e.g. Callon 1994; Ziman 1994; Gibbons *et al.* 1994; David, Foray, and Steinmueller 1997) offer interesting insights on the process by which networks form, work and interact within the scientific community and the industrial one.

While in the past knowledge was generated within a disciplinary, primarily cognitive, context (Mode I), nowadays there is a new method (Mode II) of producing knowledge, where knowledge is generated in "broader, trans-disciplinary social and economic contexts" (Gibbons *et al.* 1994, p. 1). The importance of networks can be implicitly recognized in some of the attributes of knowledge production in Mode II: 1) knowledge produced in the context of application; 2) trans-disciplinarity; 3) heterogeneity and organizational diversity; 4) social accountability and reflexivity; 5) quality control.[6]

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[6] For a brief critic to (Gibbons *et al.* 1994) see (Bridgstock 1998).

Many different forms of networks have been identified in the economic and sociological literature. Networks might be a collection of inter-institutional collaborative alliances or they might be a much wider range of linkages of varying levels of formality, between a large variety of different actors (Coombs et al. 1996). Examples of networks can be: 1) collaborative agreements between institutions; 2) inter-organizational linkages of all kinds (not only by firms); 3) informal networks between individuals (where the exchange of tacit knowledge is an important component); 4) formal agreements involving legal contracts between organizations.[7]

In the new economics of science, the importance of research networks for economic growth has been long emphasized (David, Foray, and Steinmueller 1997). And, as Antonelli clearly summarizes:

> Within knowledge networks, localized technological knowledge can be understood as a collective activity characterized by the complementarity between heterogeneous and yet complementary items. Such complementarity takes place especially between external and internal knowledge and the stock of existing knowledge and the flows of new knowledge. (Antonelli 2005)

In the same way, formal and informal networks are being recognized as an important feature of TT activities, both in academic literature and in policy (Nelson 1993; Chataway 1999). As shown by a study presented in 1992, informal links are a very important channel for passing scientific and technological ideas and information to industry, and formal links such as licenses or collaboration agreements might be only the tip of the iceberg of all interactions taking place (Senker 1992). This study also shows an interesting aspect of the importance of networks in scientific research, here recognized by industrialists but easily applicable to researchers working in public or academic institutions:

> "informal contacts are also a channel for linking into other networks of academics, existing contacts unable to help with specific problems often provide the name of an appropriate person to approach" (Senker 1992, p. 2).

Informal contacts between researchers and private companies potentially develop into formal contracts. For example, a study by Harmon et al. found that, in the

[7] For an indication of selected literature on networks see (Coombs et al. 1996).

majority of cases analyzed, technology was not transferred through formal searches, but thanks to pre-existing informal relationships among individuals (Harmon et al. 1997). Similarly small companies and entrepreneurial companies that use faculty members as consultants already have personal informal links at least with the university, if not with the researcher (Shane 2002b).

Networks have been shown able to introduce new theories and behaviors in research organizations, "altering the style and quality of research, the environment in which research was done, and even fundamental policies about the kinds of research to be supported" (Hoddeson 1980). In the same way, networks may also play a role in introducing and teaching entrepreneurial behaviour into research institutions, as hinted in the model proposed by this thesis.

Finally, a recent Italian study showed that the concept of network can be invoked also to partly fill the gap of geographical and cognitive distance between academic and industrial research. The results presented are the first steps of a broader program "whose ultimate goal is – in the words of the authors – assessing the role of geographical and knowledge proximity in technology transfer not just on the basis of a few assumptions on the nature of knowledge exchanges, but as a function of the social structure supporting them", i.e. social networks (Balconi *et al.* 2004).

2. The intermediate-level: institutions producing knowledge

Institutions producing knowledge are here identified as Universities, research centers, companies, formal and established collaborations between public and private bodies, etc. It is clear that these institutions are more than the sum of their researchers, as they have internal policies and functioning methods that influence how research is conducted and eventually transferred.

Connected to the dismissal of the linear model in science policy, from the point of view of institutions, are the changing reward system in sociology of science and the importance of networks. This is the Triple Helix concept developed by Leydesdorff and Etzkowitz in 1996. They suggest that the modern knowledge-based system of innovation can be seen as depending from three main spheres of influence: government, industry and university:

> We focus on the network overlay of communications and expectations that reshape the institutional arrangements among universities, industries, and governmental agencies (Etzkowitz and Leydesdorff 2000, p. 109).

Academic research is now seen as one of the main actors in creating innovation in industry, as shown by the growing importance of joint public/private patents, incubators for start-ups, university spin-offs (Martin 2001), collaboration research contracts, consulting activities by faculty member allowed by the university, etc.

2.1 Institutions producing knowledge

As already said, knowledge production arises in different organizational structures: universities, public and private research centers, individual or corporate firms, etc. Given the focus of the thesis, organizations such as firms and private research centers will not be dealt with, as they have different rationales and different operating methods. On the contrary, universities and public research centers are directly comparable with European research centers, as they receive a consistent share of their funds from the government and as they traditionally where not directly concerned with a profit-making use in terms of money of the knowledge they produced.

Lately a good part of the research community agrees that universities and research centers are facing increasing demands from the public and private sector in terms of provision of services, public accountability, etc (increasing demand of outputs). At the same time, they are receiving ever diminishing funds, which in turn make it hard to keep human resources (decreasing amount of inputs). These are the general reasons why some level of re-organization is required to knowledge providers.

As synthesized by Jacob and Hellstrom (2003) organizational drives can be divided in two categories: "relevance" and "structure". By relevance they mean that "eligibility for funding (is becoming) dependent upon the ability of research group to demonstrate co-operation with, or the expression of interest by, specified user or stakeholder groups", but also the "responsibility to see that knowledge reaches the public". Whereas by structure they mean "the general category of problems that arise as universities try to accommodate the new demands within their organizational form".

These same authors (Jacob and Hellström 2003) apply some corporate organizational models to universities: the cellular organization, the "patching" organization and the boundaryless organization. The cellular university is organized in a federal structure where a cell might be a department or a research group; each cell is capable of semi-autonomously changing function and direction on its own and interacting with other cells.

The boundaryless university should not try to eliminate all kinds of boundaries (i.e. vertical, horizontal and external boundaries, such as size, role clarity, specialization, control, etc.) but only remove the ones that don't allow the university to deal with new demands, where the most important aspect is accede to who has the relevant information, instead of who is in charge.

Finally, the patching university is one where resources are stitched and re-stitched when and where new opportunities arise. Critical aspects for the patching process are size of the research groups, modularity among them, speed and routine of the patching process.

As they put it:

> "One may combine existing activities to create critical mass and cash flow (e.g. when departments temporarily join forces in larger project bids) or one may strategically exit existing businesses and re-stitch those resources into new areas" (Jacob and Hellström 2003, p. 58).

Another approach to organizational structure of knowledge production centers is taken by Wilts (Wilts 2000). Actor-Centered Institutionalism (ACI) "concentrates its analysis on the intentional action of both individual and collective actors and relates the outcomes of interaction to the institutional settings in which these actors pursue their particular goals and interests".

In the framework of ACI, Wilts proposes a categorization of research centers in: knowledge seekers, research contractors and service providers.

Knowledge seeker organizations are characterized by a constitution and have fixed amounts of funds based on agreements, these aspects allow them to independently set their own research agenda, without being too much concerned by applicable knowledge; in this way, the researchers are allowed to pursue individual goals such as acquiring scientific reputation through publications. However, it could be argued that even if such organizations do not have "strong incentives to accommodate their internal decision-making procedures to direct external demands and expectations"(Wilts 2000, p.772), they might have incentives to accommodate *indirect* external expectations, such as research creating at least some form of byproduct that cam be transferred to the industry, therefore allowing technology transfer and public accountability.

Research contractors are autonomous organizations, but their access to funds depends on successfully 'selling' their research results. Therefore, internal decision-making is informed by what is externally considered valuable research outcome, and individual researchers will have to orient their intellectual efforts towards organizational goals and priorities.

Service provider organizations are so much influenced by gaining funds for the necessary action resources that "it may be difficult to recognize them as independent research facilities" (Wilts 2000, p. 772). Such is the case of in-house R&D divisions of public bodies, large enterprises, banks, etc. Here the individual researcher is almost discouraged to set his personal goals in a divergent direction from the organizational objectives.

This theory, then, allows for an integration of the intermediate (=organizational) level and the micro (=individual) level.

2.2 Technology Transfer

In order for research institutions to contribute to the economy, they must have in place some kind of technology transfer (TT) mechanism. In general, in TT analyses, research centers are treated together with, and with no distinction from, universities, as they both contribute to the creation of knowledge 'freely' available to the public. Moreover good part of the existing literature focuses mostly on universities and on the institutional level altogether, often neglecting the individual researcher's role in TT.

2.2.1 Technology Transfer definition

Technology transfer is a widely used term, but it is seldom given a definition. A good exception is the linguistic definition given by Autio and Laamanen (Autio and Laamanen 1995).

The word technology is composed of two Greek words: τεχνή (read: techné) and λόγος (read: logos). Autio and Laamanen define τεχνή as skill of hand or technique, and λόγος as knowledge or science. Τεχνή means art, and therefore ability or skill – thus the meaning is near enough to Autio and Laamanen interpretation – but λόγος means word or speech, and not knowledge or science. Already in ancient Greek existed the word τεχνολογία (read: technologhia), which meant systematic speech (or treatise) about an art or skill (Rocci 1987). Therefore the word technology does not exactly mean knowledge of skills, but a speech about skills, which can be extended to mean an explanation of skills, thus approaching the definition given by Autio and Laamanen.

The word transfer is also composed of two words: the preposition *trans* means across a border and the verb *fero* (from the Greek verb φέρω, read phero) means to carry (Castiglioni and Mariotti 1987). Already in Latin existed the verb *transfero* meaning to carry something from one place to another (Castiglioni and Mariotti 1987), or to carry something across a border as Autio and Laamanen put it.

Therefore, the term technology transfer means to carry the explanation of a skill from one place to another:

> Accordingly, technology transfer can be viewed as an active process, during which technology is carried across the border of two entities. These entities can be countries, companies or even individuals. (Autio and Laamanen 1995)

Under the heading of TT many different activities can be recollected: publication, education programs, technical consultancies, physical transfer of a tangible product of research with or without a view toward commercialization, as well as the transfer of property rights as the result of ownership of the intellectual property generated during the conduct of research (Bremer 1998).

Some of these activities have been in place for centuries, in fact it has long been argued that technology transfer – at least in its broader definitions – is not a novelty in the university sector (Etzkowitz 1998; Lee 1996; Martin 2001).

2.2.2 Approaches to Technology Transfer

There are various academic approaches to technology transfer. The main distinction must be made between studies concentrating on technology transfer between countries (e.g. Robinson 1988; Mowery 1994) and studies concentrating on technology transfer between actors in the economy (e.g. Lundvall 1992). The first category – where technology is transferred from the more developed to the less developed country – was labeled as developing country oriented technology transfer research. The second category – where the focus is more on technological innovation and its effects when transferred – was labeled innovation-oriented technology transfer research (Autio and Laamanen 1995).

Within the second category, there are three main approaches to technology transfer in the existing literature (Harmon et al. 1997). Their differences lie in the relation between inventors and industrial users, which can be either: non-existent (inventors and users function independently), existent and emphasized (importance of networks) or hybrid (the focus is on TT process with some outlooks on the relationships between inventors and users).

2.2.3 Technology Transfer tradition in the USA

A good part of the TT literature focuses on the USA and sees the Bayh-Doyle Act in 1980 as a cornerstone in the evolution of technology transfer from universities (Mowery et al. 2001), with analyses comparing the situation before and after the Bayh-Doyle Act.

Until 1963, the American government did not have a patent policy for its research centers; therefore each of them developed its *ad hoc* patent policy. In the same way, until then universities and researchers did not generally considered valuable holding a patent. In 1963, a Policy Statement concerning patents was issued, giving guidelines to federal agencies for the allocation of rights to inventions. In particular, the Government was trying to convince federal agencies to enter into Institutional Patent Agreements (IPAs) with the universities. This encouraged the private sector to enter in licensing agreements with universities that had IPAs (Bremer 1998).

In 1980, the IPAs were replaced by the Patent and Trademark Law Amendments Act, more known as the Bayh-Dole Act. This Act gave American universities property rights to federally funded inventions (Shane 2002a). More in detail, it created a uniform patent policy among the many federal agencies that fund research, as it enables small businesses and non-profit organizations, including universities, to retain title materials and products they invent under federal funding (COGR 1996).

An example of the importance attached by American universities to TT activities is the yearly publication by the Association of University Technology Managers (AUTM). The yearly publication is a Licensing Survey report on the number of products currently on the market due to AUTM member licensing activities. In the financial year 2000, over 5000 licenses generated Running Royalties, and around half of those products would not presently be available if not for AUTM member licensing activities (AUTM 2001).

As a consequence of the Bayh-Doyle Act, the Stevenson-Wydler Act in 1986 authorized Federal laboratories to transfer technology to industry (Lee 1996). In particular, the Federal Technology Transfer Act of 1986 (FTTA), also known as Stevenson-Wydler Act made technology transfer a subsidiary mission of the government-owned laboratories, thus expanding the licensing opportunities for those laboratories (Etzkowitz 1994; Bremer 1998).

In 1993, the Defense Authorization Act emphasized technology transfer from Defence laboratories (Frank 1993). In fact, previous legislation treated the services as separate agencies for technology transfer purposes, but this act implements some new responsibilities regarding defence conversion, of which technology transfer is seen as a part.

2.2.4 Technology Transfer tradition in Europe

In the wake of US attention to technology transfer, Europe followed the American lead in the last three decades, giving more and more attention to public research-industry links.

Europe's history of countries collaborating in RTD programs is an old one, starting from the creation of CERN in 1952, passing through ESPRIT (European Strategic Program for Research and Information Technology) in 1983 and RACE (Research and development in Advanced Communications technologies in Europe) in 1985, to arrive to the Framework Programs (Sessano 2001).

The real turning point for EU policy towards active collaboration and enhancement of links between public and private research was the ESPRIT program. It was established to keep pace with the USA and Japan in microelectronics and it was the model upon which the Framework Programs (FP) were shaped (Sharp 2001). The first FP (1984-1987) was conceived to strengthen strategic industrial areas by funding academic and industrial research actors in the strategic areas and stimulating the formation of research networks (Sessano 2001). Since the late 1980s the European Commission started to actively stress the importance of TT through its Strategic Programme for Innovation and Technology Transfer (SPRINT) in 1989 (Charles and Howells 1992), under which a series of 16 trans-European investment fora was initiated. However, it was only since the fourth FP that technology transfer was explicitly stated as one of the objectives of the program (European Commission 1997), as it is one of the aims of the European Research Area, which the 6th FP tries to create. Finally, from the earliest proposals of the 7th FP, it is clear that TT in the broadest sense will be actively supported:

> In order to strengthen the diffusion and use of the output of EU research, the dissemination of knowledge and transfer of results, including to policy makers, will be supported in all thematic areas (CORDIS 2005).

At the single country level, UK, Germany and France have a long-standing tradition of involving potential users of research (i.e. industry) in public research advisory committees, whereas TT policy is a more recent phenomenon in countries such as Italy, Portugal and Spain (Senker et al. 1999).[8] In any case, a discussion on the different TT policies of European countries would be out of topic here, as CERN is recognized the state of international organization, and therefore it is not subject to any single state policy, but to general EU policies[9].

2.2.5 Institutional incentives to entrepreneurial researchers at CERN and in other research centers

In the TT literature reviewed until now, whenever the focus is entirely on public research centers, these are mainly analyzed as partners in research joint ventures (Leyden and Link 1999) or as sources of spin-off companies (Carayannis *et al.* 1998; Steffensen *et al.* 2000). In the latter kind of analyses it is often pointed out the importance of the entrepreneurialism of researchers, and the importance of incentives from the mother-institution to enhance such entrepreneurialism (European Commission 2000).

Within TT literature, few studies were dedicated to European basic research centers, although with no explicit focus on the individual researcher's role in TT. One of these studies, commissioned by the European Commission and entitled

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[8] For a detailed analysis of differences in public sector research in the following European countries – Denmark, France, Germany, Hungary, Iceland, Ireland, Italy, Norway, Portugal, Spain, Sweden, and the UK – see (Senker et al. 1999).

[9] At any rate, regarding TT, CERN has a policy of equal opportunities towards Member States, and this creates an important peculiarity when compared to conventional TT process analyses.

"Getting More Innovation from Public Research", concludes that more has to be done to improve and understand TT capabilities of large public research institutions, possibly through benchmarking methodologies and activities (European Commission 2000).

An introductive survey was conducted by the author in 2003 while at CERN, in collaboration with Dr. Snoeys of CERN. We wanted to gather data on how were the incomes from licensing distributed among the institution and the inventor at other major research centers and/or universities. To this goal we decided to directly contact the TT (or corresponding competent) offices. Please note that for simplicity, researchers transferring technology through the office in place were called inventors, even when they might have acted as consultants or developers.

Table 1.1 – Technology Transfer Income Redistribution at other European Institutes

EMBL - European Molecular Biology Laboratory International organization	40% to the organization 25% to the inventor's group 30% to the inventor 5% to EMBL
Paul Scherrer Institute Switzerland	33% to the organization (general fund) 33% to the inventor's group (department) 33% to the inventor
Forschungszentrum Julich Germany	85-90% to the organization 10-15% to the inventor
CEA Commissariat à l'Energie Atomique France	bonus for invention 1250 E if inventor's share < reference salary 50% to the organization 50% to the inventor for part of inventor's share > reference salary 75% to the organization 25% to the inventor
ESRF - European Synchrotron Radiation Facility International organization	inventor's share was a maximum of 5000 Euros over the duration of the patent, it was under review.
CNRS France	Up to 50% for inventor (no more details given)
Weizmann Institute Israel	60% to the organization 40% to the inventor

NB.: Instead of correct cost accounting some institutes subtract a significant percentage from the gross revenue to cover cost and to obtain the net licensing income. For those cases the percentages were calculated on gross income to avoid significant distortion.

Source: Original work by D. Sessano and W. Snoeys 2003.

The main rationale for conducting the survey as a CERN survey was to obtain data that might be used by the TT office, in order to better understand what its situation was in comparison to institutions that were faced by similar issues.

The results obtained are shown in the two tables Table 1.1 and Table 1.2 divided in European (and an Israelian) Research Centers and American Research Centers.

Table 1.2 – Technology Transfer Income Redistribution at some American Institutes

Stanford University USA		33% 33% 33%	to inventor's faculty or school to the inventor's group (department) to the inventor
MIT USA		28% 28% 28% 15%	to the organization (general fund) to the inventor's group to the inventor toTT
Columbia University USA	Up to 100k US$:	20% 20% 40% 20%	to the inventor's department to the inventor's research to the inventor toTT+overhead
	Beyond 100k US$:	20% 20% 20% Rest	to the inventor's research to the inventor toTT+overhead some to department, but not specified…
University of California (e.g. Berkeley, Davis…) USA		52% 15% 33%	to the organization to the inventor's site to the inventor

NB.: Instead of correct cost accounting some institutes subtract a significant percentage from the gross revenue to cover cost and to obtain the net licensing income. For those cases the percentages were calculated on gross income to avoid significant distortion.

Source: Original work by D. Sessano and W. Snoeys 2003.

When the survey was done, CERN resulted to be coherent with the vast majority of fellow research centers and university. In fact, from the formalization of its TT policy, CERN used to divide TT net income from a project in the following way (CERN 1999):

- 30% to the inventor
- 25% to the inventor’s group
- 45% to TT office to be reinvested.

In this way, incentives for TT activities were strong both at the individual researcher's level and at the group level. At the same time, a significant percentage would remain at the TT group so that other projects might be undergone.

However, in March 2005, the Finance Committee opted for a different method of redistributing TT incomes. TT revenue was defined as the sum of all remunerations coming from TT activities (lump sums, royalties, funds received for specific collaboration or partnership projects). Net TT revenue is given by the detraction to Gross TT revenue of: TT overheads, technical department costs (included the reward to the inventor) and material and manpower costs. TT net revenue would now be completely re-injected in the TT group, whereas to the researcher(s) responsible of the transferable technology will be remunerated, always at the discretion of the Director-General by:

- an added step (or steps) in their career path,
- and/or by an added remuneration called the "Responsibility Allowance" for the TT effort made (this is an extra-salary that is paid for the period of time for which the effort was made)
- and/or by a special remuneration called "Premium for Exceptional Services" (this is a once-only bonus given to the individual researcher).

This policy change is somewhat striking if compared to the results of the survey obtained in 2003. In fact, of all the organizations contacted only ESRF had a fixed sum of 5000 Euros as the only reward for the inventor, but it was told us that such policy was under review. No institution at all had a policy where it was entirely to the discretion of the Director-General to decide how the inventor should be remunerated of his TT activities and in what amount, on a case to case base. This awkwardness of CERN raises interesting points regarding the modelization of internal organization concerning TT policy at CERN, as will be discussed in the next chapter.

2.2.6 Concerns over Technology Transfer emphasis

Before concluding the analysis of TT literature, it is important to notice that there also are authors concerned about a too strong emphasis on technology transfer from universities and public research centers.

Although technology transfer policies have been a priority in the USA, authors are beginning to question their validity. Betz tried to identify the reasons for TT policies failure (Betz 1994):

1) lack of focus - research must be fundamental but technologically focused and usable, so any basic research project needs to designed from the beginning with the industrial partner;
2) incompleteness - research output must be applicable from the practical point of view - materials used, processes, etc.;
3) lack of recipient and/or proper incentives - recipients and/or incentives to the user must be taken into account in the project planning and focus.

Another of the main concerns is that too much attention on TT may "distract" academics from their original missions: education and research (Byckling et al. 2000; Martin 2001).

Focus on TT activities may create potentially dangerous consequences:

1) a shift in academic research towards more promptly "sellable" research;
2) an involvement of academic researchers in post-discovery activities (e.g. commercialization), instead than in new researches; and
3) changes in the ways and channels by which academic research passes to the market (Feller 1990).

This focus on short-tem research may allow capturing immediate economic returns, but may cause the unavailability of enough long-term funds to fund extensive basic research. Moreover, it can cause a shift in the norms governing academic research, giving to it a definition of knowledge as something that must produce gains, instead than something that should be pursued just to enhance human comprehension of our world. In the "new economics of science", the relationship between science and technology must be one of equals:

> "Although the contributions of scientists and technologists in the search for knowledge may be perceived to be interdependent and even symbiotic, we

> shall suggest that science as a social entity today is in danger of being undermined by the technological community's conception of knowledge as a form of productive capital” (Dasgupta and David 1987, p. 521).

2.3 Sharecropping and Technology Transfer

“In general terms, share contracting involves two or more individuals combining their privately owned resources for some mutually agreed productive purpose; the outputs being shared in mutually agreed proportions. While this is a universal feature of industrial enterprise in capitalist economies, it is also one of the most common contractual relationships in fishing enterprises and in non-capitalist farming economies” (Robertson 1980, p. 411).

Sharecropping is a classical and ancient arrangement still used in agriculture where the owner of the land capital, the landlord, is not directly involved in manually productive activities on his own land, instead it is the worker (labour supplier) who manually works the land in order to produce an output; the output is then shared between the landlord and the worker.

Debates on sharecropping have been ongoing from Adam Smith to nowadays. However, if classical economists – e.g. Adam Smith, John Stuart Mill, Alfred Marshall, Karl Marx – agreed on condemning sharecropping focusing on the undersupply in the allocation of resources, modern economists started to study this arrangement from the point of view of its insurance properties (Braido 2003)[10].

In his seminal paper, Sitglitz (Stiglitz 1974) showed that understanding sharecropping can enlighten the “complex phenomena of shareholding in modern corporations” (Stiglitz 1974, p.219), by focusing on risk sharing and incentives. Later on in the thesis, it is shown that the same concept can be used to explore the TT policy of CERN and that of a number of other research centers which have a similar policy.

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[10] For a good review of modern economics studies on sharecropping see (Braido 2003) and (Robertson 1980).

At this point, it might be useful to remember that the incentives theory states that economical subjects must be provided incentives to behave efficiently, even in presence of asymmetry of information, by setting contract terms rewarding them in case of good performance and penalizes them in case of unfair behaviour or adverse selection (Nicita 2005).

In a series of elaborations of the model, introducing each time more variables, Stiglitz (1974) showed that – contrary to the then common view – sharecropping is an arrangement which is efficient in an economy where there is an asymmetry of information. In fact, under sharecropping the landlord is not able to perfectly measure the effort of the worker as the output is not only a function of a measurable input (e.g. hours of work), but also a function of effort (i.e. pace of work, thoroughness, efficiency, decision making and inventiveness) and of other variables which can not be forecast, as weather, disease, etc. (Stiglitz 1974). If information were perfect, the worker would receive a wage. But as information is not perfect, than the worker is given a share to provide him incentives to produce and the risks are shared between the landlord and the worker (Stiglitz 2000); whereas, in case of wage, the worker would have less incentives and bear no risks, giving rise to moral hazard problems[11] and the landlord would have to monitor him. The contrary would be true in case of a rental contract, where the worker would have all the incentives but bear all the risks of fluctuations in output.

As Stiglitz himself explains, the alternatives to sharecropping are the following:

> "Sharecropping represented a compromise between balancing concerns about risk sharing and incentives. The underlying information problem was that the input of the worker could not be observed, but only his output, which was not perfectly correlated with his input. The sharecropping contract could be thought of as a combination of a rental contract plus an insurance contract., in which the landlord "rebates" part of the rent if crops turn out badly. There is not full insurance (which would be equivalent to a wage contract) because such insurance would attenuate all incentives." (Stiglitz 2002, p. 465)

[11] We have a moral hazard problem when – after the contract – the actions of the agent (i.e. the worker, the one that has more information) are not entirely observable by the principal (i.e. the landlord, the one who has less information), by these same actions affect the utility of both the agent and the principal. The impossibility by the principal to observe the behaviour of the agent, allows the agent to act for his own goals to the detriment of the principal (Nicita 2005). Moreover, as in the case of sharecropping, the principal can only observe the output, which is only partly influenced by the actions of the agent.

In the theoretical chapter, it will be shown that is possible to use Stiglitz's concept of sharecropping to explain the TT policy of CERN. In the parallel, CERN is the landlord, as it is CERN who owns the laboratory and the capital (=the field) to undertake the research; the researcher is the worker, who uses the assets owned by CERN to do his/her research; incentives are present for both CERN and the researcher to transfer the results of the research or the technologies used for the research to the industrial sector as economical revenues are shared between the two.

3. The micro-level: knowledge producers and users

Single knowledge producers (= researchers) and knowledge users (=entrepreneurs) are also very important in analyzing the interactions between science and the economy. As a sum, in fact, they influence the overall picture (and particularly the institution in which they are inserted) with their own behaviors and beliefs. In the same way, the incentives they have will affect what they do and how. And the same is true for both researchers and entrepreneurs.

3.1 Knowledge producers: the researchers

3.1.1 The reward system

In the sociology of science, Merton (Merton 1957) seminal work explains that the normative system is constructed around the concept of advancing knowledge. In fact, the scientist's role is to advance the existing knowledge and his fulfillment is to do it in the best possible way. As, knowledge advances through originality, the scientist that made original contributions to the stock of knowledge is the scientist that will gain the recognition and esteem of his colleagues. In this way, the self-interest of the scientist (gain esteem and establish his position) and the moral obligation (advance the existing knowledge) come together to form science normative system. It comes by itself, that the claim of priority is fundamental in establishing the originality of the scientist's contribution.

In Mertonian terms, the reward system in science is based on the importance of the scientist's contribution to knowledge (Merton 1957). Rewards can be honorific – eponymy, awards and membership in honorary academies – and material – advancement in university hierarchy, and increase in remuneration.

One limit of such a reward system is the Matthew effect, which states that higher level of recognition is given to those with past successes:

> "The Matthew effect consists in the accruing of greater increments of recognition for particular scientific contributions to scientists of considerable repute and the withholding of such recognition from scientists who have not yet made their mark". (Merton 1968, p. 58)

Much earlier Lotka had already noted that publication counts were skewed as a small number of people made the majority of contributions, whereas over 60% of the authors made only one contribution (Lotka 1926). More recent studies show that Lotka's law and Matthew effect still apply in the awarding of prizes, even if the quantity and richness of the rewards has increased (Zuckerman 1992).

Whereas Merton's idea of reward systems was based upon reputation effects, recent studies go further by identifying a process of "capitalization of knowledge" (Etzkowitz 1998), where researchers actually treat knowledge as a commodity upon which to capitalize. The focus is not anymore on the material rewards deriving from scholarly activity (i.e.: how much a new publication or citation increases scientist's remuneration), but on whether the scientist is interested in "commercializing" his/her knowledge to obtain financial gains. Such a behaviour is consistent with that of most economic agents and shows that scientists are interested in rewards coming from industry, such as ownership of stock holdings, consulting fees, licensing agreements, etc (Stephan and Everhart 1998).[12]

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[12] As will be seen in Chapt. 3, sect. 3.1 and sect. 4, CERN researchers can not directly interact with industry and any income deriving from their collaboration with industry as part of their activity at CERN does not automatically create a remuneration, although a reward (monetary or otherwise) can be awarded by the Director General on a case-to-case base..

3.1.2 Complements and substitutes

The enlargement of scientists' interests to economically rewarding activities raises the question whether performing scientific research and trying to profit from this research are complements or substitutes activities.

Being one of the most classic in economics, the concept of complementary or substitutive goods was raised at the institutional level concerning scientific and entrepreneurial activity (Geuna 2001; Stephan and Everhart 1998). To our best knowledge there is a gap in the literature as this concept was not raised at the individual level, analyzing whether there is a shift towards more applied research to the detriment of basic research or towards entrepreneurial activities to the detriment of classic scientific activities (research and teaching).

Research could be seen as an activity which has a dual use: one "academic" for reward in Mertonian terms, and one industry-oriented, for reward in monetary terms. In this sense, analogies with "dual use" technologies might be hypothesized.

The concept of dual-use technology states that technologies and R&D developed for military use can be transferred into the civilian economy to stimulate civilian technologies (Etzkowitz 1994).

Paraphrasing, it might be said that research and technologies developed for academic use can be transferred into the civilian economy to stimulate civilian technologies.

A further reason for considering the problem of complementarity or substitution effects is the different attitudes towards the dissemination of scientific knowledge in the scientific and industrial communities. In the scientific community knowledge is usually made readily available because of the priority race, whereas in the industrial world knowledge is usually kept as secret as possible to keep an advantage on competitors.

3.2 Knowledge users: entrepreneurs

Entrepreneurship research is not yet considered a self-standing domain of social sciences by most of its own scholars. This is due to the fact that research focuses on a too wide array of problems and from multiple perspectives and disciplines: economics, psychology, finance, marketing and management (Low 2001).

Between entrepreneurship research scholars there are still open debates on fundamental questions such as the definition of entrepreneurship (Low 2001), the purpose of entrepreneurship research (Davidsson *et al.* 2001), and the need for a theory of entrepreneurship (Davidsson, Low, and Wright 2001; Low 2001) and research gaps that need to be addressed are identified (Ucbasaran *et al.* 2001).

An overview of entrepreneurship research literature is presented below to give a general framework for subsequent concepts useful for this study. Such presentation is kept short in order not to be drawn in considerations external to this thesis[13].

3.2.1 Entrepreneurship research: an overview

Entrepreneurship research received increasing attention after the publication of a seminal paper by Low and MacMillan (Low and MacMillan 1988), where the authors identified six design specifications that should be present in every entrepreneurship research work: purpose of the research, theoretical perspective, focus of the phenomena investigated, level(s) of analysis, time frame and methodologies. Already at that time, Low and MacMillan noticed that too many definitions of entrepreneurship were present in research papers and concluded that "each (of these definitions) are captures an aspect of entrepreneurship, none captures the whole picture" (Low and MacMillan 1988). Discussing the purpose of entrepreneurship research, the authors proposed that it should try to explain and facilitate the role of new enterprises in economic growth (Low and MacMillan 1988).

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[13] For a brief summary of the main schools of thought in entrepreneurship research see (Shane 2000).

Over ten years later, Low seems to have softened his position into a purpose that varies according to the envisaged role of entrepreneurship research. If it is seen as teaching support then the purpose should be just that of facilitating the role of new enterprises; if entrepreneurship research is considered a "potpourri" of other academic domains, then there is no space for a specific purpose; if entrepreneurship research is seen as a set of issues that can and should be investigated from multiple disciplines, then there is no need for a purpose and a theory of entrepreneurship, whereas there is a need for a theory in economics (or psychology, finance, etc.) to address the different aspects of entrepreneurship; finally, if entrepreneurship is to be constructed as an academic field *per se* then it needs to narrow its focus according to the definition of entrepreneurship that will be adopted (Low 2001).

A good number of approaches within entrepreneurship research saw the light since Low and MacMillan seminal contribution: opportunity recognition theory, resource acquisition theory, behavioral aspects of entrepreneurs, categorization into different types of entrepreneurs, entrepreneurial teams, external environments (see Ucbasaran, Westhead, and Wright 2001 for a brief critical description of these approaches).

3.2.2 Entrepreneurship shaped by context, process and outcomes

What most scholars of entrepreneurship research seem to agree upon is that research should focus on process, context and outcomes. This methodology of research, first proposed by Low and MacMillan (Low and MacMillan 1988), has been widely accepted by researchers, although the interpretation of what "process" means has given way to variations. Some, for example, see it as an indication that beyond entrepreneurs' characteristics and efforts, also organizational, environmental and creation processes influence the entrepreneurial adventure and outcomes (Gartner 2001). Others interpret the process as the recognition and exploitation of opportunities process (Shane and Venkataraman 2000). Others understand this focus on process, context and outcomes as an indication that an evolutionary approach should be used in entrepreneurship research (Aldrich and Martinez 2001). The importance of networks is recognized by various authors, such as Lin (1999) and Burt (1992) (cited in Aldrich and Martinez 2001). The importance of social context is highlighted also by those trying to find a compromise between psychological and social determinants of entrepreneurship (e.g. Katz 1992).

A number of approaches have been used in entrepreneurship research and bear connections with this research project: psychological determinants of entrepreneurship, personality characteristics of the entrepreneur, entrepreneurial orientation and entrepreneurial intent, theory of planned behaviour, behavioral and cognitive aspects of the entrepreneur, the role of networks in entrepreneurship, opportunity recognition and exploitation by entrepreneurs, and environmental factors affecting entrepreneurship.

Although these approaches differ from a theoretical perspective – some of them identifying the determinants of entrepreneurship within the entrepreneur, while others emphasize the role of external factors in entrepreneurship (Gartner 2001) – they can offer useful insights in trying to explain what factors might influence an entrepreneurial behaviour in researchers.

3.2.3 Entrepreneurial intent – theory of planned behaviour

Entrepreneurial intent has been the goal of explanation of some theories within entrepreneurship research. One of them is the theory of planned behaviour.

Originally developed in the 1980s mainly by Ajzen, it recognises three antecedents to entrepreneurial intent. As explained by Autio et al. (Autio et al. 2001), the first – attitude towards behaviour – reflects the evaluation of the behaviour by the individual; the second – subjective norm – reflects the social pressure to undertake the behaviour; the third – behavioral control – reflects the control perceived by the individual in actually undertaking the behaviour. This last aspect is considered to be the most important one in influencing the intention of performing the behaviour. As rightly stated:

> “If the person does not perceive to have control over the behaviour and its outcome, intentions are not likely to lead to behaviour, even though subjective norms and attitudes towards the behaviour would be favourable”(Autio et al. 2001)

It might be possible to relate this theory to Etzkowitz’s stress on the influence of social norms in entrepreneurial studies (Etzkowitz 1998, 2001). In this way, a theoretical confirmation of the importance of social norms in entrepreneurial behaviour can be obtained.

3.2.4 Entrepreneurial orientation

The concept of entrepreneurial orientation (EO) is analyzed in some depth by Lumpkin and Dess (Stephan 1996). According to them, “entrepreneurial orientation refers to the processes, practices and decision-making activities that lead to new entry. (…) Thus, it involves the intentions and actions of key player functioning in a dynamic generative process aimed at new-venture creation”. Five dimensions of EO are presented. Although referred to the firm level, four of the five dimensions might be applied at the individual level too, thus helping to characterize some of the attributes possessed by entrepreneurs and aspiring-entrepreneurs. These dimensions are: autonomy (independent action of an individual in bringing forth an idea or a vision and carrying it through to completion); innovativeness (in the Schumpeterian sense of “creative destruction” and “new combinations” of existing products and processes); risk taking (financial, personal and social risks); and finally, proactiveness (a forward-looking perspective). Again, without being drawn into entrepreneurship research, these dimensions are important aspects of which to be aware in creating the questionnaire for CERN’s researchers.

3.2.5 Opportunity recognition and prior knowledge

Three elements have been recognized as essential for the success of nascent entrepreneurs: human capital, financial capital and social capital (Aldrich and

Martinez 2001). By human capital is meant the entrepreneurial knowledge: formal education, previous experience and informal training of the entrepreneur. Financial capital is of course the initial endowments necessary to a new firm. And the social capital is understood as the access to, and position in, social networks, which will allow the entrepreneur to obtain information, knowledge, and other resources that he/she does not have.
It was also proposed that the study of entrepreneurship should be defined as "the scholarly examination of how, by whom, and with what effects opportunities to create future goods and services are discovered, evaluated, and exploited" (Shane and Venkataraman 2000,. p.218). Therefore, entrepreneurship research should focus on the sources of opportunities, the process by which such opportunities are discovered, evaluated and exploited, and the individuals that see and use such opportunities.

Entrepreneurial opportunities are defined as situations in which new goods, services, raw materials and organizing methods can be introduced and sold at greater than their cost of production (Casson 1982 cited in Shane and Venkataraman 2000).

To recognize an opportunity an entrepreneur must have a prior knowledge (Shane 2000) that allows him to capture the potential marketability of the new product or process. The fact that prior knowledge is highly personal, helps explaining why new opportunities are obvious only to some people and not to everybody. Therefore, it has been argued that opportunity discovery is a function of the distribution of information in society (Shane 2000), which is in turn connected to the issue of asymmetric information.
In this optic, there are three main research questions in entrepreneurship studies:
(1) why, when, and how opportunities for the creation of goods and services come into existence; (2) why, when, and how some people and not others discover and exploit these opportunities; and (3) why, when, and how different modes of action are used to exploit entrepreneurial opportunities. (Shane and Venkataraman 2000, p. 218)

Conclusions

This whole chapter was based on the assumption of discussing concepts that will – directly or indirectly – inform the model proposed in the theoretical framework chapter.

In fact, we will try to show how an institution (CERN, in this case) and its knowledge producers (researchers) are interconnected, while trying to understand whether the researchers are interested to act as 'entrepreneurial' scientists in the broad sense, i.e. to actively transfer, in the broad sense, their knowledge industry. We will propose that internal policies and rules and incentives influence both what researchers can do (= behaviour) and would like to do (=norms). This, in turn, affect CERN, as an organization, transfers its knowledge to the wider world than specialists.

Chapter 2 – CERN: what is it and how does it define its Technology Transfer

Introduction

This chapter intends to acquaint the reader to the multifaceted world of CERN, in general, and of its Technology Transfer service and policy, in detail.
The chapter is divided in four sections.

The first and second sections give a general presentation of CERN, highlighting its uniqueness, presenting its organization and its day-to-day activities. Literature about CERN and by CERN is also considered. A number of studies have been conducted since the creation of CERN, analyzing it from many different perspectives: historical, economic, etc. (e.g. Pestre and Krige 1988; Pavitt *et al.* 1982).

The third section focuses on Technology Transfer Policy (TTP) at CERN. It gives an overview of the steps by which it was introduced and put into practice. It also presents the TT service, giving a brief explanation of how this group is organized and works.
Documents for these two sections are to be found exclusively within CERN. Some of them, as the financial committee reports are not public, and the author thankfully acknowledges the permission granted to access them. Specific economic figures could not be reported, but general indications are available throughout the chapter.
Finally, the fourth section presents the Human Resources database of CERN, from which descriptive data can be drawn.

1. The history of CERN

CERN[14] mission is to investigate the fundamental constituents of matter and what forces hold them together (CERN 2005b), in a quest to understand how the universe came to be as it is.
CERN studies the particles that constitute the atomic and subatomic structure through an accelerator, now being upgraded to become the Large Hadron Collider (LHC), housed today in a 27 km ring that accelerates particles to almost the speed of light, and particle detectors – equipments able to register and analyze the fragments of matter coming out from the collisions among particles. Since its creation, the results of its research are freely accessible to the public and there is no connection with any kind of military activity or commercial exploitation of nuclear power.

As clearly stated in Article II of its founding convention, CERN goals are the following:
"The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available." (CERN 1953)

CERN was officially born on 29 September 1954 by twelve European countries, although the first steps for its creation were taken in 1949-50. The history of CERN is a long and fascinating adventure, which has been fully documented and deeply analyzed in a two volumes study by an *ad hoc* "CERN History team" composed of Armin Hermann, John Krige, Ulrike Mersits and Dominique Pestre. In this study, they make an in-depth historical and critical analysis, taking into account the political dimension, the scientific and technical determinants and the uniqueness and originality of this international research center, its uniqueness

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[14] The acronym comes from the original French name Conseil Européen pour la Recherche Nucléaire, European Council for Nuclear Research.

lying in the fact that from the very beginning it is depoliticized, demilitarized and truly multinational. (cfr. Hermann *et al.* 1987).

The creation of CERN has been one of the first European joint ventures, and the very first European *scientific* collaboration. In the years, different reasons for its foundation have been proposed.

The main rationale for its creation being that a leading-edge nuclear research centre would require financial means and human resources far in excess than those available to a single country. In the meantime, not only a European research centre would bring together scientists from countries that were at war only few years before (CERN 1991) – when CERN was created not even ten years had passed since the end of the Second World War. Moreover, CERN also had a role of bridging opposing cultures during the Cold War, an example being the scientific exchanges with Soviet scientists beginning as early as in 1960 (Cashmore and Kirpichnikov 2004).

Another 'traditional' explanation for setting up this international research center is normally considered to be the Europeist approach permeating the political dimension of the 1940s-50s: governments and politicians were creating the European Economic Community, thus favouring European collaboration in various fields.

An additional and more subtle rationale was identified as being the distinctiveness of the original group of scientists actually proposing to build what became CERN and the particular historical period for the involved nations, which at the time did not have clear science policies. "Individuals were thus left 'free' to act as champions of 'products' that they then managed to 'sell' to key people in their government. […] Power remained effectively in the hands of a group of people who were at once influential at home and free to act from personal conviction without having to wait for an official mandate" (Pestre and Krige 1995).

In 2004, CERN celebrated its 50th birthday with a ceremony that brought together authorities from all its Member States and a majority of its Non-Member States.

In this occasion, a point was made of celebrating its internationality and its role in bridging people from different countries in the name of science:

> "Physics and fundamental research could contribute to this endeavor through their intrinsic neutrality, consistent need for objectivity, and their ability to stimulate thought and bring people together in a common purpose.
>
> It was in this spirit of bringing peoples together in the pursuit of peace and human progress that CERN was founded." (CERN 2004a)

Of interest for the history of CERN were the only surviving founding patron's words in explaining one of the unexpected effects of the creation of the organization, if compared to motivations. Mr. François de Rose said:

> "Robert Oppenheimer once said 'What we know, we have learnt in Europe. But (…) it would be basically unhealthy for the Europeans to have to go to the US or the USSR to be able to continue contributing to fundamental research'. And indeed CERN was created so that Europeans were not forced to go to the United States.
>
> Today, Americans are coming to Europe to work on CERN's machines, something which I don't think Oppenheimer had anticipated. I find that an extraordinary turnaround". (CERN 2004a)

2. CERN Organization

2.1 Member States and Non-Member States

Member States make a contribution to the capital and operating costs of the CERN programs. They are represented in the Council and are responsible for all important decisions about the Organization and its activities (CERN 2005c).

There currently are 20 member countries supporting CERN.
Eleven are the original founders (as Yugoslavia withdrew in 1961): Belgium, Denmark, France, Germany, Greece, Italy, Netherlands, Norway, Sweden, Switzerland, and United Kingdom.
Others joined later on: Austria, Bulgaria, Czech Republic, Finland, Hungary, Poland, Portugal, Slovak Republic and Spain.

States (or International Organizations) for which membership is either not possible or not yet feasible have Observer status. Organizations with Observer status are the European Commission and UNESCO (United Nations Educational, Scientific and Cultural Organization) (CERN 2005c). The Observer status allows these countries and organizations to attend Council meetings and to receive Council documents, without taking part in the decision-making procedures of the Organization.

Non-Member States Institutes and Universities participating to the CERN program are from all over the world, for a total of 72 countries (CERN 2006d), including Canada, Russian Federation, Latin America, People's Republic of China, Pakistan, etc., for a total of 224 Institutes and Universities. By April 2006 a total of 6775 Users were supported by the following countries: 4716 from Member States, 709 from Russian federation, 52 from CIS, 59 from Eastern Europe, 69 from Canada, 751 from USA, 45 from Latin America, 98 from Japan, 47 from People's Republic of China, 53 from India, 39 from Israel and 137 from other countries world wide.

The Member States provide financial contributions in proportion to their Net National Incomes. CERN's budget is drawn up in Swiss francs, the currency of the country where the Organization has its legal seat. The expenses budget in 2006 amounts to 1.238,9 million Swiss francs (CERN 2006b). The Contribution to CERN budget from the Member countries amounts in 2006 to over one thousand million Swiss francs.

Universities, research institutes and funding agencies both from Member and Non-Member States are responsible for the financing, construction and operation of the experiments on which they collaborate, as CERN spends much of its budget on building new machines and it can only partially contribute to the cost of the experiments.

Table 2.1 – Member states contribution to CERN budget and users in 2006.

Country	Percentage	Million CHF	Users at 12 June 2006
Germany	20.19%	198,310	704
United Kingdom	17.35%	170,486	495
France	15.09%	148,178	703
Italy	12.18%	119,614	1,388
Spain	7.97%	78,279	223
Netherlands	4.36%	42,853	135
Switzerland	3.22%	31,646	231
Belgium	2.62%	25,705	92
Sweden	2.61%	25,620	49
Austria	2.17%	21,288	49
Norway	2.16%	21,194	48
Poland	2.11%	20,703	149
Denmark	1.70%	16,654	50
Greece	1.75%	17,236	82
Finland	1.28%	12,580	99
Portugal	1.09%	10,729	89
Hungary	0.83%	8,162	33
Czech Republic	0.82%	8,033	151
Slovak Republic	0.31%	3,087	20
Bulgaria	0.19%	1,876	38
Total	**100%**	**982,234**	**4,828**

Source: (CERN 2006b)

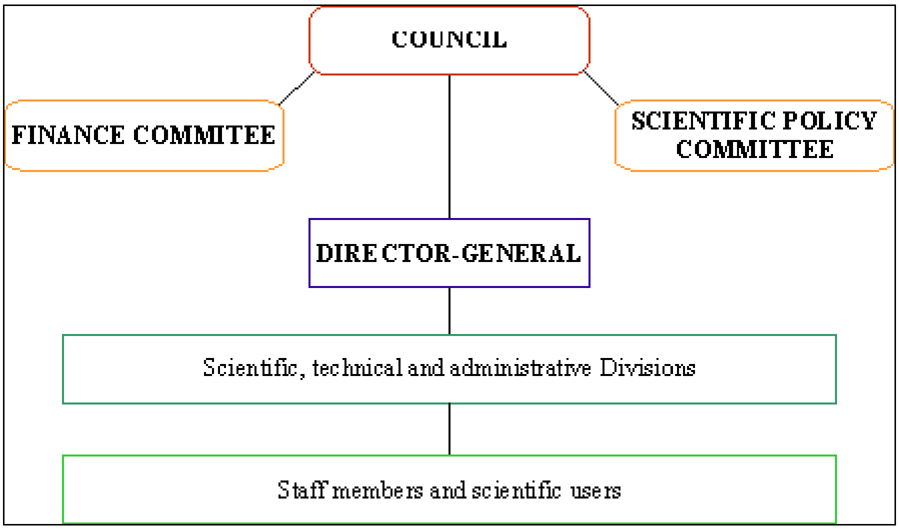
CERN is granted the status of International Organization. This is true both for its location (it extends across the border of France and Switzerland) and for its staff, who has the status and obligations of international civil servant. Over 2500 people coming from all Member States are currently enrolled at CERN. And by June 2006, 7170 scientists, half of the world's particle physicists, are at CERN for their research, representing more than 500 universities worldwide.

2.2 Internal Organizational asset

It then becomes clear that the organizational asset[15] of CERN needs to be quite specific for its particular needs. CERN organization is depicted in Figure 2.1.

[15] The upcoming paragraphs will give a brief description, for a more thoroughly description see (CERN 2005d)

Figure 2.1 – CERN organization



Source: (CERN 1998)

The highest authority in CERN is the Council, which has the ultimate responsibility for important decisions in scientific, technical and administrative matters, both in terms of policy and in terms of budgets and expenditures. The Council is composed of two delegates per Member State, one is the scientific delegate and the other is a representative of the country, however each MS has a single vote. Most of the Council's decisions require a simple majority to pass, although votes are partly weighed by the contribution of the country to the budget. In fact, as can be noted in table 2.1 above, four of the twenty countries contribute for more than two thirds to the budget, and this is correctly taken into account during voting procedures. However, whenever possible the Council tries to arrive to a consensus.

Help is provided to the Council by the Finance Committee and the Scientific Policy Committee in their respective areas.

"The Finance Committee is composed of representatives from national administrations and deals with all issues relating to financial contributions by the Member States and to the Organization's budget and expenditure" (CERN 2005d).

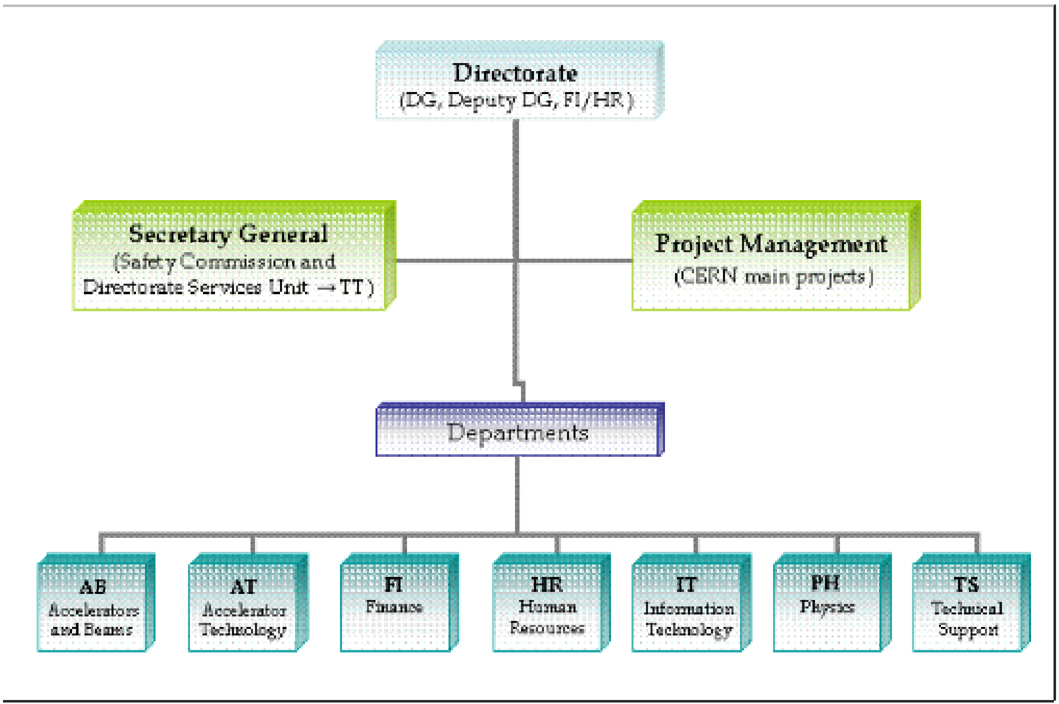
Whereas the Scientific Policy Committee is composed of scientists who are elected by their colleagues in the Committee (their election is then acknowledged by the Council, who appoints them). It should be noted that the election to the Scientific Policy Committee is only based on scientific excellence and it is independent of nationality; in fact, some of the scientists can also come from Non-Member States.

2.3 CERN day-to-day management: CERN organigram

The Council appoints the Director General (DG), who is the official representative of CERN and its Chief Executive Officer (CEO). The DG will hold his position for a five years period and, although his main responsibilities are those of a manager, he is traditionally a scientist. He reports directly to the Council, to whom he can propose any adjustment he deems necessary to meet the evolving needs of the organization. The DG is helped to run the everyday tasks at CERN by the Directorate. The Directorate is composed of the:

- Director-General;
- Deputy Director General – who is also the Chief Scientific Officer;
- Chief Financial Officer – who is responsible for Finance and Human Resources;
- Secretary General – which comprises the Directorate Services Unit, including the Technology Transfer Group, and the Safety Commission
- And, finally, the Project Management, representing the main present projects of CERN: the LHC Project, the LHC Computing Grid, the Enabling Grids for e-science in Europe (EGEE), the CERN Neutrinos to Gran Sasso (CNGS) project and the Compact Linear Collider (CLIC) study.

Figure 2.2 – CERN organigram in 2006.



2.3.1 CERN Departments

Up to 2003 daily activities at CERN were performed by 15 Divisions, whereas from 2004 the Divisions were re-organized in seven departments, each one with a Director:

- AB: Department Accelerators and Beams
- AT: Department Accelerator Technology
- FI : Department Finance
- HR: Department Human Resources
- IT : Department Information Technology
- PH : Department Physics
- TS : Department Technical Support

The AB Department hosts the groups responsible for beam generation, acceleration, transfer, control and delivery for the CERN accelerator complex. It is also in charge of specification, procurement and commissioning of the LHC machine equipments. The core competences residing in the department include: accelerator physics, particle beam generation, RF acceleration systems, power converters, beam instrumentation, controls, beam extraction and injection, targets, collimators and dumps, as well as operation of the whole CERN accelerator complex (CERN 2005a)

The AT Department mission is to use its expertise in accelerator technologies of superconductors, magnets, cryogenics & vacuum to serve the goals of CERN, in order to operate the accelerator complex, build the LHC, build the CNGS facility, provide support to the physics experiments and, finally, to contribute to accelerator and detector R&D (CERN 2006a).

The FI Department is responsible for handling all financial matters. Part of its mission is to provide the internal and external users (delegates of MS, Visiting Research Teams, Funding Agencies, etc.) of financial statements with timely accurate and relevant information and to ensure that the necessary financial control is adhered to in order to safeguard the assets of the Organization. Furthermore, the Department is in charge of all aspects of procurement within CERN (CERN 2006c).

The HR Department is responsible for handling all manners concerned with CERN staff and users. Main areas of responsibility include manpower planning, organizational development, employment and association conditions, recruitment, job classification, training and social services (CERN 2004b).

The IT Department is responsible for general-purpose computing, administrative computing, physics and engineering computing and consolidation, coordination and standardization of computing activities. “To provide its services, the IT Department relies primarily on commercial sources. The Department develops in-house solutions if commercial solutions do not exist. To maintain the quality of its services, a key emphasis of the department is on maintaining the technical competence of its staff” (CERN 2004c).

The PH Department carries out the basic research in the field of experimental and theoretical particle physics. It is composed of two units, the Theory Unit and the Experimental Physics Unit. The former has the objective of developing new theoretical ideas aimed at understanding the fundamental constituents and forces of nature and study their relevance for the experimental program of CERN. The Experimental Physics unit is composed of different groups, which are active in the domains of detector technologies, including mechanics, electronics and experiment related computing and participate in the construction and running of experiments and in the physics analysis (CERN 2006f).

Finally, the Technical Support Department has to provide support for the technical infrastructure of CERN, accelerators, experiments and services related to the site operation and maintenance. This means that it has the responsibility to ensure monitoring and operation of the technical infrastructure of the whole site 365 days per year and 24h/24.

3. Technology Transfer at CERN

3.1 The introduction of technology transfer at CERN

The planning of the LHC, in the mid 80s, led to the realization that a strong involvement of industry would be necessary from project design up to implementation, in order to make this machine come to life. It was then clearly understood that such an interaction would lead to a technology improvement thanks to science push.

In 1986 an internal committee made an in depth analysis of the relations between CERN and industry (Bressan 2004). And in 1987, CERN Member States suggested a more pro-active attitude towards TT. This finally led to the formal establishment of an Industrial Technology Liaison Office (ITLO). Its mandate was to become the point of contact between CERN and industry for all aspects not directly related to procurement. This had to be done by enhancing and strengthening contacts on industrial matters with CERN MS delegates and the Industrial Liaison Officer, as well as external bodies such as commercial attachés, regional bodies, industrial parks, etc.; by promoting technology transfer in general; by adequately protecting CERN intellectual property rights and by exploiting them if and when it might be of interest (Bressan 2004). The foundation of ITLO became the real beginning of an institutionalized TT office at CERN.

In the following years, steps were taken to gather experience in a more proactive technology transfer, for example by filing a few patents (Barbalat 1995). At the same time, a revision of CERN Staff Rules set general provisions concerning IPRs and its staff and associated personnel[16] (CERN 1996, chapt. I, sect. 4). Article 4.01 sets the definition and interpretation of IPR at CERN, art. 4.02 gives the general principles governing IPRs in the organization, art. 4.03 is concerned with the protection of the interests of the Organization regarding intellectual property, and finally art. 4.04 concerns awards for IPRs.

> I4.01 The term "intellectual property" shall be interpreted in the widest sense. It shall include inventions, copyright material, designs as well as technical and other developments.
>
> I4.02 All intellectual property rights which result from or a substantially based on a member of personnel's activities at the Organization are automatically vested in the Organization. The Director-General shall decide whether or not an intellectual property right results from or a substantially based on a member of personnel's activities at the Organization.
>
> I4.03 The Director-General shall lay down the conditions under which a member of the personnel may have his name associated with a publication by the Organization or with copyright material. The member of the personnel concerned shall be entitled to have his name associated with any patent for which the Organization has applied.

[16] Associated personnel comes from institutions of Member States, and are on such institutions payroll and not on CERN payroll.

I4.04 The Director-General may waive the aforementioned intellectual property rights or make them over to a third party, particularly when such rights are claimed by the home institution of an associated member of the personnel.

R I4.01 So as to enable the Organization to protect its intellectual property interests, a member of the personnel shall declare to his Division Leader at the Organization any work or inventions which he considers to fall within the scope of Article I 4.01 of the Rules, including any work or inventions realized its specific task in the Organization, and shall disclose all relevant information concerning such work or inventions. Members of the personnel shall not claim intellectual property rights or apply for intellectual property protection unless they have obtained prior written approval by the Director-General.

R I4.02 The aforementioned obligations shall continue to apply for a period of three years with the effect from the date of termination of the contract of the member of the personnel concerned.

R I4.03 The Director-General may decide to grant an award to the author of any work or inventions falling within the scope of Article I 4.01 of the Rules.

The enhanced attention of CERN executive bodies towards interactions between the Organization and the industrial world, finally led to an explicit definition of a Technology Transfer Policy at CERN. Priorities to enact such a policy were identified as being: creation and/or consolidation of appropriate structures; adequate IPR protection practices; proper documentation of the CERN technology portfolio; expert TT-oriented auditing of that portfolio, so to enhance the means of making available the portfolio; additional raising of awareness inside the Organization; and finally specific training and more experimentation with various forms of TT in close collaboration with the Member State industries (CERN 1999).

The founding principle of IPR and TT policy at CERN was stated as “To make known and available to third parties, under agreed conditions, technical developments achieved in fulfilling the laboratory's mission in fundamental research” (CERN 1999, p. 2). A lot of attention was paid to create an active TT policy which would not be in contrast with CERN mission of making its scientific results generally and freely available, as only technology and instruments to achieve such results would fall under IPR protection and TT mechanisms, and not the results themselves.

Reasons to undertake a proactive TT approach at CERN were identified as transferring the Organization expertise in front-edge technologies to the industrial sector in its Member States (which could also result in giving them a pre-competitive advantage), and having a pool of industrial collaborators capable of responding to the extreme technical necessities of the Laboratory. Contemporarily, for the first time, it was recognized that TT from CERN to the industrial world might also provide a powerful accountability and justification tool towards the general public, which often does not have the means to appreciate what is generally done in basic science research laboratories. In fact, it was stated that one of the reasons to pursue TT policy at CERN was "to make sure that the interest and usefulness of CERN's technological work is widely understood" (CERN 1999, p. 1)

In order to enact the TT policy, a new division was created in 2000, the Education and Technology Transfer division[17]. One of its missions was to enhance TT at CERN. In order to do so, a TT Director was identified, a TT group and an IPR group were assembled and their activities were coordinated by the ITLO Director. The following year, the TT group and the IPR group were joined in a single TT group.

A Technology Advisory Board (TAB) was appointed. It was composed of the TT Director, the ITLO Director, the CERN - EU link person, a member of the Legal Service, a member of the Purchasing Service, senior experts from the Laboratory in areas such as: computing, cryogenics, electronics, magnets, material technology, sensors, vacuum, etc. Also external experts might be invited to TAB meetings, whenever necessary, so to give an informed advice on industry, or specific stakeholders, points of view.

[17] Public education through visits, press relationships and access to the library was deemed related to the general aim of TT policy of providing public recognition of CERN activities.

As well summarized by Bressan (2004), "the CERN TT service was mandated to identify, promote, protect and transfer technologies developed at CERN in research, accelerator and information technology domains to industry".

3.2 Technology Transfer in practice at CERN

Although it might seem normal that the importance of TT would be self-evident to CERN scientists, the general view was that TT is fine, but it is not part of CERN mission. The TT group had to find ways to spread around the Organization the concept that technology transfer is an integral part of CERN mission, as often stated by the present Director General, and it does not impair CERN mission, on the contrary it is complementary. The mission of the Laboratory being to make freely available the results of its research: scientific discoveries, theories and mathematical methods, this would not contradict with the scope of protecting intellectual property rights by means of patents. On the contrary, when the technologies and the technological processes developed to reach these scientific results can be protected by patents and copyrights, this would have the double merit of a) providing a widely accepted means of communicating technical innovation to industry and b) identifying CERN's subsidiary role as a generator of technology which, in general, is often overlooked by the public at large (CERN 1999). This might also have the additional credit of enhancing public interest in nuclear and particle physics research and therefore of improving public recognition and understanding of the importance of basic science not only for a deeper understanding of our world, but also for the advancement of society.

To pass along CERN the concept of the goodness of a pro-active technology transfer, a number of meetings, workshops, conferences and seminars were and still are organized and networks have been created both internally and externally. Some of them are aimed at group leaders or division leaders, others ask for the participation of members of specific groups, others are open to anybody who might be interested. Workshops are also being held to provide information and means of entrepreneurialism such as identifying opportunities to partnering with CERN or to create a spin-off, seek funding, etc.

CERN often extends the limits of technology, and stimulates technical developments to obtain from industry the best possible products at an affordable cost. These developments may have applications in areas beyond high energy physics, and CERN should be in a position as to use the substantial value of its technology and expertise. On this base, a campaign for information retrieval of technologies that might be of value and relevance for industry started in 1999. Together with the identification of prior work, a technological watch for the early assessments of new developments was set in place. These activities have led to the implementation of a TT database which was serving both external and internal working needs. This is now going to be substituded by a new more user-friendly tool, especially designed to attract industry interest.

If in 1997, in his final presentation as Head of ITLO, Dr. Barbalat identified three means of Technology Transfer at CERN – namely TT through people, through purchasing and through collaboration agreements with industry (Barbalat 1997) – in 2000 (CERN 2000), after the formal introduction of a proactive TTP, a fourth type was identified as: TT through R&D special projects.

At the same time, technology transfer through patenting and licensing fell under the tasks absolved by the IPR group, as well as TT through start-ups and spin-offs and the maintenance of the technology database (developed in the previous years, in order to identify technologies that might be interesting to industry). All of these types of technology transfer fall now in the tasks undertaken by the TT group, which since 2005 is part of the Director Services Unit.

From the beginning of the implementation of a pro-active TTP at CERN, two practical priorities were identified: first, develop an in-house understanding of the importance of TT for CERN; and, second, identify the existing technologies or processes that might be of interest to industry.

3.2.1 TT through collaboration agreements and partnerships for R&D special projects

Collaborations are funded by a number of institutes interested in applying technologies that were developed for high energy physics in other domains. The R&D activities are carried out at CERN and in collaborating institutes. "The results are usually proof of concepts aimed at validating the pertinence of the technologies in the considered application domains" (CERN 2006g, p. 4).

Partnerships are aimed at further developing – with industry – a technology to a stage where its commercial opportunities can be exploited. Partnership agreements are therefore intended for parties interested in technologies that are sufficiently mature for a targeted application to be envisaged (CERN 2005e) The results are normally prototypes and demonstrators. In the case of partnerships, R&D activities are done with the support of CERN personnel, but are completely funded by external sources (either the commercial partner, collaborating institutions or different research-funding bodies).

In order to protect its position, CERN has adopted the custom of including IPR statements systematically and at early stages of its collaborations and partnerships agreements. In 2005, the TT group was dealing with up to 175 collaboration and partnership agreements, twenty-one of which were signed in 2005. Of these 175 total R&D projects, thirty nine of them are signed with industrial partners, while the rest is with other institutions (CERN 2006g). Seventy five percent of collaboration and partnership agreements are related to developments in domains such as accelerators, magnets, cryogenics, vacuum, radio frequency, mechanics, material science, electronics and information technology (CERN 2002b).

3.2.2 TT through IPR: patenting and licensing

The general IP strategy of CERN is to protect its right to its technologies and to preserve their commercial potential. Based on the singular case at hand, the TT group decides what kind of IPR protection is the most appropriate between:

- Patent protection;
- Copyright protection;

- Trademark protection; and
- Confidentiality (non disclosure) agreements.

CERN policy concerning patents and other forms of IPR protection consists in filing the application for such protection only after an in-depth assessment of commercial opportunities for the case at hand has been conducted. In such case, the application for protection is filed through the appropriate structures (patent office, etc.) and the protection is maintained only for a limited period of time, unless they are not licensed to potential users or a market opportunity really arises. This is why it is important that effort be expended by the inventor(s) as well by TT group and CERN to timely find an exploiter for the license[18].

In 2005, actions to obtain protection for CERN IPRs were undertaken for two patents, six copyrights, two trademarks and six confidentiality agreements. A total of twenty-five technologies were under patenting activities by the TT group, for eleven of them the patent was already obtained. The total portfolio cost for patents in 2005 adds up to 435 kCHF. In more general terms, CERN holds a total number of 36 agreement among patents, copyrights, trademarks and confidentiality agreements. Twenty-one of them are signed with industrial partners (CERN 2006g).

License agreements at CERN often include the provision of technical assistance or consultancy, in order to facilitate the effective transfer of the technology. Financial conditions for a license normally include a lump sum that covers the access to the technology and any technical assistance or supply, and also royalty payments related to its commercial exploitation by the licensee. In 2005, twelve license agreements were signed during the year[19] (CERN 2006g).

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[18] On this topic compare (Bressan 2004).

[19] As sums are considered confidential information, it is not possible to give a detailed figure, although the lump sum was in the range of some hundred thousands Swiss Francs.

3.2.3 TT through consultancy and services

Consultancy agreements are signed when CERN is asked from external bodies to provide specialized advice and/or to transfer the know-how and unique expertise embedded in some of its staff.

Services agreements are signed when CERN is required the use of its unique installations by companies or other research institutes that would be unable to access otherwise.

In both these cases, agreements cover IP issues as well as the cost of the consultancy or access itself. In general CERN requires to be recognized as the source of the know-how that will be transferred (CERN 2002b).

Up to 2005, a total number of 94 agreements for licenses, services and consultancy were signed; in particular, 45 of them were signed by industrial partners.

3.2.4 TT through people

CERN has and was always recognized its educational role throughout the years of its existence. However, since the inception of its TT policy, the importance of technology transfer to people has been re-evaluated and it has been the object of knowledge transfer studies (Bressan 2004; Cruz *et al.* 2004). CERN turn-over of visiting staff adds up to some thousands of people per year. Their core competencies vary through the whole spectrum of technologies used at CERN. Some of these people, after their commitment with their home institute ends, may pass to industry.

This allows for a continuous flow of knowledge transfer to external institutions and industry, both in Member and non-member states. All visiting staff can liberally access the numerous seminars and training courses held at CERN all year long concerning the most recent developments in the disciplines used in the Laboratory.

Some States have established special schemes to allow engineers and applied physicists to train at CERN in technology domains. Other States reinforced such programs. In the same way, some companies have established agreements with

CERN to train, at their own expense, their personnel for some months by participating in relevant research projects. The same free access to training activities at CERN is available to these visitors.

Similarly, every year hundreds of students working on their thesis projects for their graduation or for their Master or PhD title join CERN. Whereas some of them will remain in the academic and research sector, most of them will finally find a position in industry, where the experience they gained in the top-edge technological environment of CERN is highly valued. Above the normal training programs already mentioned, special "schools" are held at the laboratory to train students.

3.2.5 TT through purchasing

Throughout its history, CERN actively worked with industry mainly through its procurement activities. In fact, equipment for carrying out research is purchased by companies, which are given the specifications by CERN and produce the required equipment or develop it, if it already exists in the Laboratory. Industry will, through the manufacturing process, acquire new skills and gain a new know-how and possibly develop new products. There are also cases where CERN asks for improved specifications, inducing firms to improve their standard products (Barbalat 1997).

The importance of technology transfer through purchasing by CERN has been analyzed since the 1970s in a number of studies: Schmied (1975), Streit-Bianchi *et al.* (1984), Nordberg (1994). Some authors interpreted TT from CERN in terms of its frontier-technology needs, which require industry to develop new technologies to satisfy CERN's requirements (Hameri and Vuola 1996; Hameri 1996).

More recently, Autio *et al.* (2003) found that technological learning and innovation benefits derived form CERN procurement activity tend to appear together and to depend on the quality of the supplier's relationship with CERN: the greater the amount of social capital interacting, the greater the learning and innovation benefits (Autio, Streit-Bianchi, and Hameri 2003, pp. 45-48).

3.2.6 TT through start-ups and spin-offs

In 1999, CERN recognized the possibility that some of its staff might be interested in creating a company of their own, either as a start-up based on the knowledge acquired at CERN or a real spin-off based on technologies, processes or research results obtained at CERN. In particular, it was decided that "CERN entrepreneurs" would be granted easy access to its facility (CERN 1999) and access to CERN technologies under favorable conditions, although the decision finally rests on the Director-General assessment. In some cases, CERN might also grant its researcher/entrepreneur-to-be an unpaid leave of absence for a limited period of time. In general, the TT group is responsible for creating links with existing incubators to help companies "arising" from CERN. In any case, attention should be paid to ensure fair competition, qualitative criteria regarding the business plan, and a fair distribution of support among spin-off companies of all Member States (CERN 2003).

As a general line, CERN has retained the intellectual property right, while establishing license agreements (either with domain-limited exclusivity or non-exclusive provisions) allowing for commercial use. In some cases, a combination of license and partnership can be envisaged in order to assist the development of the technology.

By 2005, 5 start-ups have been created as results of direct licensing (CERN 2003). Two of them are in the domain of information technology; other two of them are concerned with detectors, whereas the last of them is based on the accelerator domain and applies a CERN patent to the production of radioisotopes for medicine[20].

At any rate, the total number of start-ups and spin-offs generated by CERN know-how or based on CERN technologies in the Host States of France and Switzerland went from 7 to 17 between 200 and 2004 (Carchia and Loeffler 2006).

To our knowledge, to the present only a Finnish case of a spin-off from CERN was found to be analyzed in depth, in terms of commercial outcome (Byckling *et al.* 2000). Therefore, it might be an interesting and over-needed study to contact

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[20] Respectively, as numbered in the list of TT cases by CERN: cases 5 and 26 in IT, cases 23 and 68 in detectors, and case one in accelerators.

the aforementioned cases and investigate if and how they developed their business and if they carried out further R&D, and if so, if they did it with or without CERN.

Concerning CERN spin-outs and spin-offs, part of an Interreg Project, currently underway, is focusing on the creation of new firms in the geographical area around CERN and by CERN former staff or users (ADEPGBB, 2005). An initial survey was done, analyzing the reasons for creating the firms and the tools and structures used by the researchers/entrepreneurs to open their firms. At the same time, a first comparison with technology transfer support structures in place at two other European organizations – ESA and EMBL – was conducted, to see what CERN situation compared to its fellow organization was.

3.2.7 Complementary TT activities

Starting from 2002, CERN recognized that other activities might be complementary to TT: standardization, publication and promotion. All of these complementary activities are intended to raise awareness of CERN as a centre of excellence for technology and intend to establish and exchange best practices with the various actors involved in technology transfer activities in general.

Standardization

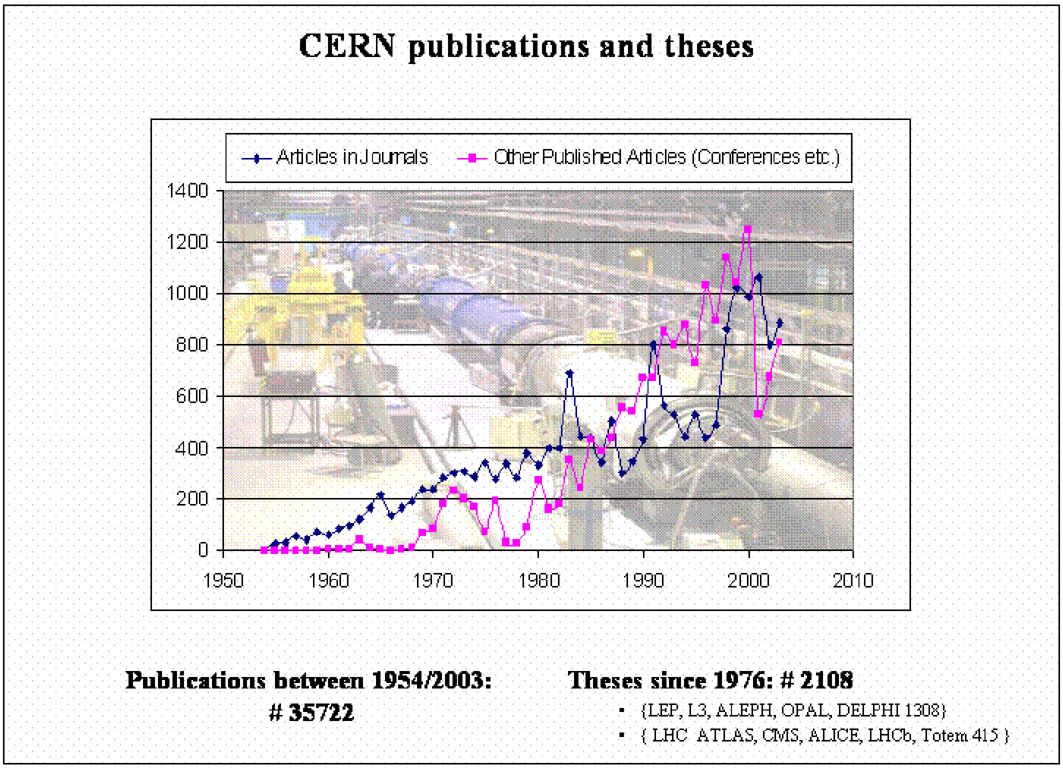
As already mentioned, CERN has happened to be the developer (either directly or indirectly) of various technologies. In this sense and through the efforts in establishing standards and the willingness to act as a test-bed, CERN can act as a support in enhancing the competitiveness of European industries. The Laboratory was already involved in two cases of standardization, one concerning vacuum technologies and the other concerning IT (CERN 2003).

Publication

A large number of technology preprints by CERN personnel are produced each year, and most of them are submitted and accepted for publication by the most important journals and in international conference proceedings. Between 1954 and

2003 a total of 35722 publications have been published by CERN scientific staff, which means more than 700 each year. It should be noted that this is a very conservative value, as for about twenty years the number of papers published in conferences or journals was not recorded. The same is true for theses done at CERN.

Figure 2.3: CERN theses and publications between 1954 and 2003



Source: elaboration by Dr. Marilena Streit-Bianchi, 2004, CERN.

Promotion

These are activities to promote technology transfer from CERN to the outside through the creation and maintenance of the TT database, through the participation to promotional events (conferences, workshops, etc.) and through the preparation of promotional media (leaflets, flyers, posters, books and articles).

At the same time, the TT group is also reinforcing its relationship with the Member States, especially through the TT External Network, which is composed of experienced people for TT matters, who act as the national Technology Transfer Officers (TTO) becoming the primary contact for TT promotion in the Member States, helping CERN to fulfill its obligation of impartiality with respect to TT towards all the MSs.

A corresponding TT Internal Network was created to allow for more formal "in-house" communication channels between the departments and the TT Service. Consequently, CERN experts from all departments act as the focal point within the departments on all matters relating to technology transfer and as the first point of contact between a Department and the TT Service and vice-versa.

The creation of a regular TT newsletter was one of the activities that started in 2005 as an additional channel of information and promotion, designed to raise industrial interest (CERN 2006g).

The TT database

The TT group also created and implemented a database for gathering and handling all relevant data about technologies which are deemed interesting for transfer. Users can also find names and contact details of CERN TT staff, news on upcoming events and video-clips allowing online demonstrations of selected technologies. For each technology on the database, a brief description is given; references to connected patents are also available. This part of the database is public and freely available through any Web interface. Guidelines for would-be inventors and authors are also available on the public pages of the TT database.

In this way, the TT database, available to public from the welcome page of CERN through the http://cern.ch/ttdb link, is a two-way contact point between CERN and the outside, allowing for promotion of CERN technologies and for an initial auditing of possibly interesting technologies by industry.

It is important to point out that a new database is being implemented and it will be made available by the end of 2006.

3.3 The Technology Transfer Service in detail

The mandate of TT office can be summarized in the following points:

- to maintain the Technology Transfer Database;
- to be the contact for all Intellectual Property Rights (IPR) and associated issues;
- to promote Technology Transfer through patenting and licensing, start-ups, consultancy, collaborative developments agreements, TT projects, standardization and benchmarking, people and partnership;
- to collaborates in TT through purchasing;
- to participate in the organization of related training and topical workshops.

Technology Transfer activities are divided in two categories: technology transfer processes and technical activities.

TT processes – which are carried out by the TT group – are defined as activities concerning IPR protection, promotion, commercialization and establishment of R&D agreements.

Technical activities – which are executed in the technical departments – are described as TT R&D projects and technical services provided by CERN.

CERN expenditure for Technology Transfer activities covers both TT processes by the TT group and technical activities by other departments. The following table gives an indication of CERN personnel allocated to each activity and the respective expenditure in thousands of Swiss francs.

Table 2.2 – CERN personnel & expenditure by TT activity in 2005.

Activity	**HR (#)**	**Expenditure (kCHF)**			
	Personnel	Personnel	Material	IP portfolio	**Total**
TT processes by TT group	15	1500	350	435	**2285**
R&D projects and technical services	19	495	1140	-	**1635**
Total	**34**	**1995**	**1490**	**435**	**3920**

Source: Adapted from (CERN 2006g).

Income for TT activities is the result of CERN allocated budget for TT activities and of external income, either from external funding for TT activities or from income generated by the commercialization of CERN technologies. In 2005, 1227 kCHF were obtained by external funds and 612 kCHF were gained by the commercialization of technologies, giving a total external TT income of 1839 kCHF. In the same year, TT income from CERN budget was 2130 kCHF (CERN 2006g).

The total income for TT activities in 2005 is then 3969 kCHF, which compared to total expenditure, gives a positive balance of 49.000 CHF. It is true that some external funds have not been accounted for in the 2005 budget as they are still under the previous accounting scheme. However, it should be noted that TT group is not yet able to survive without a partial allocation of CERN budget, which accounts for more than half of its income.

4. CERN HR database

Implemented in 1995, the Human Resources database was first released at the end of 1996 to allow human resources management, planning and follow-up by providing access to restricted and relevant personnel of CERN personnel data. At the beginning it ran under Microsoft Excel and was accessible only within the CERN site. Between 1999 and 2000 implementations were underway to move the database to the web. The Human Resources Toolkit (HRT) – as the new database was named – was available on-line from February 2001 (CERN 2002a).

The HRT database reports data about people at CERN (staff members, fellows, users, etc.). The database is constructed according to five functionalities (CERN *et al.* 1996). Information available in the functionalities will be differently accessible according to the access level granted to the person accessing the database:

- System: This concerns common activities such as logging-on and off, printing, saving, etc;

- Person: this concerns static personal information (name, address, telephone number, e-mail, contract and leave information, etc.) without going into details of career history and planning;
- Career: this concerns all detailed personal career and contract information history (job title, status, start/end of contract, etc.);
- Planning: this concerns statistical and personnel information required for HR planning (arrivals, transfers, departures, age profiles, etc.);
- Help: this provides support for the various search functions.

For each member of CERN staff the following information can be retrieved from the HRT database:

- General information: Name, sex, age, date of birth, nationality, second nationality, presence at CERN, CERN id (identification number), preferred language
- Office information: office number and location, telephone, GSM number, post-box, email
- Job information: Organic unit, division, group, section, status (i.e. staff member, paid/unpaid associate, etc.), roles held (since entrance at CERN)[21], job title (e.g. senior physicist, senior engineer, etc.), professional class (scientific and engineering work, administrative work, technical work, etc.), professional code (e.g. inside scientific and engineering work, the job code can be: mechanics, electricity, electrodynamics, computing, applied physics, chemistry, mathematics, etc.), experiment (to which the staff member is attached), institute (to which the staff member is attached), team (to which the staff member is attached), supervisor
- Contract information: contract type (indefinite, limited duration, fixed term, fellow), start date of the contract, end date of the contract, career path (as defined by CERN), position (as defined by CERN), remuneration, presence, hours per week, etc.
- Personal information: leave balance, leave taken, overtime balance, private address, home country address, marital status.

[21] However this voice is not always complete nor updated.

A lot of the information contained in the contract and personal categories of the database are – as easily understandable – confidential and therefore access to them was denied for information such as salary, career path leave balance, private address *et similia*.

Data from the HR database is important to understand what the composition of CERN population is. A synthetic description of such population and of the researchers who were identified as the envisaged respondents of the questionnaire is presented in the next chapter and is partly based on this database.

Conclusions

CERN is the first European research center. As other European research centers, such as EMBL …, its staff enjoys an international officer status (while also being subject to the limitations such a status imposes) and is deeply embedded in an international environment. As in all big research centers, a wide range of professions are present as well as different backgrounds and experiences.

Technology Transfer as an activity disciplined by a policy is quite recent, even though actual technology transfer has been on-going since CERN was born. TT in the Lab takes place in a number of forms and through a number of researchers belonging to different departments and with different tasks.

Having presented the research organization, it is now possible to try to set a theoretical framework for the analysis to be conducted, such framework is also constructed on the basis of the literature discussed in chapter 1.

Chapter 3 – Theoretical framework and Research Procedures

Introduction

This chapter is composed of two parts: the first introducing a theoretical framework and the second presenting research procedures.

The first part is divided into two sections. The first section deals with the intermediate level – and proposes some organizational concepts that should be considered when analyzing a basic research center. The second section deals with the individual level: a theoretical framework proposes what factors might explain entrepreneurial behaviour of researchers. The overall theoretical framework is deconstructed to its constituent parts, in order to set the hypotheses that will be tested in the empirical part of the thesis through a questionnaire.

The second part of the chapter is a presentation of the methods and procedures adopted for this study. For the purpose of presentation, this part of the chapter is composed three sections: description of the research instrumentation, description of the procedures, and description of the subjects.

The research questions that the study wants to answer to are:

- Do the researchers show an interest towards an entrepreneurial behaviour either at the individual level or at the organization level?
- Do they see scientific research and entrepreneurialism as essentially complementary or substitutive activities?
- Are there incentives that (can) play a role in encouraging CERN researchers to become (more) entrepreneurial and thus engage in technology transfer activities?

1. Intermediate level – Organizational aspects

Knowledge production arises in different organizational structures: universities, public and private research centers, individual or corporate firms, etc. Given the focus of the thesis, organizations such as firms and private research centers will not be dealt with, as they have different rationales and different operating methods. On the contrary, universities and public research centers are consistent with European research centers, as they receive a consistent share of their funds from the government and as they traditionally were not directly concerned with a profit-making use of the knowledge they produced.

1.1 Knowledge seeker, research contractors and service provider organizations

In the literature analysis, it was seen that the Actor-Centered Institutionalism (ACI) "concentrates its analysis on the intentional action of both individual and collective actors and relates the outcomes of interaction to the institutional settings in which these actors pursue their particular goals and interests" (Wilts 2000).

In the framework of ACI, Wilts categorized research centers as: knowledge seekers, research contractors and service providers. This theory allows for an integration of the intermediate (=organizational) level and the micro (=individual) level.

In proposing a theoretical framework for the organizational structure of a European research center such as CERN, it should first of all be noted that such a research center however does have differences compared to a university due to its international status and defined mission.

For example, it is not possible to fully apply Boyer's (1990) four main activities as defining the organizational form of universities: discovery, teaching, application and integration. In fact, even though training of young researchers is a *de facto* important activity at CERN, it is not part of its mission in its strictest sense. On the other side, research centers, as much as universities, are subject to increasing demands of producing "usable" knowledge.

Other factors that are unique to European research centers are internationality and inter-disciplinarity.

Internationality is here intended to point out that in European research centers, researchers come from all over the world and work with people from all over the world.[22] This means that they are exposed to different habits in terms of mentalities, customs and working procedures. Such habits might well include attitudes towards university-industry collaboration and technology transfer at large.

Inter-disciplinarity in this context intends to stress that in basic research centers is possible to find – on-place and in-house – not only physicists, engineers and administrative profiles, but also people coming from previous experiences in high-tech companies or who worked for joint university-industry projects.

A European research center (and CERN) organization is given by the following variables:

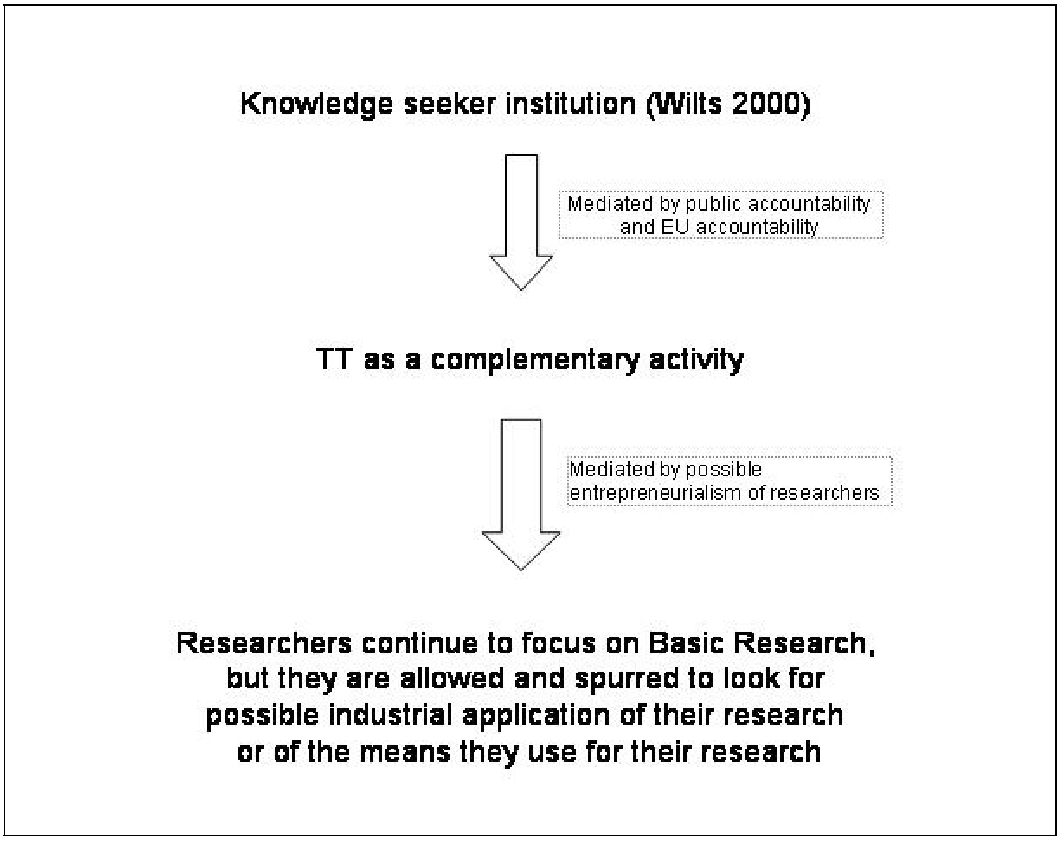
- its constituting mission as set in its founding constitution;
- fixed funds from member countries;
- accountability to European research policy;
- public accountability;
- researchers' goals and objectives.

In setting a model for a European research center, all of the above variables must be kept into account. This means that such a center has to remain faithful to its founding mission, which in the case of CERN is to produce publicly accessible

[22] As explained in Chapter 2 at CERN are present people coming from over seventy countries.

fundamental knowledge in nuclear research (in particular in high energy physics). Also, funding for a European center comes from its member states, this means that an agreement must be found on how incomes from "licensable" knowledge should be appropriated. At the same time, guidelines of EU policy must be respected and applied, but also the public justification for the center's existence should be considered[23]. Finally, researchers' goals and objectives are part of the organization's operative functioning as are variations in researchers' general behaviour and attitude.

Figure 3.1 – Organization of a European research center for basic research



At the intermediate level, it could be said that the organization of a European research center such as CERN should be as synthesized in figure 3.1, which

[23] In a moment when Europe is facing economical problems, the general public tends to have difficulty in justifying high expenses in "exotic" fields such as High Energy Physics, which is commonly seen as an interesting, but not-economically-remunerative quest in the foundation of matter.

should be read as: CERN should remain a knowledge seeker organization, where – mediated by public and EU accountability – Technology Transfer is a complementary activity to the research mission; this complementary activity has to be mediated by the eventual entrepreneurialism of the researchers, which should continue to do basic research, but also be allowed – if interested – to get involved with TT.

Such an organizational model means that CERN should remain faithful to its original mission of producing basic knowledge freely available to all those interested (i.e. Member States and not). However, it should understand the modern *dictat* of public accountability and the present EU stress on sustaining European knowledge-base society by creating and maintain a strong and excellent production of basic knowledge. This would mean using TT as a way to allow and help a more intensive use of knowledge-based byproducts (know-how, edge technologies, etc.) filtrate to the industrial sector, in order to "improve" CERN usefulness at a more practical level; i.e. not only a center of excellence for high energy physics specialists, but also a research center that is seen by the general public as producing something more usable and practical than theoretical - although fascinating - knowledge about the basic constituents of the universe. It should however be noted that the present DG of CERN is giving more emphasis to TT activities considering technology transfer as the second mission of the Laboratory

1.2 Stiglitz's Sharecropping

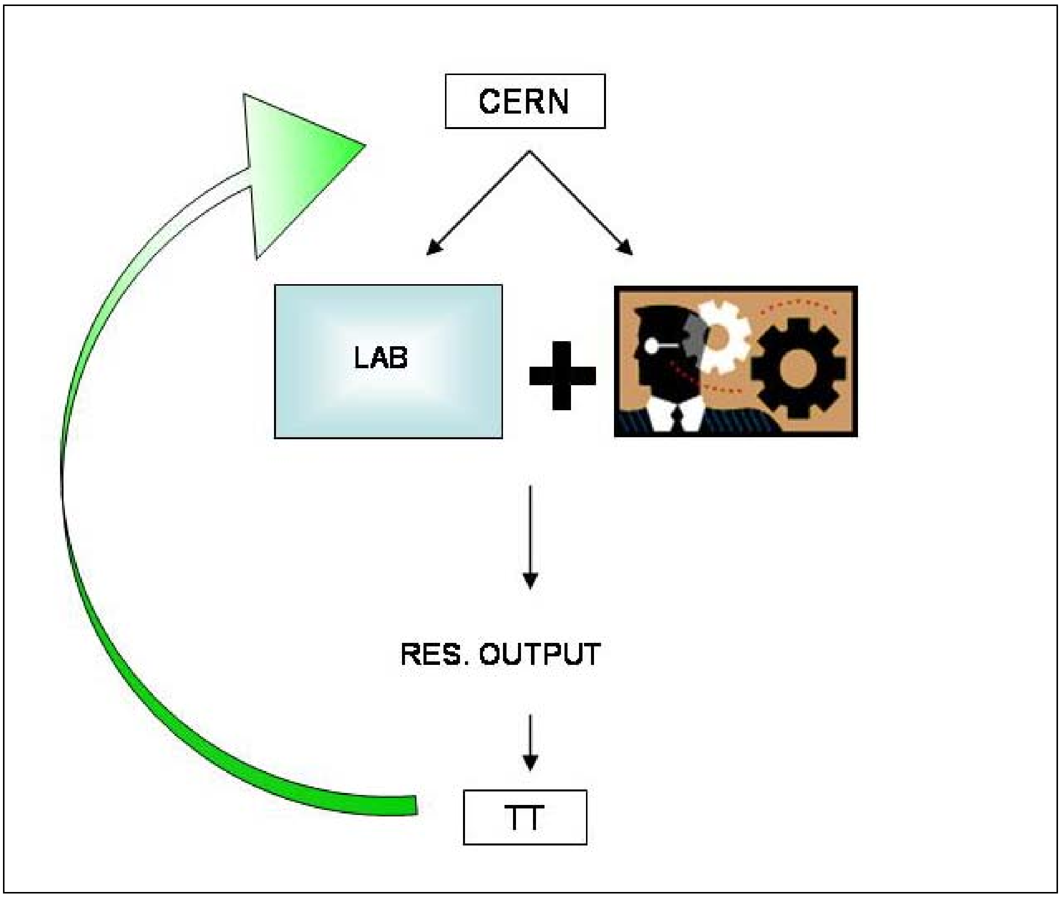
It can be proposed that, if the organizational model discussed above was to be valid, (CERN) technology transfer could be observed under a new light.

In fact, it can be argued that the actual organization of TT at CERN can be paralleled to the classical *sharecropping* organization in agriculture. In fact, as shown by Stiglitz in his fundamental paper on sharecropping (Stiglitz 1974), the sharecropping arrangement allows for both the landlord and the worker to gain from the outcome (although the worker usually also receives a fix wage) by sharing risks and allowing for incentives to the worker (see the literature chapter for a more detailed explanation). In the parallel, CERN is the landlord, as it is CERN who owns the laboratory and the infrastructure (= the field) to undertake the research; the researcher is the worker, who uses the assets owned by CERN to do his/her research; incentives can be set for both CERN and the researcher to pass the results of the research or the technologies used for the research to the industrial sector as economical revenues are shared between the two, although at the discretion of the Director General.

However, risks concerning the TT process are borne only by CERN, as the researcher receives a wage and he/she does not necessarily feel compelled to try to apply the technologies outside their field of competence or to disseminate his/her research to industry, therefore there is no “punishment” applied in case no such application exists or is recognized. There is, however, an agency problem: CERN has to extract information on the “quality” of the researcher’s efforts (an example might be an individual publications count and on the “quality” of each specific project (maybe through an analysis of the working reports) that is undergoing a technology transfer process.

For example, it could be argued that researchers with more publications are more active and are “higher quality” researchers (although we should not forget the well-known implications of Lotka’s Law). Moreover, the number of publications also could be used as a “quality” indicator of the researcher and of the results (or technologies) that he wants to transfer to industry, also through interim reports that could be checked to see how much the results or the technologies might be sellable in the future. In any case, it should also be noted that nowadays publications in high-energy physics often include tens, and sometimes hundreds, of authors, because of the number of researchers constituting the collaborations who found the results being published, and this could cause skewed results from such an indicator.

Figure 3.2 – Sharecropping in TT at CERN



The application of sharecropping to CERN is schematized in Figure 3.2, where the organization is split into its two basic components: physical assets (the laboratory) and human resources (the researchers). Research output is the outcome of the necessarily interlinked work of the two. TT is a byproduct of research output in the sense that edge-technologies (both hardware and software) are developed as means to obtain experimental proofs of physical theories. The outcome of TT, if any, is then reabsorbed by the institution.

After a few years of proactive technology transfer policy, sometimes it happens that researchers spontaneously go to the TT thinking or knowing that a technology might have applications for industry. This means that the TT office, and therefore CERN, is slowly reaching a position where, internally, it is known that TT might be possible. This also means that the effort to find transferable technologies does not rest exclusively on the TT office anymore, but it is partly shared by the staff. In the future, if the actions and results of TT are made more widely known to CERN staff, there might be a consistent, if not constant, flow of information from the base of the research center (a bottom-up flow).

However, the fact that some researchers go to the TT office to propose a possibly transferable technology does not solve the agency problem. It is still important for CERN to assess the quality of the researcher and of the technology/project, even if the agency problem is now narrowed down to the specific case.

Similarly to what is conventionally done in many other institutions, up to the beginning of 2005, CERN actual organization of TT revenues (at the net of the costs) allowed, for a 30% to the inventor(s), for a 25% to the group to which the inventor belongs, and the rest went to CERN TT budget.

In March 2005, the finance committee decided that net TT revenues should go to CERN to further TT activities, whereas the researcher(s) responsible of the transferable technology will be remunerated, always at the discretion of the Director-General by: an added step (or steps) in their career path; and/or by an added remuneration called the "Responsibility Allowance"; and/or by a special remuneration called "Premium for Exceptional Services"[24]

In this sense, CERN is actually comparable to the landlord, as it is the organization who receives the revenues from the TT process (the crop) and then it shares it with the worker according to its own discretion.

As in the case of share cropping there is an asymmetry of information, although reversed. In fact, even though CERN is not able to perfectly observe the input provided by the researcher, the researcher receives a wage. But, it is the researcher *in primis* who is in the position to understand that a research or a technology

[24] See chapter 2, paragraph 4, for a discussion on this policy change and its peculiarity compared to other European research institutions.

might be interesting for industry, therefore it is the researcher who has a stronger position concerning TT aspects. It is for this reason that the incentive issue becomes particularly important. If the researcher is not motivated enough, he will not necessarily make the information available to CERN, falling back to the classical moral hazard problem.

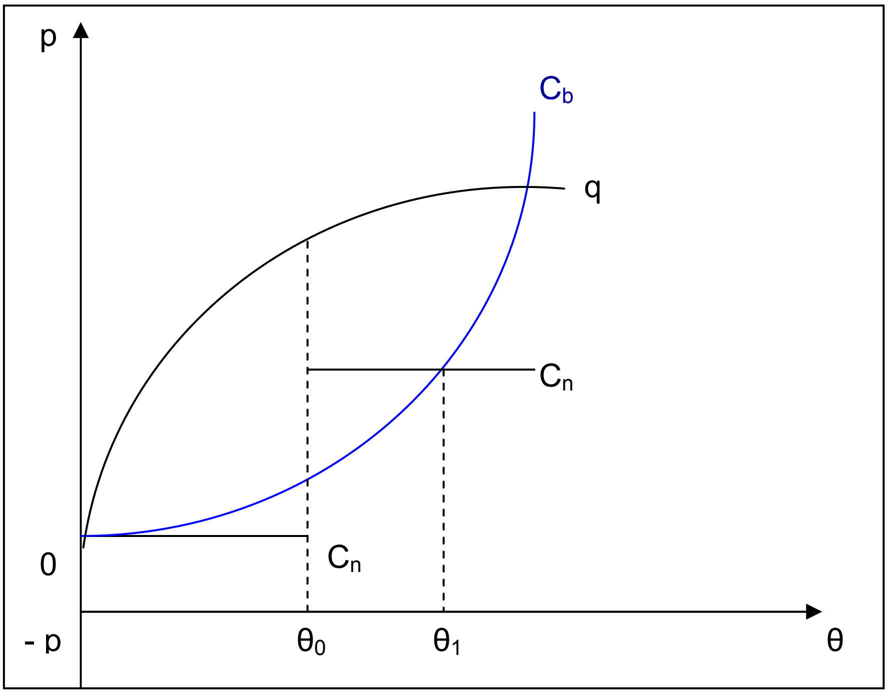
If we focus for a moment on the institutional aspect of TT at CERN, we can try to visualize the present situation in the following way.

We can say that output *q* is an aggregated function of the researchers' aggregated in-house effort *e* and of their aggregated collaboration with industry *θ*, however the collaboration results can not be entirely controlled neither by the researchers, nor by industry nor by CERN in their being productive and/or rewarding (because of all the uncertainties embedded in basic and almost basic research itself). Therefore the output can be expressed as q(e, θ), a function expressing a technology with decreasing returns, so that q''<0.

Now, the researchers' wage *w* in the past was a function of both in-house effort *e* and collaboration with industry *θ*, so that w(e, θ). Nowadays, instead, the researchers wage is only a function of their in-house effort, so that w(e). In particular, we can see it as a threshold contract, where for θ lower than a θ_0 the wage remains a flat wage, whereas for θ higher than a θ_0 the wage is – eventually – increased by a certain amount decided by the Director General.

For simplicity sake, we can assume that CERN costs – in TT case – are given by the aggregated researchers' wage, and they are in one case costs as it was before $C_b = w(e, \theta)$ and costs as it is now $Cn = w(e) + p_n$, where p_n is a monetary reward for $\theta > \theta_0$. Also, in order to give a graphical representation, we can assume that effort *e* is given and does not bring about any change at θ changing and also that *q* does not change with the change in contract.

Figure 3.3 – Outputs and costs



We now see that CERN profits (i.e. the value of innovation appropriated by the organization = q -w) are higher with the present wage of researchers for $\theta<\theta_0$ and for $\theta>\theta_1$. This means that for CERN is convenient not to have researchers' wage based on θ, other than in the case when the award and/or career advancement gives the researchers a higher wage than the one they would have in case the wage is also based on θ (i.e. a fraction of revenues from the collaboration), as in the case when $\theta_0<\theta<\theta_1$.

However, from such an arrangement some questions arise both at the intermediate and at the micro-level.

For example, concerning the intermediate (organizational) level, might it be more efficient to use part of the net revenue from TT activities to finance CERN research in general, in view of shrinking budgets faced by CERN nowadays? Or would it be in contrast with CERN mission?

It should be noted that this solution might not be seen very favorably by CERN management, as it might prove a double-edged weapon. We should consider that at the present CERN budget comes from the funds given by its Member States

(plus a small part obtained by European funds for strategic research projects). Now, if increasing funds were available from technology transfer activities, it might prove unwise to finance CERN general mission with them, as the organization might be factually swayed to a more contract seeker orientation, which is against the defined CERN mission.
At the micro-level, are the researchers aware of the possible rewards? Which is, is the incentives structure efficient in CERN? Should the researcher be made responsible for part of the risks bore by CERN in the TT process? And also, what is the researchers' opinion on a more proactive TT policy by CERN?

It's a given that for technology transfer to really become an important part of CERN activities, researchers need to be spurred to become attentive to possible industrial application of their research, thus incentives must really be seen as such by researchers in the first place. At the same time, it is important to understand what researchers think of a traditionally research-only organization becoming involved in TT activities. If the general attitude of researchers turns out to be indifferent, or even adverse, to TT by CERN, its effects are felt at the organizational level, and it might be necessary for the organization to work toward a better understanding with its own staff.

Even though, the goal of this thesis is not to propose a different model for CERN's organization, its actual organization can be tested against the above mentioned model and similarities and discrepancies can be noted and propositions can be made. This can be done as long as it is kept in mind that the focus of this thesis is to analyze whether CERN's researchers are becoming more interested in collaborating in any way with industry, therefore allowing for an opening from the inside to an increase of technology transfer activities as generally envisaged by policy's guidelines.

2. Micro-level – Entrepreneurial Behaviour of researchers

Both the organizational model of a knowledge-seeker institution and that of sharecropping give relevance to the figure of the researcher. In both of them, the researcher is an active part in what happens both in the institution and in the TT process. This is the reason why it is so important to study and understand if and how researchers' behaviours are changing regarding the technology transfer process at large.

At this point, it is fundamental to try to understand what, if anything, moves an individual researcher toward becoming involved in a technology transfer process, which is to say toward an entrepreneurial behaviour.

The definition adopted throughout the thesis is that the Entrepreneurial Behaviour of the researchers is their interest (both at the practical and theoretical level) in (co)ownership patents, copyrights, trademarks, licenses, proprietary rights on the products of research as well as their interaction with the industrial and commercial sector, in form of consultancy, equity shares in companies, creation of spin-offs, professional training to industry, etc.

In the context of this thesis, a researcher is defined as having an Entrepreneurial Behaviour not necessarily by being an entrepreneur (i.e. owing its own firm), but also by being active towards technology transfer and partnership with industry. Here we adapt the concept of Etzkowitz's entrepreneurial university (Etzkowitz 2003) to the researcher, who becomes an "entrepreneurial researcher". The focus is what might move the researcher to become involved in TT at large, and not what practical actions he undertakes nor what the results of his actions are.

2.1 A model of Entrepreneurial Behaviour of CERN researchers

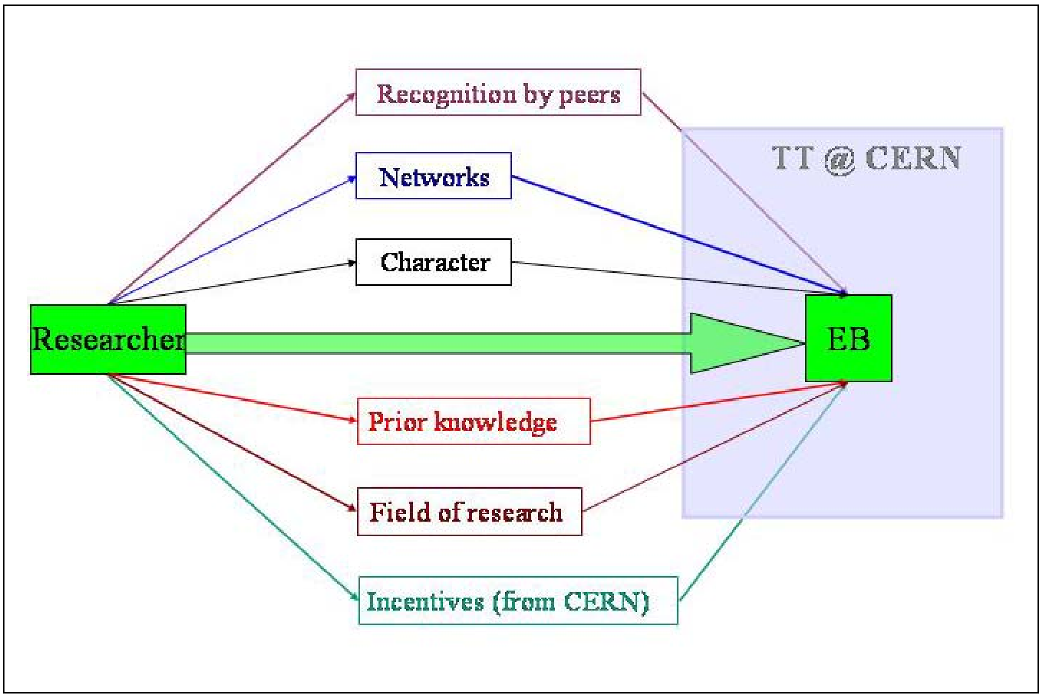
A model is here proposed and sketched to explain what factors might explain the entrepreneurial behaviour. Or better what factors can be expected to influence entrepreneurial behaviour (EB) of CERN researchers.

The main building blocks (in green in the picture) are the researcher and the entrepreneurial behaviour by the researcher. Factors influencing a researcher's entrepreneurial behaviour were recognized to be the following:

- Recognition by peers
- Networks
- Personal character
- Prior knowledge
- Field of research
- Incentives

Whereas the two factors identified as 'Recognition by peers' and 'Networks' represent a connection between the individual researcher and the community in which s/he is embedded, the factors identified as 'Prior knowledge', 'Field of research' and 'Personal character' represent the more characteristic aspects of each person as an individual. Finally, the 'Incentives' factor wants to identify a connection between the researcher and the specific organization into which s/he works and to which s/he is under contract.

Figure 3.4 – Researchers and Entrepreneurial Behaviour



2.1.1 - Recognition by peers' influences on EB

Increasing attention on university-industry collaboration might be playing a role in modifying the evaluative norms of the scientific community in Mertonian terms. Authors (Etzkowitz 1998, 2001; Lee 1996; Etzkowitz et al. 2000) are proposing that the scientific community is now willing and able to accept claims of priority that are covered by IPR protection or that are exploited on the market. Scientists collaborating with or working for industry are not seen as "outsiders" or B-category researchers any more, but as experts whose value is also recognized by sectors other than academic.

If the researcher feels that there is a positive recognition by peers concerning contacts with industry, then entrepreneurial behaviour is positively affected. In particular, approval by peers of entrepreneurial activities positively influences researchers' norms concerning EB: it is not seen any more as an outlaw activity, which could get them banished, therefore interest in EB can be constructively pursued if willed.

On the contrary, if entrepreneurial activities are perceived as negative for the scientist's career, it is probable that the researcher will tend to negatively consider EB himself, or anyway reject the intention of pursuing EB if his interest is primarily 'scientific excellence' recognition by peers.

It should be noted that the change in perceived norms might, but not necessarily will, result in a change of practice. Therefore, the fact that the researchers feel that an EB is not assessed as negative anymore, might make him more comfortable about considering to act entrepreneurially, but he still might not want to undergo the whole process (taking contacts with industry or with TT office, propose a transferable process or product, etc.).

H1: *The first hypothesis is that there is a positive relation between recognition by peers and EB by researchers.*

It is also interesting to note that there might be a backward relation too. EB norms of the researchers might cause a change in evaluative norms by peers: with more researchers starting to be entrepreneurs without feeling alienated by the scientific community because of it, entrepreneurial behaviour becomes less strange and might become incorporated (at least in part) in recognition rules. Whereas a complete absence of EB by researchers might also have a negative influence on peers' evaluation system: a not common behaviour is hardly seen as good by colleagues.

2.1.2 - Researcher's networks influence on EB

As in the case of recognition by peers, also norms shared in networks or examples of practices within networks can influence the EB of researchers. In fact, professional networks are made up of researcher's peers also from other institutions than his own, but they are still very important in forging what is his 'scientific value' (i.e. is the researcher considered to be a valid scientist by his peers in the network?).

In research policy literature, the importance of formal and informal networks for technology transfer and research activities is recognized (Gibbons *et al.* 1994; David, Foray, and Steinmueller 1997; Chataway 1999). Networks were also shown to be able to introduce new behaviors in research organizations (Hoddeson 1980). Therefore if within the network in which CERN's researchers are inserted (even if it extends outside CERN), entrepreneurial intentions are seen in a constructive way, then the researchers probably hold positive perceptions of entrepreneurial behaviors. Whereas, if within the network EB is negatively assessed, the researcher might not pursue his/her entrepreneurial intention.

Moreover, the researcher's networks may also influence his/her entrepreneurial behaviour in a much more practical way. For example, experiences of other's EB within the network can show solutions to practical problems faced by the would-be-entrepreneur. Also, the network can offer the researcher an access to information, knowledge and resources (Aldrich and Martinez 2001) that he/she personally does not have. Finally, networks acquaintances might actually facilitate the EB of the researcher, or – at least – the network might make it look more feasible to the researcher.

H2: *The second hypothesis is that there is a positive relation between network's assessment of EB and the researcher's norms about entrepreneurial behaviour.*

Also in this case, there might be a backwards pattern too, as EB by researchers (and his factual entrepreneurial experiences and experiments) might influence the network in return.

2.1.3 - Researcher's character influence on EB

The researcher's character surely plays a role in his/her entrepreneurial behaviour. A lot of literature on entrepreneurship, and the entrepreneur as a person, concentrated on the importance of the entrepreneur's character. However, most of this literature deals with psychological factors (e.g. Katz 1992).

An individual's character is an expression of his/her psychological attitudes and can hardly be studied from a science and technology policy point of view. For this reason, although acknowledging a direct positive relation between the researcher's character and his/her EB, the matter will not be explored any further, as it concerns a field other than this thesis'. The psychological/character factor is taken as a given.

2.1.4 - Researcher's prior knowledge influence on EB

The specific knowledge (mainly professional/academic knowledge, but not only) of the researcher makes it easier for him/her to recognize niches in which commercial opportunities were not exploited, so it facilitates EB.

Literature on opportunity recognition perceived the importance of prior knowledge (Shane 2000). It argued that different people discover different opportunities in a given field because they have different prior knowledge (Venkataraman 1997), this allows them to have an informed and peculiar perspective on the issue at hand and to be able to pinpoint aspects that to others are not at all self-evident.

Such prior knowledge is the result of each individual's life experiences and also of random events, as Nelson and Winter (1982) put it: some people have information that others don't have through "blind luck".

Prior knowledge that might affect the researcher's entrepreneurial behaviour has been identified as:

- Professional, for example having worked within a small company; having industrial experience, consulting experience, etc.;
- Academic, as having developed process of products for a joint project between industry and university, and similar;
- Personal, as might be having had relatives owning their own business; or having already tried to start his own business, or such.

It then becomes clear that the researcher's prior knowledge is an important factor affecting his entrepreneurial behaviour, as his prior experiences will affect his disposition to get involved with industry at large. A researcher who had an industrial experience (both, personally or in his family or in university) will probably be more open to the possibility of getting involved with in a technology transfer process (although he might be more disenchanted than some colleagues). Whereas a researcher who had no contact at all with industry might be more sustained in his attitude toward TT and working with industry in general.

> **H3:** *The third hypothesis is that there is a positive relation between the researcher's prior knowledge and the practical aspects of his/her entrepreneurial behaviour.*

2.1.5 - Field of research influences his/her EB

The field of research in which the researcher is directly involved bears important consequences on his/her recognition of entrepreneurial opportunities (and here there is a reconnection to the discussion about prior knowledge), as there are domains of research that bear possibilities of closer links to industry than other domains. For example, experimental physicists with computing knowledge, software engineers, electronic engineers have specific knowledge that is more easily transferable to industry under consultancy form than that of a theoretical quantum mechanics physicist. In the same way, some kind of research fields require for their experiments machines to be created that might – after necessary changes – be passed to industry for high-tech applications.

> **H4:** *The fourth hypothesis is that there is a positive relation between field of research in which the researchers is involved and his/her entrepreneurial activities.*

It should be noted that also in this case (as in the one of possible additional financial gains as part of the incentive scheme) a shift may occur in the research focus in order to concentrate on more applicable research. In fact, always remaining within his/her own field of research, a researcher may envisage to move towards more sellable research results.

A change in focus of the research may occur because of many different reasons. In CERN it has happened that researchers (were) moved from one research group to another with subsequent modification of research focus. Such a shift might also be hypothesized as a consequence of a prospect of additional financial gains or of the field of research in which the researcher is involved.

Shifts may occur at the personal (or research group) level to achieve research results or to develop instruments that may be more easily transferred to industry. Or simply, such shifts may highlight results that could be used in industry or create competencies that might be useful to industry, thus having an influence on entrepreneurial behaviour.
However, similar shifts may also cause a deviation from industrial application of research results or researcher's knowledge. In any case, there are too many reasons for possible shifts in research focus and therefore it will not be feasible within this thesis framework to test how a such a shift may correlate to EB of the researchers. Here we just want to highlight that such a correlation might exist, but it will not be taken further into account.

2.1.6 - Incentives influence on EB

Incentives from the mother institution tend to increase scientist's entrepreneurialism (Mowery et al. 2001; European Commission 2000). Incentives from CERN take a number of forms: from sensibilization of researchers about entrepreneurial activities (leaflets and seminars about spin-offs creation, consultancy and licensing) to practical help in filing and obtaining patents (copyrights, etc.) and cost bearing on the institution and not on the single researcher. All these activities are done and/or coordinated by the Technology Transfer office, which also has the important task of reducing incomplete information faced by the researchers.

As already pointed out, additional incentives for researchers are the possibility of advancing in their career and of obtaining an extra remuneration for a positive result as a consequence of their pro-active role in a technology transfer process. The possibility of increased financial gains may create an interest in the researcher towards entrepreneurial activities. Financial gains from TT activities may generate additional incomes for both the researcher and his/her research group (e.g. Trune and Goslin 1998; AUTM 2001; COGR 1996; Mejia 1998). Such a motivation can contribute to entrepreneurial practices. Although it cannot fully justify the scientists' entrepreneurialism, as strongly argued by Mowery and Rosenberg and by other authors (e.g. Mowery and Rosenberg 1989; Miyata 2000).

An additional form of incentive for researchers is given by the possibility of having additional funds, and most of all, additional staff (usually graduate and PhD students) to divert to R&D activities that would not be otherwise pursued. The reason for this is that most of CERN forces are now concentrated on completing the LHC and, in the next couple of years, will be focused on having the new accelerator functioning at maximal speed and new experiments taking data and analyzing them. This causes a drain of resources, both financial and human resources, for LHC implementation, thus causing an ever diminishing number of other activities to be undertaken. However, technology transfer allows for R&D to go ahead within such constraints and that is why, for the time being, the possibility of having resources to allocate to activities other than LHC can be seen as a real incentive for CERN researchers.

Incentives that will be called general incentives are not CERN-dependant, but can be recognized in any kind of organization. These incentives to the researchers can be material incentives – such as pay/salary, shares in success using bonuses, shares in success using variable payment shares – such as self-realization, additional qualifications, gather experience for entry into industry/business, start and expand personal, career-supporting relationships (Walter *et al.* 2002).

H5: *The fifth hypothesis is that there is a positive relation between general and/or CERN incentives to the researcher and his/her intention of entrepreneurial activities.*

It should be noted that the possibility to obtain additional income might also cause a change in research focus towards more applied research which is more readily sellable.

3. Research Instrumentation Description

3.1 Questionnaire construction

In order to test what factors correlate to entrepreneurial behaviour of researchers, a questionnaire was handed out to the selected population. The questionnaire was constructed as a sum of three previously published questionnaires, each analyzing different aspects of the behaviour of academic researchers.

The three original questionnaires were obtained directly by the respective authors – whom the author hereby formally thank – after explaining what they would be used for. All the authors provided also a copy of the papers and/or reports for which the questionnaires were developed. Internal consistency was ensured by absorbing the questionnaires without major changes, if not substituting some terms to adapt the questions to CERN environment.

The questionnaire by Prof. Jones-Evans was developed as part of a project, coordinated by the professor himself, which intended to study the process of technology transfer from universities to industry in different regions of Europe (Jones-Evans and *et al.* 1998). The project had a multi-level approach, as technology transfer policies and practices at institutional level with a focus on Industrial Liaison Offices and as results of single academics activities. In this latest case, as in the present thesis, academic entrepreneurship was broadly defined as including contract research, technical consultancy, patenting and licensing activities, as well as the creation of spin-off firms, by university staff (Jones-Evans and *et al.* 1998).

The questionnaire by Prof. Autio *et. al.* was created to study what factors influence entrepreneurial intent among university students (Autio *et al.* 2001). Based on the theory of planned behaviour, factors affecting entrepreneurial intent were categorized as being based on three independent antecedents: attitude towards entrepreneurship, subjective norms and perceived behavioral control. The study, based on international comparisons, showed that perceived behavioral control seems to be the most important determinant of entrepreneurial intent.

The questionnaire by Prof. Lee was developed to study what was the specific role that academicians believe they can play in technology transfer and how they might want to collaborate with industry (Lee 1996). The main point of the study was to see how academics personally responded to institutional pressures towards technology transfer and where they would draw the boundaries to university-industry links, in the light of major concerns such as decreasing national funds to research and concern to loose academic freedom to pursue basic research because of stronger links with industry.

On these bases, the questionnaire used in the present thesis was assembled by incorporating into an harmonic unit the three questionnaires, in order to study the various causes of the entrepreneurial behaviour (or the causes of a disinterest towards an entrepreneurial behaviour) both at the individual and at the organizational level from the point of view of the researchers.

3.2 Questionnaire protocol

The resulting questionnaire (which can be found in Annex I) is made up of different parts, corresponding to different information to be obtained and therefore different type of protocols.

Question 1 to question 12 and then question 19 wanted to gain information about the respondent: nationality, age, gender, status and job at CERN, academic background, previous work experience, previous entrepreneurial experience. Questions concerning nationality, age, academic background, unit and department at CERN and average number of publications per year, were open questions. The remaining questions of this group had multiple choice answers.

Questions 14 to 18 were asked in order to gather information about technology transfer at CERN, both about the TT unit and technology transfer policy, so to have useful indications for the TT unit that supported the author throughout the thesis development. These were yes or no questions.

The remaining questions use Likert protocol on a five scores scale, with the sole exception of question 13 with a three scores scale.

The overall length of the questionnaire was of 27 questions over six pages. The questionnaire took ten to fifteen minutes to complete and it was administered by e-mail. The body of the e-mail contained a presentation of the author, an indication of the author's supervisor at CERN – dr. Marilena Streit-Bianchi – and a brief explanation of the research, although in general terms so not to influence the respondent. The questionnaire had the organization logo in all pages, so that the receivers would know it had been authorized.

3.3 Hypotheses testing

The questionnaire was used to test, in general, what is the attitude of the researchers towards entrepreneurial behaviour both at the level of CERN and at their own individual level.

Perceived entrepreneurial behaviour at the level of CERN, but always from the point of view of the researchers, was defined as:

1) a series of activities that are presently done by the organization with industry – and the researcher was asked to express a judgement on the opportunity of the Lab engaging in such activities and the perceived impact of such activities on the Lab environment;
2) a series of activities with industry that – according to the researcher – CERN should engage into, sometime in the future.

Entrepreneurial behaviour at the level of the researcher was identified as expressing what career alternative he/she would choose outside working at entrepreneurial behaviour CERN.

The following table schematizes the model used in the statistical analysis that will be presented in following chapter.

Table 3.1 – Schematic representation of the experimental design.

			Hp 1	Hp 2		Hp 3		Hp 4	Hp 5	
			D20	D13	D25	D9	D10	D19	D24	D26
CERN EB	D21	CERN work with industry								
	D22	Displacement of mission Loss of freedom Pressure for short-term res. Reduce basic research Conflict of interest								
	D23	Commercialize research Set up incubator Encourage consulting								
Researcher EB	D27	Corporate career Civil service career Entrepreneurial career Academic career								

Entrepreneurial behaviour measurements were given by answers to questions number twenty-one (D21), twenty-two (D22) and twenty-three (D23) for EB at the level of CERN and question twenty-seven (D27) for EB at the level of the individual researcher.

The different factors supposed to influence entrepreneurial behaviour attitudes of researchers were expressed by the following questions:

- Recognition by peers (hp. 1) – D20;
- Networks (hp. 2) – D13 and D25;
- Prior knowledge (hp. 3) – D9 and D10;
- Field of research (hp. 4) – D19;
- Incentives (hp. 5) – D24 and D26.

The data collected was analyzed using the Pearson correlation test. The highest level of confidence employed for the rejection of the null hypothesis was 0,10; however the level of confidence was specified for significant result as being either $p < 0.001$, $p < 0.01$, $p < 0.05$ or $p < 0.10$.

4. Description of Procedures

4.1 Submitting the questionnaire

As already stated, the questionnaire was administered uniquely by e-mail to all of the 487 researchers identified as having a fellowship or a limited duration contract and working in scientific (other than theoretical physics) and engineering assignments identified by job code 1 and 2 by the HR department.
The first run of e-mails was sent in four subsequent days in the last week of May 2006. A remainder run of e-mails was sent fifteen days later, given that e-mail questionnaires tend to be completed within the first days upon receipt.
In the first run, all 487 researchers received the questionnaire. In the remainder run, the questionnaire was sent again to all those who had not responded the first time. Time, seasonal and institutional constraints made it impossible to do another call.
There were 47 respondents to the first run and 38 of them answered within two days of receiving the questionnaire. The second run had 56 respondents, again the

majority answered within 48 hours. Finally, a total of 104 filled-in questionnaires could be collected.

In contacting the subjects, a number of ethical considerations were addressed.
The subjects were informed of the general aim of the study and were asked consent to use their answers for the study itself. They were also assured that their answers would be treated confidentially and that the data analysis would insure them complete anonymity.
At the same time, respondents were informed that the questionnaires results would be used in a PhD thesis and that, therefore, the finding will be freely accessible. Those who specifically asked for a communication on the study results will be provided a short report and all reference details of the thesis.
The respondents who asked for a more detailed explanation of the study project were debriefed and offered the chance to accept or refuse to fill in the questionnaire at their discretion.

4.2 The Human Resources Department

From the beginning of the PhD project, the author received a major support from CERN, given that the whole second year and part of the third year of PhD was spent at the Laboratory in the TT unit on a part-time basis to acquire basic data and understanding of the organization. Following the on-site period, the author had the possibility to remain connected to CERN as an Unpaid Associate in the TT, which granted free access to resources and continuous contact with the organization and, in particular, with the supervisor.

In order to submit the questionnaire to CERN staff, permission had to be asked to the HR department. Such permission was promptly granted from the HR Director himself, whom the author hereby formally thanks, with only a minor change to the questionnaire. The only stipulation to the permission for submitting the questionnaire was that permanent staff should not be involved in the study because of career position, on the one hand, and time constraints for the LHC, on the other. At any rate, the HR department leader, being interested in the research altogether, said that the results of the study should be communicated to him and his services.

Once permission was granted, the HR department provided the names and e-mail addresses of the 487 researchers present at CERN in the spring of 2006 with a limited duration or a fellowship contract. At the same time, the HR department also provided a series of data requested by the author: gender, age, job code, job title and job description and finally duration of the contract with CERN. The use of this information is purely statistic to describe the population under study. Furthermore, the original list – as well as the emails containing the filled-in questionnaires – was destroyed, so that from the anonymous questionnaire the respondent could not be tracked back.

5. Description of Subjects

At the beginning, the subjects of the study were intended to be researchers and engineers who are on CERN payroll; this means some one thousand people, identified by their contract with CERN. The following groups were selected and can be classified according to their contract:

- Fellows: they are typically young researchers who have a two or three years long contract which can be renewed for another two or three years; there were 199 fellows in the list given by HR;
- Limited Duration contracts: these are people who are enrolled by CERN with a fixed term contract depending on the estimated duration of their task at CERN; there were 288 people with LD contract in the list given by HR;
- Indefinite contract: these are people that are enrolled to build the accelerators and carry out the support necessary to the CERN users and have with CERN a contract of indeterminate duration, which may eventually end up at retirement age.

The organization staff varies greatly for age, educational and cultural background. CERN has researchers coming from over seventy countries. The staff with academic background varies from engineering to physics to informatics. Researchers may have academic experience, but some of them also had previous professional experiences in industry. By end 2005, the CERN staff accounted to 2635 staff classified according to the following categories: 2.9% Researchers, 36.2% Scientific and engineering services, 34.8% Technical Services, 8.7% Manual and skilled workers and 17.4% Administrative duties.

In 2002-2003, when the work began, it was assumed that almost all CERN researchers would be sent the questionnaire. This would have meant all staff and fellows with job code 1 and 2 (Scientific work in Experimental and Scientific and Engineering work), other than theoretical physicists (who are a small group of about 30 people), whose field of research is generally too abstract to have any interest for industry.

At the moment of actually sending the questionnaire to the subjects of the study, it was finally decided to send it out only to all CERN staff with a limited duration or a fellowship contract and with job code 1 or 2, other than theoretical physicists. The questionnaire was then sent to 487 researchers.

The reason to send the questionnaire only to these researchers is twofold.

On the one side, they constitute the young part of CERN researchers (as we saw that a big part of permanent contract staffs are over 51 years old as can be seen in Annex II). Whereas LD contracts and Fellows are the ones who still do not have a definite position in the labour market. On the contrary, they have contracts that can be renewed only once and most of them will have to leave CERN and find a position outside the Laboratory, might it be in industry, academy or other research centers. In fact, there are only few openings for permanent contracts, compared to the number of people enrolled at CERN with limited duration or fellowship contracts.

These two types of contracts are for a two or three years period. If one can obtain a renewal of a fellowship contract (for a total of four years) and then a LD contract (renewed once for a total of four to six years), still this person will feasibly find him/herself at the age of 35-40 becoming available for the European job market.. It is then self-evident that these are the kind of people that are most interesting from the point of view of their behaviour towards industry in general and entrepreneurship in particular.

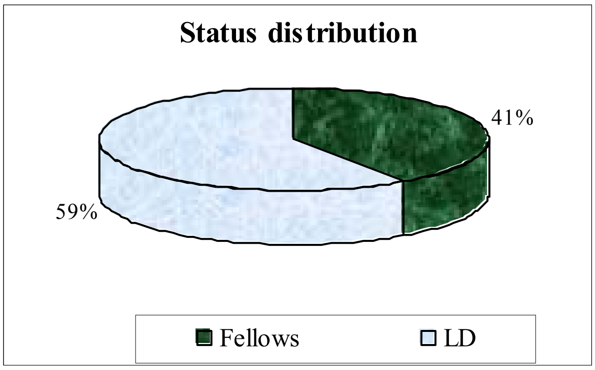
On the other side, the HR department explicitly asked not to send the questionnaire to permanent staff. The first reason being – in substance, if not in words – the same as the above. The second reason was that at the time of the questionnaire, around mid 2006, staff was deeply and busily involved in keeping the time schedule for the LHC to arrive to an end and the HR felt it would not pay to try sending them the questionnaire, as there would not be a significant response rate.

Given the limited number of components of the selected population and given the chosen procedure of an e-mail questionnaire, it was decided that the whole population could be used as subject pool; therefore no sample was extracted from the population. This approach was chosen also in view of a possible low rate of response to e-mail questionnaires.

5.1 Presentation of selected population

Some graphics describing the entire scientific staff of CERN can be found in Annex II, whereas here is provided a short presentation in terms of descriptive statistics of the main characteristics of the population selected for the study.
Of the 487 researchers whom have been sent the questionnaire, 198 of them are fellows and 289 have limited duration contracts.

Figure 3.5 – Status distribution of selected population at CERN



Source: elaboration on row data about selected population

The selected population includes researchers who have different tasks at CERN. The following table and figure provide the description of the jobs of the researchers. It is interesting to note that almost 41% of the population has computing tasks (figure 3.6), which can be explained by the advanced computing skills necessary to program and run a complex machine such as the LHC and by the people being member of the EGEE, an EU founded project.

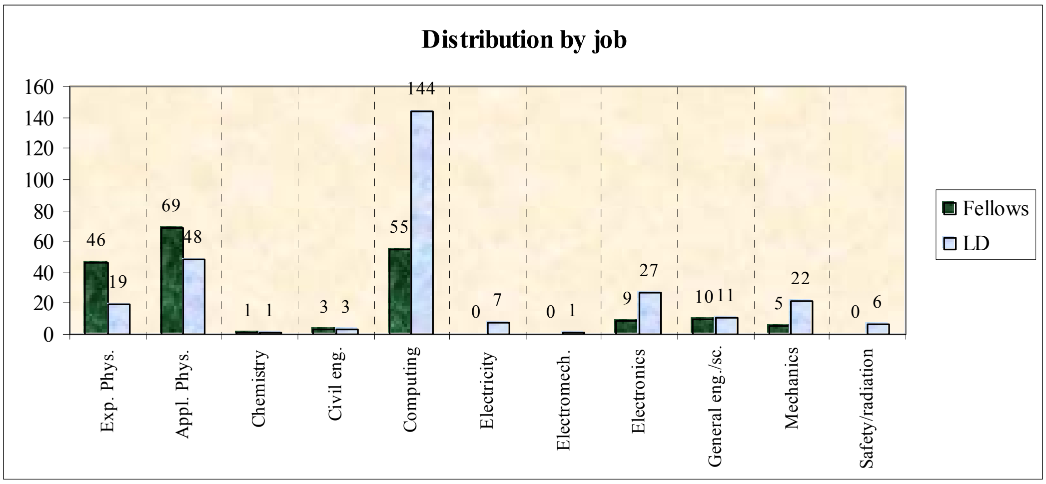
Table 3.2 – Fellows and LD contracts by job.

Job code and title description	Abbreviated	Fellows	LD	Total
1 - Experimental physics	Exp. Phys.	46	19	65
2 - Applied physics	Appl. Phys.	69	48	117
2 - Chemistry	Chemistry	1	1	2
2 - Civil engineering/surveying-topometry	Civil eng.	3	3	6
2 - Computing	Computing	55	144	199
2 - Electricity	Electricity	0	7	7
2 - Electromechanics	Electromech.	0	1	1
2 - Electronics	Electronics	9	27	36
2 - Engineering/Scientific work - General or combination of code	General eng./sc.	10	11	21
2 - Mechanics	Mechanics	5	22	27
2 - Work safety/radiation protection	Safety/radiation	0	6	6
Total		198	289	**487**

Source: elaboration on row data about selected population

The second more frequent job – 24% of the population – is applied physics, although this is the activity of the highest number of fellows (normally nuclear engineers). The third most frequent job is experimental physics – for 13% of the population – and again fellows make up the majority of people with this job, this is usually the case of experimental (particle) physicists. These three jobs alone employ more than 78% of the whole population, and the same holds true for the entire research staff at CERN, permanent jobs included.

Figure 3.6 – Fellows and LD contracts by job.

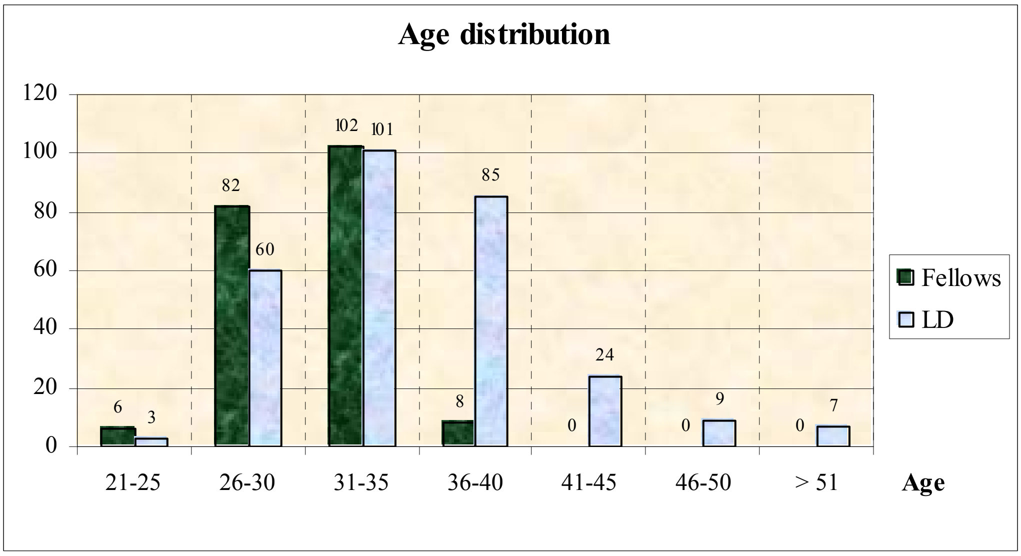


Source: elaboration on row data about selected population

Concerning the age of the population, there are significant differences between Fellows and LD staff. In fact, whereas all fellows are below 40 years old, LDs are up to 63 years old, seven of them are over 51 and thirty-three of them are in their forties (for a total of 14% of LDs over 41 years old). Figure 3.7 gives the age distribution.

If a comparison is done between Figure 3.7 here and Figure A.3 in Annex II, it can be seen that while 61% of CERN staff is over 41 years old (and 34,6% is over 51), the selected population is much younger with all Fellows below 40 and only.

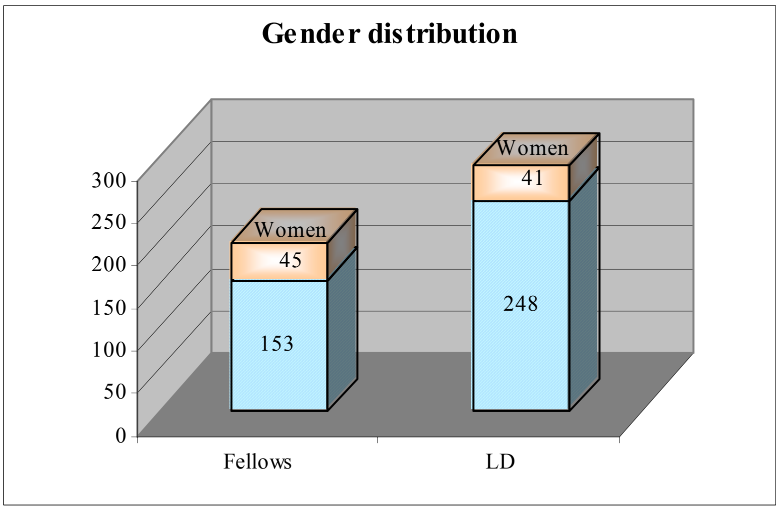
Figure 3.7 – Age distribution of selected population



Source: elaboration on row data about selected population

The percentage of women in the selected population is 18%. In 2005 the percentage of women at CERN in general is about 20%. However, women are 23% of fellows and only 14% of staff with limited duration contracts.

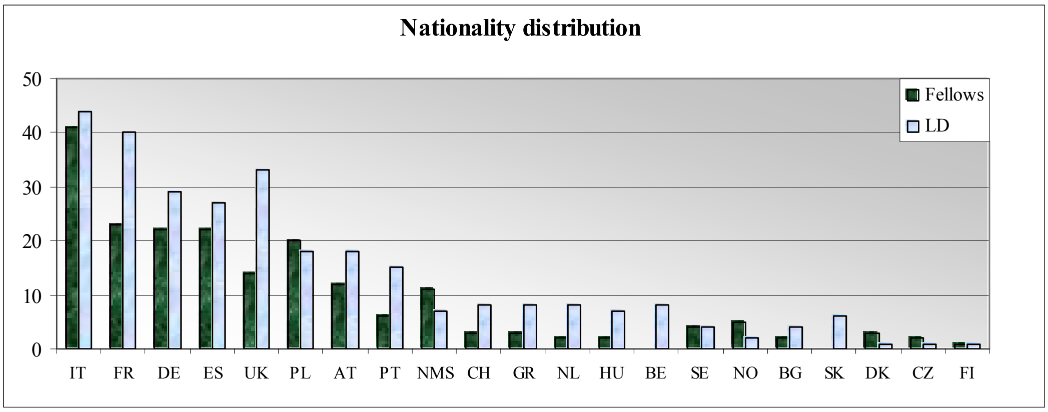
Figure 3.8 – Gender distribution of Fellows and LD contracts.



Source: elaboration on row data about selected population

The nationality distribution of fellows and LD contracts sees Italy as the most represented country with a total of 85 people, followed by France (63), Germany (51), Spain (49), and United Kingdom (47). These five countries are also the biggest contributors to CERN budget. Non-Member States are represented by 18 people, coming from countries such as India, Japan, Russia, etc. Such distribution is consistent with that of staff in general (as can be seen in Figure A.5 in Annex II).

Figure 3.9 – Nationality distribution of selected population



Source: elaboration on row data about selected population

Conclusions

Having set some organizational concepts that should be considered when analyzing a basic research center, this chapter proposed a theoretical framework to recognize factors which might explain entrepreneurial behaviour of researchers.

Having explained how the questionnaire was constructed and submitted to the subjects of the research, it is now possible to consider what results were obtained, under the consideration that the core of the study is the individual level.

Chapter 4 – Analysis results

Introduction

The purpose of this work is to examine what factors might be correlated to an expression of interest towards Entrepreneurial Behaviour by the individual researchers at CERN. A total of one-hundred and three answered questionnaires were used to review the hypotheses presented in Chapter 3. Following are the results of the analysis of the survey.

This chapter is divided into seven sections. The first introduces the statistical method used. The following five sections correspond to the five hypotheses relating to factors influencing EB and describe the results for each of them. The final section presents some descriptive analysis that is of interest to understand researchers' attitudes.

1. Statistical procedure

It was interesting for the model to see the linear correlation between the identified factors influencing entrepreneurial behaviour and the expression of interest and attitudes towards EB by the single researcher both at the level of CERN and at the level of the researcher him/herself.

In order to test if such a linear correlation existed, it was decided to use the Pearson's R correlation coefficient, because it gives an indication not only of the magnitude, but also of the direction of the association between two variables that are on an interval or ratio scale.

The correlation coefficient can vary between +1 and -1. This number tells us about the magnitude and direction of the association between two variables.

The magnitude is the strength of the correlation. The closer the correlation is to either +1 or -1, the stronger the correlation is. If the correlation is 0 or very close to zero, there is no association between the two variables.
The direction of the correlation indicates how the two variables are related. If the correlation is positive, the two variables have a positive relationship (as one increases, the other also increases). If the correlation is negative, the two variables have a negative relationship (as one increases, the other decreases).
The level of confidence, the probability level for rejection of the null hypothesis, was set and identified in each case between 0.001 and 0.10. The following notation was adopted: ***($p < 0.001$); **($p < 0.01$); *($p < 0.05$); +($p < 0.10$).
It remains understood that correlation refers to the departure of two variables from independence, although correlation does not imply causality.

A previous analysis was done checking for the Spearman correlation coefficient, to analyze whether an arbitrary monotonic function could describe the relationship between the two variables at hand, without making any assumptions about the frequency distribution of the variables. Given that the significant results had an almost 99% match over significant corresponding values of Pearson's R, it was decided to use this last coefficient in the analysis.

2. Hypothesis 1 – Recognition by peers

The first hypothesis stated that there is a positive relation between recognition by peers and entrepreneurial behaviour by researchers.
The perception of research credit for patentable inventions being greater than or at least equal to refereed journal articles was set as a measure of recognition by peers that might influence entrepreneurial behaviour in terms of what researchers think of EB by CERN and at the individual level.

Table 4.1 – Research credit correlation to entrepreneurial behaviour

			Research Credit
CERN EB	D21	CERN work with industry	-0,045
	D22	Displacement of mission	0,045
		Loss of freedom	0,109
		Pressure for short-term research	0,023
		Reduce BR	0,154
		Conflict of interest	0,170 +
	D23	Commercialize research	0,047
		Set up incubator	0,101
		Encourage consulting	-0,077
Researcher EB	D27	Corporate career	0,091
		Civil service career	0,055
		Entrepreneurial career	-0,028
		Academic career	0,220 *

Pearson's R, signif.: ***(p < 0.001); **(p < 0.01); *(p < 0.05); +(p < 0.10).

Research credit for patentable inventions was found to a have a positive and significant correlation to the fact that a close CERN-industry collaboration for technology transfer and commercialization would not cause conflict of interest between research and "business" at CERN.

The same variable has a positive and significant correlation to the choice of academic career as an alternative to employment in CERN.

Results do not show other significant correlations between recognition by peers and entrepreneurial behaviour by CERN or by the individual researchers.

Judgement by peers does not result as a variable having much of correlation to attitudes towards entrepreneurial behaviour, according to the researchers interviewed.

3. Hypothesis 2 – Networks

The second hypothesis is that there is a positive relation between network's assessment of EB and the researcher's attitudes about entrepreneurial behaviour both at the CERN level and the individual level.

Table 4.2 shows the coefficients for the correlation between unspecified networks in which the researcher is embedded and entrepreneurial behaviour.
In particular, the perception that entrepreneurship by researchers and a career alternative in industry are considered good by the network in which the researcher is rooted are positively and significantly correlated to the fact that a close CERN-industry collaboration would not cause a displacement of the Organization mission, nor a loss of freedom and autonomy for the Lab, nor a pressure for short-term research, nor would it reduce research activities or cause a conflict of interest.

Networks general perceptions about entrepreneurship also have a positive and significant correlation to the view by the researchers that CERN should commercialize its research by more strongly support its technology transfer office, as well as set up an incubator and encourage its staff to provide consulting services to private firms (a case in which correlations were quite significant, particularly in the case of entrepreneurship considered as a good career alternative by the network members).

Table 4.2 – Networks correlation to entrepreneurial behaviour

			Networks				
			Res. entr.	Coll. entr.	Entr. as altern.	I know entr.	Ind. as empl.
CERN EB	D21	CERN work with industry	0,096	0,099	0,066	0,066	0,153
	D22	Displacement of mission	0,153	0,170 +	0,275 **	0,134	0,228 *
		Loss of freedom	0,220 *	0,187 +	0,366 ***	0,106	0,415 ***
		Pressure for short-term res.	-0,058	0,065	0,247 *	0,177 +	0,266 **
		Reduce BR	0,093	0,061	0,263 **	0,177 +	0,320 **
		Conflict of interest	0,248 *	0,213 *	0,327 **	0,156	0,328 **
	D23	Commercialize research	0,182 +	0,118	0,187 +	0,180 +	0,115
		Set up incubator	0,186 +	0,245 *	0,202 *	0,225 *	0,144
		Encourage consulting	0,119	0,225 *	0,357 ***	0,168 +	0,337 **
Researcher EB	D27	Corporate career	0,103	0,17 +	0,353 ***	0,091	0,334 **
		Civil service career	0,143	-0,051	0,131	0,045	0,238 *
		Entrepreneurial career	0,278 **	0,251 *	0,385 ***	0,052	0,293 **
		Academic career	0,007	-0,164 +	-0,269 **	-0,01	-0,146

Pearson's R, signif.: ***(p < 0.001); **(p < 0.01); *(p < 0.05); +(p < 0.10).

The idea that the networks in which the researcher is embedded have a positive view of entrepreneurship and collaboration with industry also shows a positive and significant correlation to career alternatives in industry and also in self-employment (in this last case the correlations were particularly significant). On the contrary, and quite consistently, there was a negative correlation to the choice of academic career as an alternative: the strongest the idea that entrepreneurship is considered good, the least appealing a career in university.

The analysis showed no significant correlation between present-day CERN-industry collaboration and the perceived position of network members towards entrepreneurship or employment in industry.

Table 4.3 shows the coefficients for the correlation between the perception of CERN network to which the researcher participates daily and entrepreneurial behaviour.

Table 4.3 – CERN network correlation to entrepreneurial behaviour

			CERN network	
			Entrepreneurship	Contract research
CERN EB	D21	CERN work with industry	-0,188 +	-0,017
	D22	Displacement of mission	0,124	0,225 *
		Loss of freedom	0,127	0,168
		Pressure for short-term research	0,002	0,06
		Reduce BR	0,175 +	0,16
		Conflict of interest	0,211 *	0,387 ***
	D23	Commercialize research	-0,089	0,142
		Set up incubator	0,12	0,114
		Encourage consulting	0,04	-0,129
Researcher EB	D27	Corporate career	-0,02	0,033
		Civil service career	0,235 *	-0,005
		Entrepreneurial career	-0,114	-0,088
		Academic career	0,084	-0,083

Pearson's R, signif.: ***(p < 0.001); **(p < 0.01); *(p < 0.05); +(p < 0.10).

A perceived supportive environment inside CERN towards staff getting involved in the development of entrepreneurial activities was found to have positive significant correlations to a hypothetical closer collaboration between the Lab and industry as not impacting on reducing basic research or causing conflicts of interest and civil service as a career alternative, but a negative correlation to the present collaboration as being too close, thus not showing coherency. On the contrary, a perceived supportive environment towards staff getting involved in contract research had positive and quite significant correlations to small chances of displacement of mission or interest conflicts.

4. Hypothesis 3 – Prior knowledge

The third hypothesis is that there is a positive relation between the researcher's prior knowledge and his/her attitudes towards entrepreneurial behaviour.
Prior knowledge as a factor affecting researchers' attitudes towards entrepreneurial behaviour at CERN level and at the individual level was defined both as previous work experience by the researcher and also as prior knowledge of entrepreneurship – both personally or familiarly – and of big or small companies.

Table 4.4 presents the correlation coefficients relative to previous work experience.
Only in the case of researchers with prior experiences in manufacturing there was a positive although loosely significant correlation to the perception that CERN is not working closely enough to industry in transferring technology and commercializing its research.

Interesting results concern the impact that a close CERN-industry collaboration (D22) would have on various aspects of the Lab's environment. In the case of researchers having experiences as consultants, the correlations were all positive and significant in indicating that a strong collaboration between the Organization and industry would not cause shifts in the implementation of research.

Table 4.4 – Prior knowledge (previous work) correlation to entrepreneurial behaviour

			Previous work experience					
			No exper.	Manufact.	Consulting	Public	Univ.	Other
CERN EB	D21	CERN work with industry	-0,039	0,188 +	0,057	-0,082	-0,132	0,127
	D22	Displacement of mission	-0,077	0,041	0,245 *	-0,007	-0,131	0,021
		Loss of freedom	-0,049	-0,132	0,239 *	0,018	-0,126	0,087
		Pressure short-term res.	-0,164 +	0,005	0,280 **	-0,054	-0,067	0,111
		Reduce BR	-0,064	0,108	0,247 *	-0,160	-0,08	0,054
		Conflict of interest	0,006	-0,038	0,236 *	-0,103	-0,119	0,027
	D23	Commercialize research	-0,107	0,155	0,166 +	-0,006	-0,037	-0,020
		Set up incubator	-0,031	0,111	0,057	0,020	-0,077	-0,005
		Encourage consulting	0,066	0,044	0,024	0,001	-0,063	0,136
Researcher EB	D27	Corporate career	-0,076	0,123	0,055	-0,075	0,069	-0,003
		Civil service career	-0,089	0,045	0,019	-0,074	0,238 *	-0,063
		Entrepreneurial career	0,066	0,078	0,190 +	-0,138	-0,172 +	0,173 +
		Academic career	0,052	-0,05	-0,252 **	-0,119	0,293 **	-0,081

Pearson's R, signif.: ***(p < 0.001); **(p < 0.01); *(p < 0.05); +(p < 0.10).

Concerning the actions that CERN should undertake, there is only one significant result, which is consistent with what was said just above. In fact, the case of researchers with consulting experience is positively correlated to the possibility of CERN commercializing its research, although quite curiously no significant correlation was shown with encouraging staff to do consulting.

Consistency is also found in the career alternatives considered by the researchers. There is a negative correlation that is quite significant between previous experience in consulting and academic career as a desirable alternative, and a positive correlation to entrepreneurship. The opposite is true for those with prior experience in university: positive and significant correlation to academic career and public sector career and negative correlation to entrepreneurship. Finally, a positive correlation emerges between other kinds of previous work experience and the alternative of self-employment.

Table 4.5 presents the correlation coefficients relative to previous work experience: entrepreneurial experience was set in terms of having had own or family business: previous work experience was set as having worked in a big or small business.

Table 4.5 – Prior knowledge correlation to entrepreneurial behaviour

			Prior knowledge				
			Family bus.	Own bus.	Big bus.	Small bus.	Other
CERN EB	D21	CERN work with industry	-0,165 +	-0,024	-0,002	-0,142	0,043
	D22	Displacement of mission	-0,055	0,078	-0,083	-0,102	0,003
		Loss of freedom	-0,025	0,124	-0,093	-0,036	0,111
		Pressure short-term res.	0,109	-0,027	-0,269 **	-0,05	0,049
		Reduce BR	0,004	0,016	-0,174 +	-0,105	-0,007
		Conflict of interest	-0,009	0,137	-0,183 +	-0,009	-0,026
	D23	Commercialize research	0,131	-0,173 +	-0,044	-0,044	0,107
		Set up incubator	0,182 +	-0,06	-0,064	-0,062	0,022
		Encourage consulting	0,124	0,075	-0,214 *	-0,061	0,224 *
Researcher EB	D27	Corporate career	0,166 +	-0,063	-0,064	-0,057	-0,061
		Civil service career	-0,069	0,145	-0,082	0,105	0,001
		Entrepreneurial career	0,134	0,21 *	-0,084	-0,076	-0,015
		Academic career	0,091	0,188 +	0,346 **	0,281 **	-0,02

Pearson's R, signif.: ***(p < 0.001); **(p < 0.01); *(p < 0.05); +(p < 0.10).

Prior knowledge of entrepreneurship in terms of family business was found to have a negative correlation to the present working situation of CERN with industry. Researchers who had experience in big business (indicated in the questionnaire as those with more than fifty employees) expressed a view that a close collaboration between the Lab and industry would induce a pressure for short-term research, a reduction of basic research activities and a conflict of interest between basic research and business (all expressed by negative significant correlations).

Prior knowledge of researchers was also differently correlated to entrepreneurial behaviour applied to CERN. So, entrepreneurial experience via family business was positively correlated to setting up incubators as a desirable action by CERN. Encourage consulting by staff had a positive significant correlation to other kinds of prior knowledge, while it had a negative correlation to the case of previous experience in big business. Interestingly, a prior experience in self-employment was negatively correlated to the idea that the Organization should commercialize its research.

Finally, considering researchers indication of desirable career alternatives significantly positive correlation were found between: a) corporate career and prior experience in family business; b) between academic career and self-employment, but also employment in big and small business; c) as expected, between own business experience and entrepreneurial career.

5. Hypothesis 4 – Field of research

The fourth hypothesis is that there is a positive relation between field of research in which the researchers is involved and his/her entrepreneurial activities.

Researchers at CERN are employed in different kinds of research activity. Their working time is variously divided between basic and applied research and prototyping, according to their academic background and their division and unit they belong to and the kind of task they are working upon.

Table 4.6 – Research activity correlation to entrepreneurial behaviour

			Research activity at CERN		
			Basic research	Applied research	Prototyping
CERN EB	D21	CERN work with industry	-0,088	0,018	0,010
CERN EB	D22	Displacement of mission	-0,049	0,056	-0,047
CERN EB	D22	Loss of freedom	-0,103	0,140	0,101
CERN EB	D22	Pressure short-term res.	-0,083	0,072	0,012
CERN EB	D22	Reduce basic research	-0,038	0,136	-0,042
CERN EB	D22	Conflict of interest	-0,064	0,121	-0,023
CERN EB	D23	Commercialize research	-0,266 **	0,044	0,169 +
CERN EB	D23	Set up incubator	-0,235 *	0,264 **	0,133
CERN EB	D23	Encourage consulting	-0,268 **	0,299 **	0,132
Researcher EB	D27	Corporate career	-0,169 +	0,293 **	0,049
Researcher EB	D27	Civil service career	0,100	0,151	-0,083
Researcher EB	D27	Entrepreneurial career	-0,096	-0,009	0,081
Researcher EB	D27	Academic career	0,235 *	-0,021	-0,117
Pearson's R, significance: ***(p < 0.001); **(p < 0.01); *(p < 0.05); +(p < 0.10).					

When basic research accounts for most of the researcher's activity, there is a negative and significant correlation to entrepreneurial activities in which CERN should get involved. Coherently, at the individual level corporate career is not seen as a desirable activity, as shown by the negative correlation, whereas academic career is positively and significantly correlated.

When applied research is the respondent's main activity, there is a positive and significant correlation ($p<0,01$) to envisaged EB by the Lab in form of setting up incubators and encouragement of consulting activities by staff, but no significant correlation was found towards commercialization of research results. A positive and significant ($p<0,01$) correlation was present in case of corporate career as an alternative to a job at the research center.

Finally, prototyping as a main activity is significantly and positively correlated only to the perception that CERN should commercialize it research.

6. Hypothesis 5 – Incentives from CERN and general incentives

The fifth hypothesis is that there is a positive relation between incentives to the researcher and his/her entrepreneurial behaviour.

Different kinds of incentives were identified as possibly influencing the entrepreneurial attitudes of researchers both at the level of CERN and at the individual level. Those incentives were divided in incentives by CERN and general incentives.

Table 4.7 shows correlation coefficients relative to CERN incentives.

The identified incentives by CERN did not show a very high number of significant correlations to EB of researchers, but the significant ones do show interesting results. When CERN is perceived to encourage researchers to actively pursue their ideas in application of research, such a perception is positively and significantly correlated to a view that the Organization should encourage its scientists to engage in consulting activities and no conflict of interests would arise from a close collaboration with industry. In the same way, the fact that at CERN a good number of people can be found to have good ideas for starting firms is positively correlated to no perceived risk of displacement of mission or loss of freedom of the Lab. And the perception that international status holds back people from engaging in entrepreneurial activities is positively correlated to no pressure for short term research arising from collaboration with industry.

Table 4.7 – CERN incentives correlation to entrepreneurial behaviour

			CERN incentives				
			Encourage application	Good ideas for firms	Internat. status	Clear TT policy	Good TT infrastructure
CERN EB	D21	CERN work with industry	-0,129	-0,102	0,016	-0,284 **	-0,189 +
	D22	Displacement of mission	0,162	0,180 +	-0,033	-0,015	-0,056
		Loss of freedom	0,126	0,185 +	0,037	0,081	-0,032
		Pressure for short-term res.	0,126	0,104	0,176 +	-0,062	-0,118
		Reduce BR	0,133	0,143	0,162	-0,087	-0,128
		Conflict of interest	0,241 *	0,138	0,138	0,013	-0,008
	D23	Commercialize research	0,011	-0,047	-0,018	-0,115	-0,216 *
		Set up incubator	-0,012	-0,088	-0,026	0,043	-0,258 **
		Encourage consulting	0,244 *	0,114	0,072	0,006	0,073
Researcher EB	D27	Corporate career	0,206 *	0,116	0,275 **	0,107	0,108
		Civil service career	0,226 *	-0,037	-0,069	0,015	0,052
		Entrepreneurial career	-0,068	0,083	0,044	0,029	-0,008
		Academic career	0,064 *	0,113	-0,054	0,107	0,041

Pearson's R, signif.: ***(p < 0.001); **(p < 0.01); *(p < 0.05); +(p < 0.10).

It is interesting to note that awareness of a clear TT policy concerning IPRs is negatively correlated to present collaboration with industry (which is then seen as too close) and also the perception of a well functioning TT infrastructure at CERN has negative correlations to collaboration with industry as well as to the advisability of commercializing research results or setting up incubators.

Finally CERN incentives are positively correlated to careers alternatives in industry, public sector and university but not significantly correlated to entrepreneurship.

Table 4.8 shows the correlation coefficients relative to general incentives and entrepreneurial behaviour at CERN and individual level.

General incentives did not show any significant correlation on the perception of the goodness of present collaboration between CERN and industry. On the contrary, numerous and significant and positive correlations on perceived outcomes of a possible closer collaboration were found. In particular, financial incentives were positively correlated to no perceived loss of freedom, nor pressure for short term research nor conflict of interests, whereas all 'personal' incentives were positively correlated to almost all outcomes of such a collaboration as not being harmful at all.

Financial incentives were also correlated to the view that CERN should encourage consulting activities by its staff and – in the case of remuneration in form of shares – to setting up incubators. Self-realization was positively correlated to all EBs of the Organization as being desirable and obtaining additional qualification was in positive correlation to set up incubators.

Table 4.8 – Incentives correlation to entrepreneurial behaviour

			Incentives						
			Pay	Bonus	Share	Self-realizat.	Qualificat.	Exper.	Relation.
CERN EB	D21	CERN work with industry	0,059	0,038	0,065	0,079	-0,073	-0,157	-0,075
	D22	Displacement of mission	0,153	0,154	0,136	0,164 +	0,167 +	-0,005	0,136
		Loss of freedom	0,276 **	0,219 *	0,170 +	0,184 +	0,243 *	0,254 *	0,281 **
		Pressure for short-term res.	0,206 *	0,141	0,105	0,196 *	0,248 *	0,165 +	0,332 **
		Reduce BR	0,128	0,093	-0,014	0,115	0,199 *	0,177 +	0,265 **
		Conflict of interest	0,287 **	0,312 **	0,288 **	0,265 **	0,249 *	0,192 +	0,367 ***
	D23	Commercialize research	0,053	-0,074	0,000	0,178 +	0,034	-0,053	0,056
		Set up incubator	0,049	0,160	0,209 *	0,205 *	0,202 *	0,027	0,150
		Encourage consulting	0,167 +	0,280 **	0,247 *	0,254 *	0,294 **	0,238 *	0,314 **
Researcher EB	D27	Corporate career	0,318 **	0,310 **	0,269 **	0,307 **	0,221 *	0,289 **	0,236 *
		Civil service career	-0,012	-0,099	0,046	0,056	0,188 +	0,141	0,261
		Entrepreneurial career	0,191 +	0,104	0,206 *	0,354 ***	0,199 *	0,388 ***	0,334 **
		Academic career	-0,047	-0,193 +	-0,121	-0,107	0,071	-0,082	-0,134

Pearson's R, significance: ***(p < 0.001); **(p < 0.01); *(p < 0.05); +(p < 0.10).

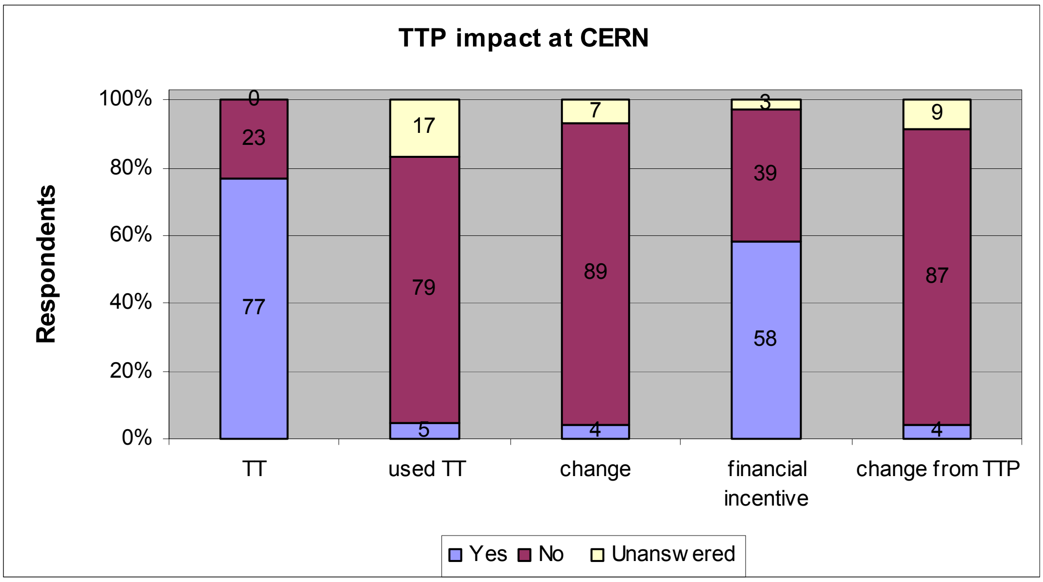
It is particularly interesting to note that all incentives are positively and significantly correlated to encourage consulting activities by CERN staff.

Finally, all incentives were also positively correlated to a career alternative in industry and also all of them, but bonuses, are positively correlated to an alternative entrepreneurial career. Incentives in the form of bonuses are coherently in a negative correlation to a career in university.

7. Descriptive statistics

Some of the questions (D14 to D18) that were asked to the researchers referred to the introduction of a formal technology transfer policy at CERN and the existence of the TT office, within the organization, and how these affected their relationship with industry. It was of particular interest to understand if the researchers were aware of what the Lab is doing and trying to do in terms of technology transfer.

Figure 4.1 – Impact of technology transfer policy on CERN researchers



The graph above illustrates how the vast majority of the respondents are aware of the existence of a TT service inside CERN, however very high shares of them – respectively 89% and 87% – do not feel that the creation of a TT service changed

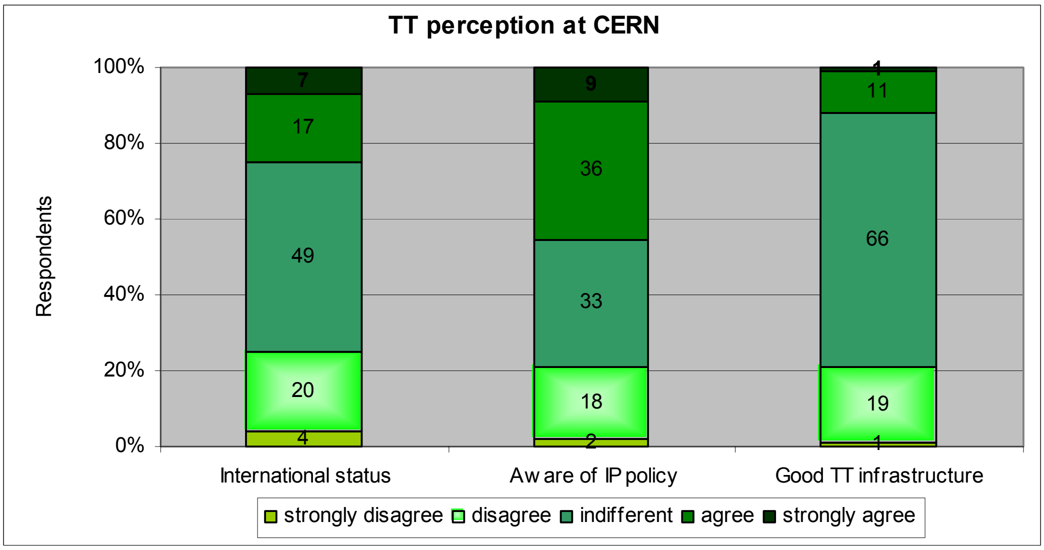
their interaction modalities with industry nor that the introduction of a proactive TT policy change their attitudes towards it.
When asked to say if financial incentives would motivate them to transfer technology 58% of them answered yes.

If the data just presented seem quite encouraging for the TT group, they should be checked against the data in the following graph (Figure 4.2). Here percentages to three items of question D26 are presented. These items are directly connected to TT group activities at CERN.
The international status of CERN researchers means that for any activity in which staff is involved that may provide financial gains, the individual has to ask and be granted a special permission by the Director General. It is interesting to note that 49% of researchers declared themselves indifferent to the fact that international officer status holds back people at CERN from engaging in entrepreneurial activities. Whereas 24% of respondents said they strongly disagree with this, while another 24% said they agree (the remaining 3% is given by those who didn't answer the question).

A more positive result for the work of the TT group is given by the answers to the item "I am aware that CERN has a clear policy regarding the intellectual ownership of ideas developed during research". In this case, 45% of respondents agreed with the statement, 33% declared themselves indifferent, whereas 20% disagreed.

Finally, when asked to express agreement or disagreement with the statement that at CERN there is a well functioning infrastructure in place to support technology transfer, the very high majority of researchers answered that they were indifferent; an additional 20% said that they did not agree, whereas only 12% approved of the TT infrastructure in place in the organization.

Figure 4.2 – Perception of TT activities at CERN and impact of international status.



Question D11 asked if, since joining CERN, the researchers had any direct contact with industry in one or more of the following ways:

- I approached an industrial organization for procurement – selected 38 times;
- I approached an industrial organization for R&D outside procurement – selected 23 times;
- An industrial organization approached me for consultancy – selected 11 times;
- No contact – selected 57 times.

In case the researcher had had any kind of contact with industry, he/she was asked to select what type or types of activities he/she had been involved in. In particular, the respondent was also asked to specify if he/she carried on these activities with or without CERN. This question was consciously left not very specific as to when those activities had been done, although having answered yes to the precedent question understated that these should be activities done since joining the organization, with CERN itself or externally to it, which – for contract – the researcher should not be allowed to, as we noticed before. In the following table are presented the number of times that each item was selected.

Table 4.9 – Activities in which the respondent was involved since joining CERN.

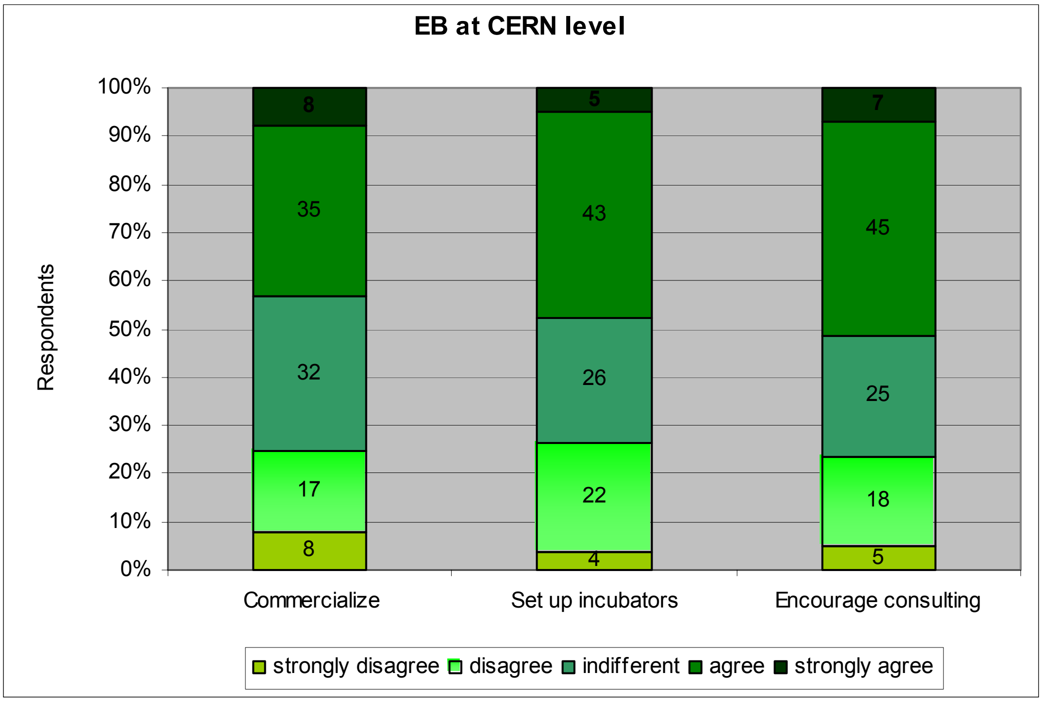
	With CERN	Without CERN
Participating in research projects with industry	24	12
Patenting / licensing research results	2	4
Consulting / provision of personal expertise	12	15
Teaching to non-university individuals (ex.: continuing education)	7	8
Spin-off: the formation of a new organization to exploit the results of the research	1	4
Other	4	2

What is of interest in understanding researchers attitudes towards entrepreneurial behaviour as defined in this study is that twelve people out of one-hundred and three have worked on research projects with industry outside of CERN and fifteen people have been consultants outside of contracts formally signed by the organization. Other eighteen people were involved either in professional training, patenting, aiding in the creation of spin-offs or some other kind of activity.

Question D23 asked the respondent to express agreement and/or disagreement on whether CERN should: a) commercialize its research by more strongly support its technology transfer office; b) set up its own incubator to help start up new technology-based businesses; c) encourage staff to provide consulting services to private firms.

The graph in Figure 4.3 illustrates the percentages of responses given to each item.

Figure 4.3 – Indication of desired entrepreneurial behaviour at CERN level.



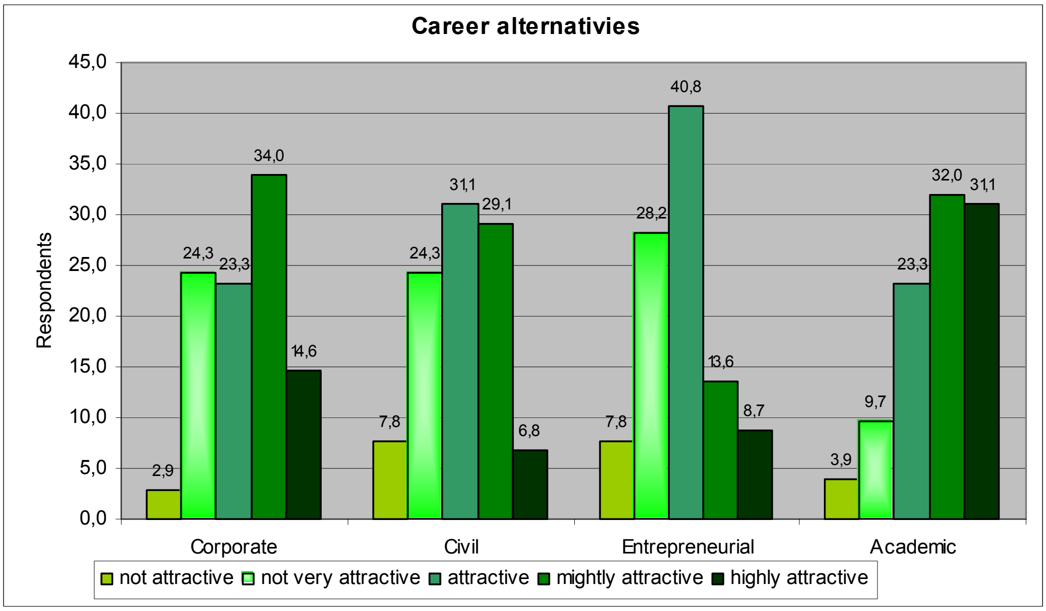
As can be observed, in each case the majority of researchers agreed with the option that CERN should engage in a more active contacts with industry, although a good portion of respondents also said to de indifferent. The statement that the organization should encourage consulting activity by its staff to private firms was the one that had the highest share of agreement (52% between agree and strongly agree). A total of 48% of respondents agreed with the statement that the Lab should set up incubators. Somehow smaller (43%) was the share of respondents expressing the view that CERN should commercialize its research. Leaving aside those who declared themselves indifferent, the researchers that clearly disagreed with these options were in a significant smaller number compared to those agreeing with such possibilities.

Finally, question D27 was asking the respondent to grade how attractive they would find each career alternative if the had to choose an alternative career.

Figure 4.4 illustrates the percentages of respondents grading each item.

The career that resulted the preferred one by the vast majority of researchers was a professional life in university, which received high grades of attractiveness by most respondents (for a total of 86% over 103 answers from attractive to highly attractive). The second preferred career was in a large company (72%), followed by a career in the public sector (67%) and finally the entrepreneurship alternative (found attractive in 63% of 103 cases). The entrepreneurial alternative was the one with the highest number of respondents finding it attractive (41% compared to other medium attractive career with lower percentages, such as 23% for corporate or academic career), but also with the highest number of researchers not finding it attractive (28% not very attractive, plus 8% not attractive at all).

Figure 4.4 – Career alternatives selected as desirable by respondents (%).



Conclusions

From the analysis of the questionnaires the following results can be summarized. Concerning recognition by peers, this factor had significant and positive correlations only to two items of EB. General networks have many positive correlations to EB both at CERN and individual level, whereas CERN network has positive correlation to potential EB of CERN in the future, but negative correlation to present-day collaboration between CERN and industry. Previous

work experience in consulting is positively correlated to almost all EB at both levels, whereas Prior work experience in business is negatively correlated to EB. As a factor explaining entrepreneurial behaviour, basic research activity is negatively correlated to EB; applied research is positively correlated to EB at CERN level and once at individual level; and Prototyping has only one significant and positive correlation to EB. General incentives are positively correlated to almost all expressions of EB at both levels, whereas Two CERN incentives have positive correlations to EB. The 2 TT incentives have negative correlations to EB.
While aware of a technology transfer policy and infrastructure, researchers claim there were no significant changes in their relationships with industry, although the existence of financial incentives would push them to engage in TT-related activities. High shares of respondents also agree that the Lab should commercialize its research and/or technologies, set up incubators and mostly encourage its staff to provide consulting services to the industrial sector. Finally, academic career was recognized as the most attractive, followed by corporate, public sector and entrepreneurial career.
From these results some interesting interpretations might be drawn.

Chapter 5 – Interpretations

Introduction

This chapter presents interpretations that can be drawn from the study presented in earlier chapters. After a bottom-up approach, it is now appropriate to try and provide a general interpretation framework at the three levels that were considered throughout the thesis: the macro-level, the intermediate level and the individual level.

The present chapter is divided into three sections. The first one deals with policy interpretations that can be inductively proposed at the macro-level, concerning science and technology policy in general. The second section presents strategy interpretations that can be referred to the intermediate level, that of the research institutions. Finally, the third section proposes interpretations at the micro-level, in terms of the individual behaviour of researchers.

1. Macro-level: some policy interpretations

The macro-level, as defined in the present study, concerns the knowledge-production system and the knowledge-governance system. Applying an inductive approach to the empirical results, especially in light of the fact that CERN-related factors were not significant, it is possible to propose some general interpretations in terms of science and technology policy.

Researchers' interest towards collaborations with industry; technology transfer projects, as well as cooperation projects between industry and research centers, born from applications developed for basic researches; technologies implemented for pure science goals and sold on the market after standardization for industrial users' needs; all these allow recognizing basic research as a highly prolific potential generator of industrial applications[25].

In this sense, from the point of view of science policy research, a partial revival of the linear model, integrated by a reshaped reward system allowing scientists to get credit also for entrepreneurial activities, may be proposed. In the case of basic research, such as high energy particle physics, one may identify problem domains that are at the same time overlapping and disjoint with near-term potential applications. In other words, there are problem domains that have no current overlap with practical purposes. But the means for exploring these domains, however, are very likely to have overlaps. Hence, there is no reverse causation from practical pursuits to, say, the pursuit of Higgs' boson or string theory for example. But if there are specific tests of string theory hypotheses to be made the problem domains relevant for making tools for performing these tests are likely to overlap with practical problem domains. Learning gains for private firms by developing state-of-the-art technologies for high energy physics were recently demonstrated by Autio, Erkko, M. Streit-Bianchi, and Ari-Pakka Hameri (Autio, Streit-Bianchi, and Hameri 2003)

Then, the concept of "entrepreneurial university" (Etzkowitz 2001), as an institution that emphasizes its 'third' mission of contributing to the economy as much as its teaching and research missions, can be borrowed and applied to knowledge-seekers institutions. In terms of science and technology policy, Etzkowitz's words can be used as a recommendation to policy-makers to drive and direct research centers to make "entrepreneurship […] compatible with the conduct of basic research through a legitimating theme that integrates the two activities into a complementary relationship" (Etzkowitz 1998). The idea is that the present trend of a re-organization of the research environment, which is becoming a hybrid of traditional academic research and the knowledge-based

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[25] The case of EGEE (Enabling Grids for E-SciencE), a huge IT project funded by the EC under the 6th FP and coordinated by CERN, is a good example of industrial interest towards academic research. Among the industrial users in the forum, there are representatives of some of the leading companies, and not only of the IT sector: Microsoft, IBM, Alcatel, HP, Fujitsu, Oracle, Sun Microsytems, Vodaphone, France Telecom, Novartis, Sanofi-Aventis, Total, Renault, Michelin, Airbus, and many others.

economy, should be orchestrated at the European level, with the understanding that "collegial recognition will remain an important normative element for academic researchers, together with entrepreneurialism and societal accountability" (Benner and Sandstrom 2000, p. 300).

In terms of science and technology policy, also some other interpretations can be proposed on the base of the results of the study.

As shown by Cohen and Levinthal 1989, in-house R&D efforts are important because they allow the firm to create new knowledge, but also because it enhances their 'absorptive capacity', i.e. their capability to assimilate, understand and exploit external knowledge (Cohen and Levinthal 1989). This same absorptive capacity must be present in basic research centers. Researchers from these centers can form the base for a pool of informed producers and users of knowledge, from which the industrial sector can draw specialized personnel.

> "Firms also look to universities as a source of technology as well as trained personnel. Local and regional government also view local universities in a new light as a potential source of contribution to the economy through the formation of start-up firms" (Etzkowitz 1994, p. 11).

Scientists working in front-edge research are in a privileged position, from where they can first identify technologies which might be useful for industrial applications and thus provide a competitive advantage to the European industry sector, much in accordance with the objectives of the Lisbon strategy.

Spill-overs are but a form of technology transfer in its broader definition and are valued by firms, universities and governments. The case of CERN is but one of the many publicly funded European research centers that are recognized world-wide excellence. Spill-overs from basic research centers are also possible and should be better studied and understood as well as sustained by European S&T policy.

Finally, in terms of science and technology policy, the results obtained are in accordance with the attributes of knowledge production in Mode II – knowledge produced in the context of application, trans-disciplinarity, heterogeneity and organizational diversity, social accountability and reflexivity, quality control –

which can also all be recognized in the case of basic research centers. The results are consistent with the proposition that nowadays there is a new method (Mode II) of producing knowledge, where knowledge is generated in “broader, trans-disciplinary social and economic contexts” (Gibbons *et al.* 1994, p. 1).

2. Intermediate level

The results presented in the previous chapter can be interpreted as a tangible clue that researchers do show attitudes towards entrepreneurial behaviour. This forms the base for the sharecropping model proposition to explain how the relationship between Laboratory and its research staff might be interpreted when technology transfer is a complementary part of the job of scientists.
It was also hypothesized that in a basic research centre interested to engage in TT activities, output is a function of both in-house effort e and collaboration with industry θ. The questionnaire showed that collaboration with industry is an activity that researchers do find desirable.

The results of the questionnaire on CERN staff are in accordance with a trend that has been theorized upon and recorded by a number of authors, whose contributions have been highlighted in the literature chapter and in the theoretical chapter. See, for example, participation to networks - par. 1.3.1., chapt. 2 - as a form of technology transfer (Nelson 1993; Chataway 1999; Senker 1992; Harmon *et al.* 1997; Shane 2002b); process of capitalization of knowledge – par. 3.1, chapt. 2 - (Etzkowitz 1998; Stephan and Everhart 1998; Geuna 2001); entrepreneurialism of researchers – par. 3.3, chapt.2 – (Etzkowitz 1998; Walter, Auer, and Gemunden 2002; 2001; Etzkowitz *et al.* 2000; Lee 1996; Scott 1998; Autio *et al.* 1996).

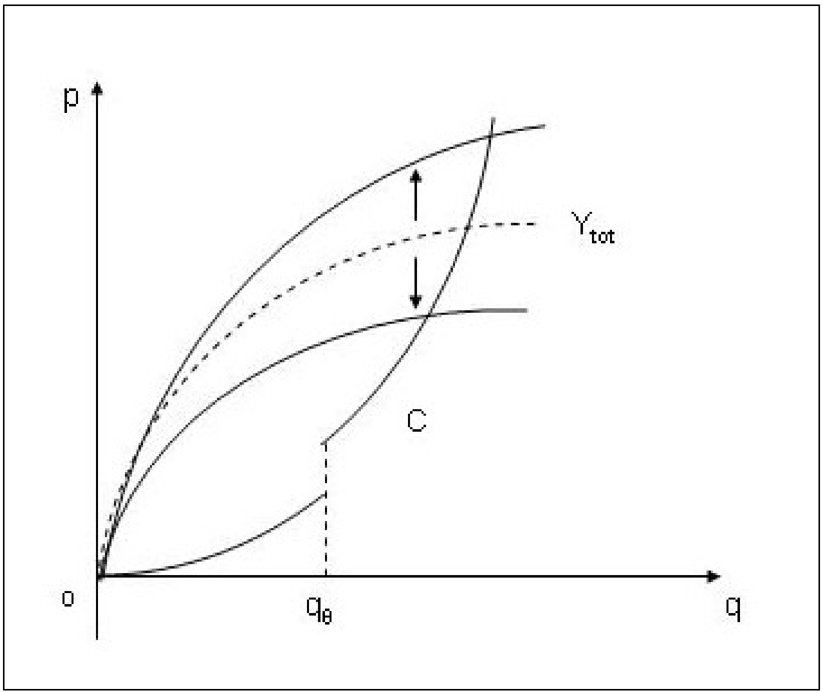
All these works show that there is a growing interest by researchers to transfer their knowledge to the “outside” world. If this is true, then the sharecropping model and the hypothesis of total output interpreted as the sum of output from research and technology transfer activities can both be extendable in general to any research center and not only to the case of CERN.

2.1 Research activities, technology transfer activities, outputs and costs

Independently from CERN particular situation, this means that nowadays in a research centre where both research and TT activities are implemented, the lab general output (Y_{tot}) can be expressed as really being a function of both research AND technology transfer, or better it is given by both the output from research activities (Y_R) and the output from TT activities (Y_{TT}), so $Y_{tot} = f(Y_R, Y_{TT})$.
When this is the case, different types of relations can be hypothesized to come into being between research and technology transfer output affecting total output. Costs are intended as total costs, made up of personnel costs – given by wages in the form of a threshold contract – personnel selection costs, fixed costs, and all costs generally sustained by a research laboratory.

Additive relation between output from research and output from TT
The first possibility is that there is an additive relation, i.e. output from research and output from TT activities add to each other, but there is no interference between them, which means that the two activities are not directly related to each other.
Focusing entirely on outputs and abstracting from costs changes for the moment, total output Y_{tot} will be the sum of the two activities Y_R and Y_{TT}, and its overall increase or decrease will depend on the sign and the dimension of the two. "θ" indicates the point of the threshold contract where, for a collaboration with industry higher than a certain amount θ_0, the researcher can be rewarded with a monetary prize.
This is the typical case of complementarity.

Figure 5.1 – Additive relation



Substitutive relation between output from research and output from TT

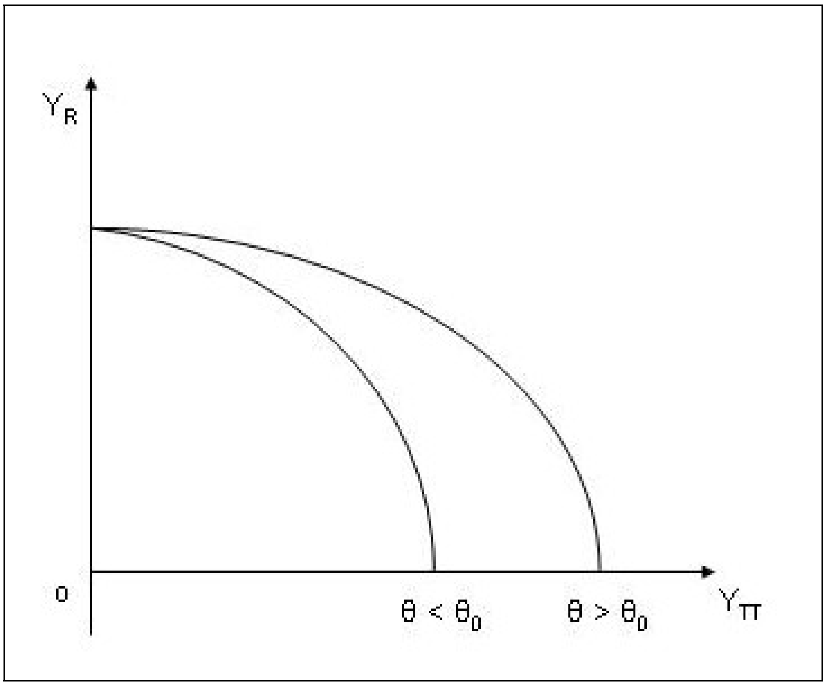
The second possible relation is that there might be a substitutive relation between output from research activities and output from TT activities.

Total output is always a function of Y_R and Y_{TT}. In this case, if output from one activity increases, output from the other decreases as there is a direct interference between the two activities on each other. Here, too, the focus is entirely on outputs effects, so costs are supposed not to change for simplicity sake.

This is the typical case of a substitution effect.

The substitution effect might be complete (i.e. Y_{tot} remains the same) or partial, in which case the total output might increase or decrease depending on the relative weight and direction of Y_R and Y_{TT}.

Figure 5.2 – Substitutive relation



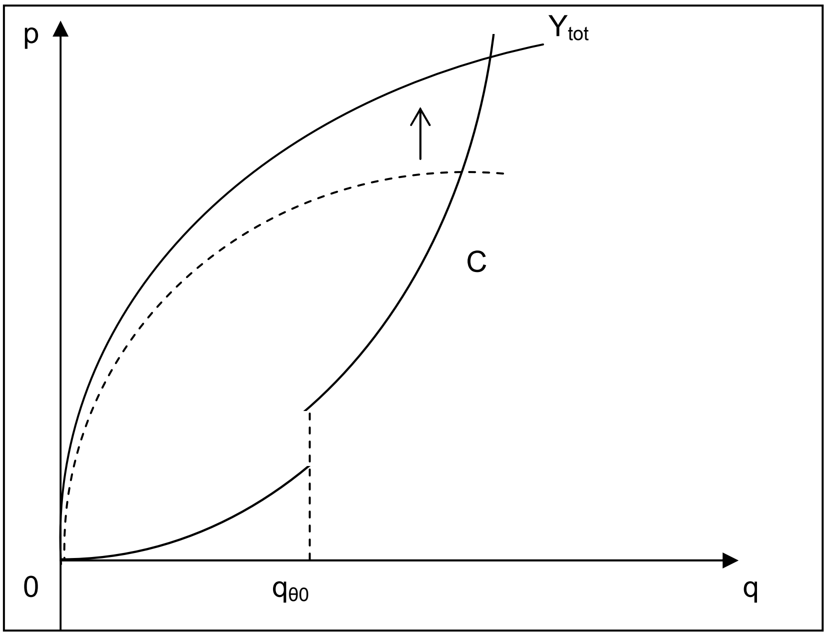
Multiplicative relation between output from research and output from TT

The third possibility is that there is a multiplicative relation between output from research activities and output from TT activities.

Here there is an interference between the two activities in the sense that engaging in one will improve the possibilities and/or capabilities of engaging into the other, in the sense of the user-producer absorptive capacity. In this case the total output will increase as a result of the two activities Y_R and Y_{TT}, where Y_{TT} itself is dependant from the output of pure research activities (Y_R). Basically, doing research provides the means (both practical and intellectual) to engage in TT activities that might not be undergone if research is not done. This means that output from TT activities is directly connected to additional research output.

Again, the focus is entirely on outputs effects, so costs are supposed not to change.

Figure 5.3 – Multiplicative relation

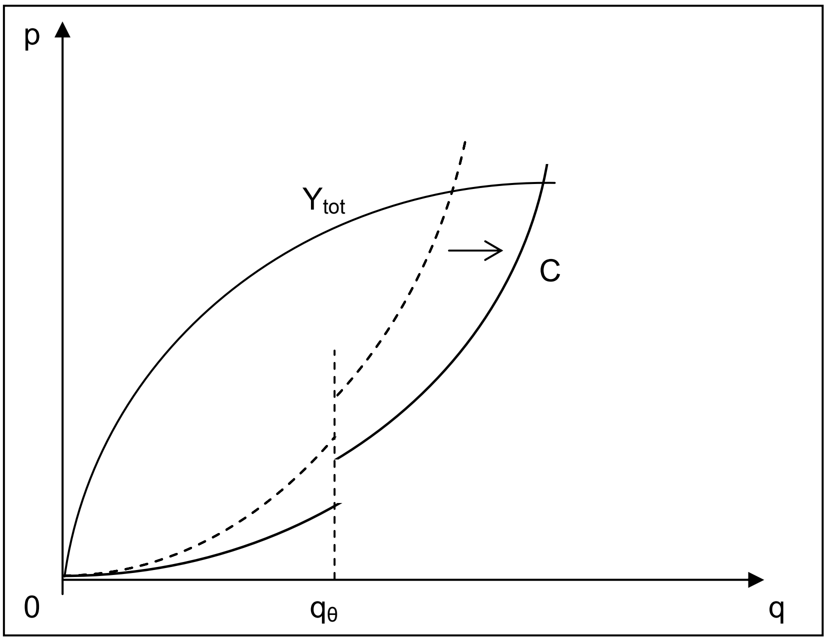


A kind of “industrial” effect on selection costs

In this case, the focus is entirely on costs. Here a kind of “industrial” effect on total costs can be hypothesized in the sense that the fact of engaging in technology transfer activities and of keeping in place a fixed-term threshold contract for researchers allows to test them in order to see who, among them, are the really valuable resources, without actually having to hire all of them.

The fact that some – and only some – researchers engage in TT activities, can be used as an indicator (maybe together with publications and research results) of which researchers are the most productive. And this actually becomes part of the selection process. Therefore the Labs overall costs are lowered as selection costs are lowered.

Figure 5.4 – Selection costs effect

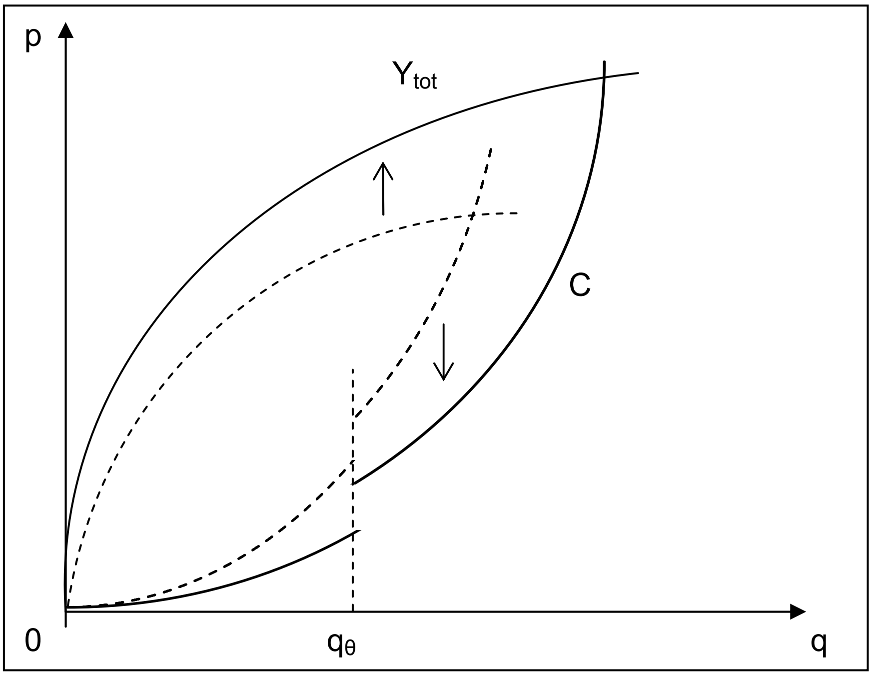


Synthesis towards a more realistic depiction

In a more realistic situation, whereas the case of additive relation is probably too simplicistic and the case of substitutive relation is probably screened out by the organization statute, it might well be that the proper situation might be pictured by an intertwining of the multiplicative and the industrial relation. This means taking into account the absorptive capacity given by also engaging in TT activities and the selection costs effect.

This can be visualized as in the following figure, where total output increases and total costs decrease.

Figure 5.5 – A possibly more realistic depiction



This would mean that a research center can increase its revenues from non-governmental incomes. Such a case would also give the laboratory a better public justification for its costs. But it could also be a double-edged weapon, because institutional funders might find it a justification for lowering funds. At the same time, this provides a justification to the utilization of fixed-term threshold contracts for junior researchers.

2.2 Sharecropping

In terms of sharecropping, the problem is whether a fixed-term threshold contract is considered by the researcher a good enough incentive. In effect, the results showed that financial incentives are considered important by researchers to engage in technology transfer activities. If researchers are not motivated enough to engage in technology transfer, they not only will not participate to TT activities, but they might retain information about transferable technologies, thus creating an information asymmetry. This means that they would stick to strictly research activities and, therefore, no additional output would be generated, therefore no additional input can be redistributed because there is no additional input.

Such a case might be seen as a principal-agent situation. And, if we were to analyze whether the best environment for TT was with the previous contract (where researchers would get a share of eventual TT outcomes) or with the present researchers' contract (where researchers eventually get a monetary prize or a career advancement), we would need to solve for two different principal-agent problems. It is not within the scope of this work to say which of two contract schemes is the best one, but it does make sense to highlight the fact that such a point should be studied in the future.

In the case of past contract scheme, there would be a maximization problem, where the principal (CERN) has to maximize its utility in appropriating the value of innovation spurring from TT in a situation in which the researchers' wage is a function of the output q, which in turn is a function of in-house effort e and collaboration with industry θ. Therefore, we have:

$$q(e, \theta)$$

$$w(q(e, \theta))$$

and the maximization problem is:

$$\max EU_{CERN} (q(\tilde{e}, \theta) - w(q(\tilde{e}, \theta)))$$

subject to the incentive compatibility constraint, to give the agent (the researcher) an incentive to choose the desired effort $\tilde{e}$:

$$\tilde{e} = e^{\text{argmax}}\, EU_{res}(e, w(q(e, \theta)))$$

and the participation constraint:

$$EU_{res}(\tilde{e}, w(q(\tilde{e}, \theta))) \geq \bar{U}$$

where $\bar{U}$ is the utility below which the agent will not participate, the so-called reservation utility.

Whereas, at present the maximization problem is given by:

$$\max EU_{CERN} (q(e, \theta) - \hat{w}(e, \theta))$$

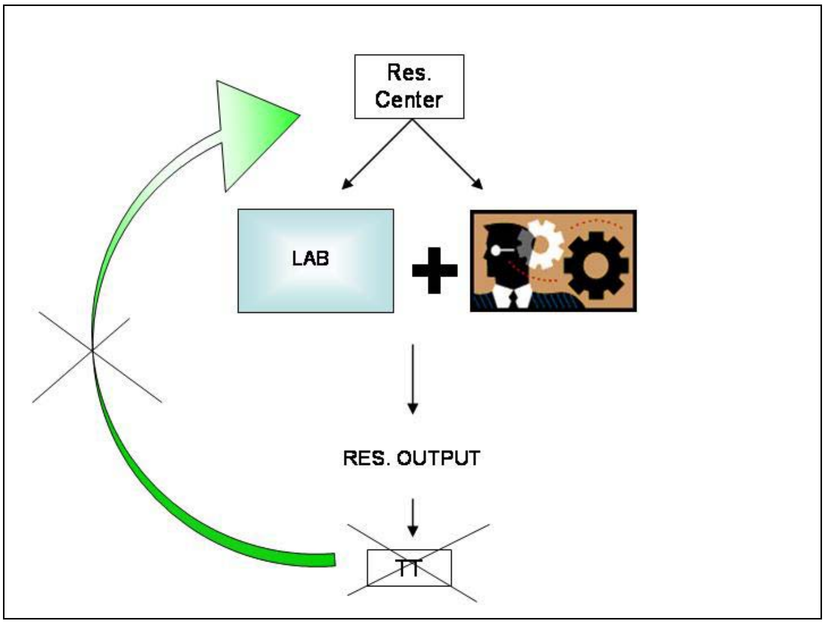
where ŵ(e) is the function that makes the agent just willing to accept the contract, so that

$$U_{res}(e, w(e, \theta)) = \bar{U}.$$

The problem here is that the researchers wage is given by a threshold contract which sets $w(e, \theta<\theta_0) = w(e)$ and $w(e, \theta>\theta_0) = w_O$, which means a flat wage for low levels of collaboration with industry θ plus a bonus if collaboration at least reaches θ_0.

Visually, this can be expressed as the absence of technology transfer from the depiction of normal running of a basic research laboratory.

Figure 5.6 – Absence of sharecropping



At this point there is no gain for anybody, not even for the landlord. On the contrary, at the public and political level, for a research center to have a TT office that does not fully exploit the center's potential, might be seen as a negative point, even when it is not an infrastructure problem, but an internal policy problem.

A good incentive for researchers might be to reinvest part of the TT income at least on the researcher's group, if not on the researcher himself.

2.3 A "patching" organization

As seen in chapter 2, Jacob and Hellstrom (2003) apply some corporate organizational models to universities. Among these, they propose the idea of a "patching" university where "one may combine existing activities to create critical mass and cash flow (e.g. when departments temporarily join forces in larger project bids) or one may strategically exit existing businesses and re-stitch those resources into new areas" (Jacob and Hellström 2003)

The concept of "patching university" can interestingly be applied to basic research centers in terms of strategy. In the case of CERN, for example, the Laboratory somehow already uses this kind of approach, as different research groups work once for a project, once for another, joining forces according to the competences needed to achieve the research goal. The same holds true for the researchers and/or groups called to be involved in TT activities. This allows CERN to have a high potential mobility, which might be more profitably used for TT purposes.

Basic research centers could well absorb the concept of "patching" organization, without applying it to its fullest. That is, by making use of "mobile" human resources, within the organization researchers can be used to co-operate with different units in order to reach specific goals. By shaping and applying the idea of "mobile" human resources to the co-operation with industry, research centers would allow their researchers to more freely work with industry as needs arise and facilitate the process by which industry can get scientists as consultants. In this way, researchers could be seen as resources which are stitched and re-stitched as required on a case to case base.

3. Individual level

The precedent discussion holds true if the overall hypothesis that among researchers employed by the Lab there is a general interest towards collaborating with industry might be sustained as was the case of the results showed in the previous chapter.
From those results, some general conclusions might be drawn concerning the factors hypothesized to explain the entrepreneurial behaviour of researchers.

3.1 Recognition by peers

It was seen (table 4.1) that the variable research credit had significant and positive correlations only to two items of entrepreneurial behaviour. Concerning EB by the Organization as desired and judged by the respondents, recognition by peers was correlated exclusively to the perception that a close CERN-industry collaboration would not result in conflict of interest between research and business activities.
The fact that this variable is not significantly correlated to any other item expressing EB by CERN is an indication that – expressed in the terms used in the questionnaire – recognition by peers is either not well captured or that recognition by peers is not correlated to normative positions towards entrepreneurial behaviour at the Organization level.
However, the fact that patenting – as an activity that can give credit at least equally to refereed journal articles – has a positive and significant correlation to the choice of academic career as an alternative to employment in CERN, might be interpreted as showing that the perception of scientists being involved in patenting does not impact negatively any more on their academic tenure, at least from the point of view of the interviewed researchers.
In this sense, it might be argued that a shift in evaluative norms of the scientific community can be observed as going in the direction proposed by Etzkowitz (1998, 2001), Lee (1996) and others, that the scientific community is increasingly accepting claims of priority that are covered by IPR protection or exploited on the market.

However, it must be noted that also in the case of EB at the individual level, only one significant correlation could be observed.
All in all, recognition by peers does not result as a variable having much correlation to attitudes towards entrepreneurial behaviour. So, hypothesis one that there is a positive relation between recognition by peers and EB by researchers can not be confirmed given that not enough significant results were obtained.

3.2 Networks

As seen in table 4.2, networks in which the researcher is embedded have many and significant positive correlations to desired EB by CERN in terms of a close CERN-industry collaboration not causing any disruption of the Organization institutional asset and mission. The same holds true for desired EB by the Lab in the future.
Thus hypothesis 2 that there is a positive relation between network's assessment of EB and the researcher's norms about entrepreneurial behaviour at CERN level is confirmed for general networks.
Networks also show significant and positive correlations to career alternatives either in industry or self-employment. Particularly so when there is a good perception of entrepreneurship or industry in the network the researcher belongs to – respectively 0,353*** and 0,334** for corporate career; and 0,385*** and 0,293** for entrepreneurial career. Researchers seem to be eventually interested to careers in industry when their networks hold positive views of such careers.
Therefore hypothesis 2 is confirmed also at the individual level for general networks. This is in accordance with the recognized importance of networks for research and technology transfer activities (Gibbons *et al.* 1994; David, Foray, and Steinmueller 1997) as well as with the possibility for networks to introduce new behaviours in research organizations (Hoddeson 1980).
A much looser correlation was found in the case of CERN network, where among the different significant results only one was really strong, expressing that a perceived supportive environment towards staff being involved in contract

research with industry was correlated (0,387***) to unlikeness of conflict of interests between research and business activities at CERN.
So, for CERN networks, hypothesis 2 can not be confirmed neither at CERN level nor at the individual level.

3.3 Prior knowledge

Previous work experience does show a correlation to desired EB by CERN; in particular, it impacts on the Lab asset. Previous experience in consulting has consistently positive correlation to collaboration between the Lab and industry as not causing disruption of mission nor research activities. Experience in administration was the case of just one respondent, experience in manufacturing was the case of only 4 respondents, whereas many of them had experience in university or in other sectors. Consulting experience is positively correlated to entrepreneurial career alternative and negatively to academic career.
So, hypothesis 3 that there is a positive relation between the researcher's prior knowledge interpreted as work experience and his/her entrepreneurial behaviour holds true in the case of a previous work experience in entrepreneurial activities such as consulting. So the hypothesis should be restated as there is a relation between the researcher's prior work experience and his/her entrepreneurial behaviour, AND such relation is a positive one when the prior experience is in self-employment AND possibly in industry at large.
Prior knowledge of business – as shown in table 4.4 – in almost all significant cases (six out of 8 cases) has negative correlation to desired EB at the CERN level. So hypothesis 3 is rejected as the correlation is generally a negative one. At the individual level, the correlation is not significant enough, except for the case of academic career, where all kinds of previous business experience (but self-employment) are positively correlated to it. It would seem that previous experience in industry makes a career in university attractive. It would be interesting to see if it is because of status, recognition or security that this career results as a desirable alternative.

3.4 Field of research

When basic research accounts for most of the researcher's activity, there is a negative and significant correlation to entrepreneurial activities in which CERN should get involved. Consistently, at the individual level corporate career is not seen as a desirable activity, as shown by the negative correlation, whereas academic career is positively and significantly correlated.

So in case of basic research as main activity hypothesis 4 that there is a positive relation between field of research in which the researchers is involved and his/her entrepreneurial activities must be rejected. This is somewhat consistent with the fact that basic research does not account for a large share of activity in industry and self-employment, in this sense EB is not consistent with an interest in pure science.

When applied research is the researcher's main activity, a positive and significant correlation ($p<0,01$) is present to desired entrepreneurial behaviour by the Lab in form of setting up incubators and encouragement of consulting activities by staff, but no significant correlation was found towards commercialization of research results. So in the case of applied research, hypothesis 4 can be confirmed for desired EB at CERN level, especially in the form of consulting and of help to set up new firms, because in these cases researchers can play a role in further developing the product, whereas in case of commercialization such a role would be much smaller. A positive and significant ($p<0,01$) correlation was present in case of corporate career as an alternative to a job at the research center. So in the case of applied research, hypothesis 4 can be confirmed for desired EB at the individual level, in the form of corporate career, where the researcher can be employed to help passing from applied to pre-competitive development of the product/process.

Finally, prototyping as a main activity is significantly and positively correlated only to the perception that CERN should commercialize its research. So, in case of prototyping hypothesis 4 can be confirmed for desired EB at CERN, in the form of commercialization of research.

3.5 Incentives

CERN incentives are positively correlated to careers alternatives in industry, public sector and university but not significantly correlated to entrepreneurship, as if incentives provided by CERN are not sufficient to interest researchers to create spin-offs on the base of their acquired knowledge. Another possibility might be that not all CERN incentives were correctly identified. Whereas this might still be a possibility, it should however be noticed that there are such few cases of spin-offs that this is still probably an area where improvements should be considered in CERN technology transfer policy. In this light, whereas the existence of institutional incentives, as exemplified by the Bayh-Doyle Act (Mowery *et al.* 2001) is in place, their effectiveness could not be proved.

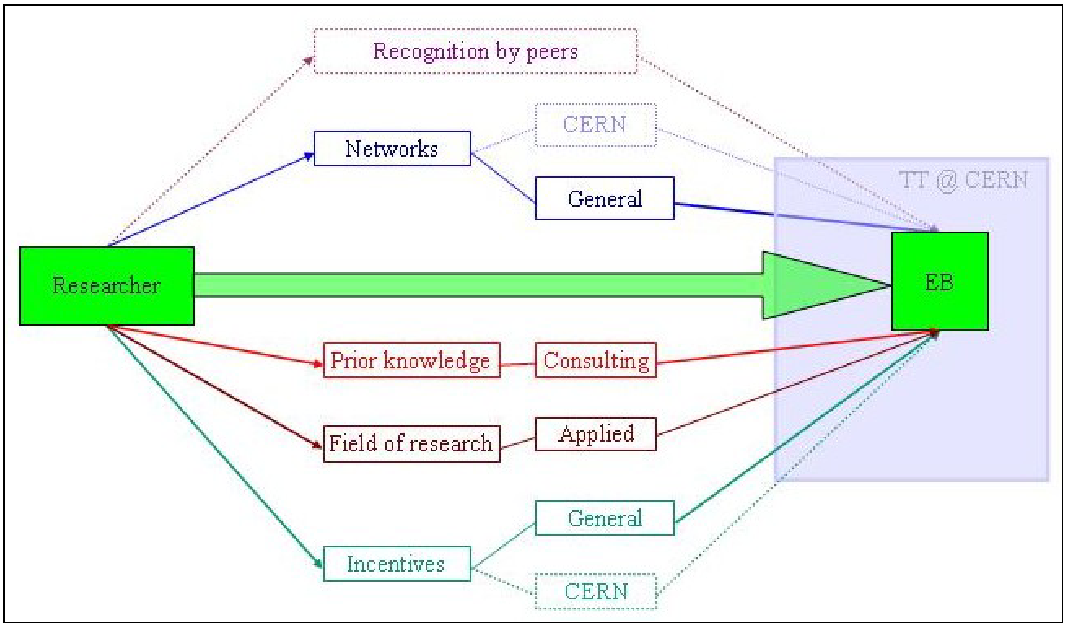
In the case of general incentives, instead, all of them are positively and significantly correlated to encourage consulting activities by CERN staff. Moreover, all incentives were also positively correlated to a career alternative in industry and also all of them, but bonuses, are positively correlated to an alternative entrepreneurial career. Incentives in the form of bonuses are coherently in a negative correlation to a career in university.

These results are consistent with the recognition that material and immaterial incentives can contribute to researchers' entrepreneurial behaviour (Walter, Auer, and Gemunden 2002).

3.6 Factors affecting entrepreneurial behaviour of researchers

Summing up the above discussion, the theoretical framework proposed in chapter 4 can graphically be depicted as in the figure below on the base of the results obtained. Dotted lines are intended to show factors that were not found to be statistically significant and therefore can not be considered to affect desired entrepreneurial behaviour of researchers.

Figure 5.7 – Desired entrepreneurial behaviour of researchers.



Hypotheses were confirmed, both at the individual level and at CERN level, that the desired entrepreneurial behaviour is correlated to general networks, general incentives, to prior experience in consulting and to applied research as main field of activity. Such correlations could not be confirmed in the case of recognition by peers, of CERN networks and of CERN incentives.

3.7 Descriptive statistics: perception of TT at CERN, indication of desired entrepreneurial behaviour and career alternatives

3.7.1 Impact of technology transfer policy on CERN researchers

Figure 4.1 summarized answers directly concerning technology transfer at CERN. In terms of perceived impact of TT and TT policy, 89% of the respondents said that the creation and existence of the technology transfer service did not change their interaction modalities with industry, and 87% said that the introduction of a pro-active technology transfer policy did not change their attitude towards it. From the organizational point of view, the fact that such a vast majority expressed no changes deriving from the introduction of TT policy and service at CERN – while being aware of its existence (77%) – is an indication that somehow the concept of technology transfer has not been "metabolized" by the researchers. In face of the resulting over-all general interest towards collaborating with industry, it almost seems as if collaborations with industry at the individual level and TT at the organization level are perceived as two disjoined concepts and activities. Worth of note is also the statement by 58% of respondents that financial incentives would motivate them to transfer technology, something that is in contradiction with the unsure financial rewards in terms of the actual TTP in place at the Lab.

3.7.2 Perception of TT activities at CERN and impact of international status

The international status of CERN researchers implies that for any activity in which staff is involved that may provide financial gains, the person has to ask and be granted a special permission by the Director General. In figure 4.2, it is interesting to note that 49% of researchers declared themselves indifferent to the fact that international officer status holds back people at CERN from engaging in entrepreneurial activities. Whereas 24% of respondents said they strongly disagree with this, while another 24% said they agree (the remaining 3% is given by those who didn't answer the question).

It might be argued that this might not be widely known, even though staff rules are issued to everybody who is under contract with CERN. This is a point that should be addressed by the Lab's governing bodies.
Connected to this topic are the results showed in table 4.9, where twelve people out of over one-hundred have worked on research projects with industry outside of CERN; fifteen people have been consultants outside of contracts formally signed by the organization and anther eighteen people have been involved either in professional training, patenting, aiding in the creation of spin-offs or some other kind of activity. This can be interpreted as a tangible clue that researchers do show attitudes towards entrepreneurial behaviour. Therefore the overall hypothesis that among researchers employed by the Lab there is a general interest towards collaborating with industry might well be sustained.

In the same figure, a more positive result for the work of the TT group is given by the answers to the item "I am aware that CERN has a clear policy regarding the intellectual ownership of ideas developed during research". In this case, 45% of respondents agreed with the statement, 33% declared themselves indifferent, whereas 20% disagreed. Whereas the one third of "indifferent" respondents might be identified as those not interested in collaborating with industry, a much more careful attention should be paid to the 20% that said that they don't agree with the fact Lab's policy towards IPRs is clear. This percentage does show that TT policy still has to be more widely spread among the personnel or, at least, presented in a more easily understandable way.

Finally, when asked to express agreement or disagreement with the statement that at CERN there is a well functioning infrastructure in place to support technology transfer, the very high majority of researchers answered that they were indifferent, an additional 20% said that they did not agree, whereas only 12% approved of the TT infrastructure in place in the organization.
Here again a 20% of respondents saying that the TT infrastructure is not perceived as being well functioning is a point worth of closer inspection by the TT group. It would be important to understand if this opinion is given by a difficult circulation

of information or if the perceived problem is that respondents do not believe the infrastructure to be appropriate for their needs.
In all cases, it seems that there is space for an improvement in communication with the personnel in regards to technology transfer matters.

3.7.3 Indication of desired entrepreneurial behaviour at CERN level

When asked whether CERN should commercialize its research by more strongly support its TT office, 35% of researchers agreed and 8% strongly agreed with the statement, although a 32% of respondents said to de indifferent and 25% disagreed with it (as seen in Figure 4.3). In a similar way the statement that CERN should set up its own incubators to help start-up new technology-based businesses was met with approval by 48% of respondents (between "agree" and "strongly agree"), whereas 26% declared themselves indifferent and another 26% disagreed with this idea.
Finally, the statement that CERN should encourage its staff to provide consulting services to private firms was the one met by the highest share of agreement: 45% of them agreed and 7% strongly agreed, whereas 25% was indifferent and only 23% disagreed with this opinion.
These results all show that the relative majority of the researchers involved in the study did show a real interest – at least at the intentions level – in collaborating in various ways with the industrial sector. This again is in good accordance with the literature supporting the claim that nowadays researchers do not want to live in an "ivory tower" anymore, but, on the contrary, they do think that there should be connections with the world outside the boundaries of their research laboratory. In this sense, it might be claimed that the concept of pure science as an "ivory tower" can now be considered obsolete.

3.7.4 Career alternatives selected as desirable by respondents

In terms of career alternatives, 86% of respondents preferred a career in the academy, the second best was a corporate career (72%), then a position in the public sector (67%) and finally an entrepreneurial career (63%), as shown in figure 4.4.

What is interesting to note is that – even though the entrepreneurial option is the one had the lowest number of preferences in absolute term, as might be expected – and it is also the one with the highest number of respondents not finding it desirable (36%), but it also is the one with the highest share of moderate attractiveness, as 41% of the researchers find it attractive. Together with the fact that corporate career was the second more desired alternative, this data shows that industry is interesting for modern researchers, who do not seem afraid by the notion of being at stake.

4. Further research

This study intended to focus on whether a researcher has a desired entrepreneurial behaviour defined as his interest in filing patents, copyrights, trademarks, licenses, proprietary rights on the products of research as well as their interaction with the industrial and commercial sector, in form of consultancy, equity shares in companies, creation of spin-offs, professional training to industry, etc.

In the context of this thesis, a researcher was defined as having an Entrepreneurial Behaviour not necessarily by being an entrepreneur (i.e. owing its own firm), but also by being active towards technology transfer and partnership with industry, thus adapting the concept of entrepreneurial university (Etzkowitz 2003) to the researcher, who becomes an “entrepreneurial researcher”.

Given the results obtained, further research might be undergone on whether the factors hypothesized and showed to be influential on CERN researchers also prove influential on researchers of other laboratories. This would allow testing if the identified factors – drawn from different areas of studies – are meaningful for the singular case of CERN, or if they are so also for other research centers, in which case they might be used as part of a general model explaining entrepreneurial behaviour of researchers.

It was not within the scope of the thesis to study what actually happens in terms of real technology transfer at CERN. It was intentionally not taken into account what kinds of TT activities are successful, or what kinds of technology have been licensed to industry, or which type of researchers actually become entrepreneurs, and so on and so forth.

Whereas similar studies already exist in case of a number of research institutions, further research might try to combine the individual and the institutional approach. Further studies might try to assess what effectively happens in terms of actual technology transfer when researchers are showing entrepreneurial behaviour as compared to when no such behaviour is observed.

Studies might also try to assess whether the previously presented relations can be proved realistic or not, both in the case of CERN and of other research laboratories. Further research could also address the question if technology transfer can benefit from different incentives schemes and different contract schemes, both at CERN and at other institutions.

Conclusions

From all of the above it seems to be quite clear that researchers interviewed do not respond anymore to the old cliché of isolated scientists only interested in pure science and not willing to have anything to do with industry. Collaborating with industry does not define a researcher as a B-category researcher and the utility – if not the necessity – of research and industry collaborating even in the case of pure knowledge seeker organizations is a possibility which is not hindered by researchers.

However, in order for technology transfer to function, some aspects should be kept in consideration: when a TT infrastructure exists, it has to be actively supported by the institutional government body; researchers must be made aware of the existence and functioning of the infrastructure and TT policy on a compulsory base, not only on a self-training base (i.e. it is part of the information given to all new and old researchers), some kind of incentive must be provided to researchers to engage in TT activities.

Conclusions – Entrepreneurial Scientists

In the last decades much attention was paid to technology transfer activities undertaken by universities and research centers. Authors also turned their research to the effect these activities had on faculty and the research community at large. Different views emerged as to the reason why academic scientists turned to entrepreneurial activities. Some authors proposed that scientists may be becoming increasingly entrepreneurs because of the prospect of financial. It was suggested that, in times of financial constraints, researchers become concerned to access additional funds for research through formal links with industry. On the other side, the idea that technology transfer and scientists' entrepreneurialism are motivated by shrinking budgets alone has found some opposition, justified by the fact that income from TT is very modest compared to governmental funds.

Therefore, the justification for researchers' entrepreneurialism should be looked for at a different level. The most interesting proposition is that researchers' support of entrepreneurial activities can partly be explained by a restructuring of the evaluative norms for scientific performance (Etzkowitz 1998, 2001; Lee 1996). This shift in evaluative norms would allow individual scientists to aim at two goals simultaneously: scientific excellence and profit making. Scientists are proposed to no longer believe in the necessity of an isolated ivory tower. On the contrary, academic scientists want partnerships with industry where they can still do cutting edge research and publishing, having at the same time adequate funding and participation in high-technology areas.

In analyzing organizational models for European research centers, all of the above must be kept into account. This means that centers have to remain faithful to their founding mission. Also, as their funding comes from governments, an agreement must be found on how incomes from "licensable" knowledge should be appropriated. At the same time, guidelines of EU policy must be respected and applied, but also public accountability should be considered. Finally, researchers' goals and objectives are part of the organization's operative functioning as are variations in researchers' general behaviour and attitude.

At the intermediate level, I proposed that that the organization of a European basic research center could be as that of a knowledge seeker organization, where – mediated by public and EU accountability – Technology Transfer is a complementary activity to the research mission; this complementary activity has to be mediated by the eventual entrepreneurialism of the researchers, which should continue to do basic research, but also be allowed – if interested – to get involved with TT.

It was also argued that the actual organization of technology transfer at research Lab such as CERN can be paralleled to the classical sharecropping organization in agriculture. In the parallel, the Lab is the landlord, as it owns the infrastruture (=the field) to undertake the research; the researcher is the worker, who uses the assets to do his/her research; incentives are present for both the Lab and the researcher to transfer technology to the industrial sector when economical revenues are shared between the two. Risks are borne only by the research center alone, as the researcher receives at least a fixed wage. Plus, there is an asymmetry of information because the Lab is not able to perfectly observe the input provided by the researcher and it is the researcher *in primis* who is in the position to understand what technologies might be transferable. It is for this reason that the incentive issue becomes particularly important. If the researcher is not motivated enough, he will not necessarily make the information available to CERN, falling back to the classical moral hazard problem.

That is why it is important to understand what researchers think of a traditionally research-only organization becoming involved in TT activities. If the general attitude of researchers turns out to be indifferent, or even adverse, to technology transfer, its effects are felt at the organizational level, and technology transfer might become a sterile and shallow expression.

Both the organizational model of a knowledge seeker institution and of sharecropping give relevance to the figure of the researcher. In both of them, the

researcher is an active part in what happens both in the institution and in the TT process.
The definition I adopted throughout the thesis is that the Entrepreneurial Behaviour of the researchers is their interest (both at the practical and theoretical level) in filing patents, copyrights, trademarks, licenses, proprietary rights on the products of research as well as their interaction with the industrial and commercial sector, in form of consultancy, equity shares in companies, creation of spin-offs, professional training to industry, etc. In easier terms, Entrepreneurial Behaviour is a researcher's interest to collaborate with industry.

I proposed that factors influencing a researcher's entrepreneurial behaviour were recognized to be the following:

- Recognition by peers
- Networks
- Prior knowledge
- Field of research
- Incentives from CERN

Whereas the two factors identified as 'Recognition by peers' and 'Networks' represent a connection between the individual researcher and the community in which s/he is embedded, the factors identified as 'Prior knowledge' and 'Field of research' represent the more characteristic aspects of each person as an individual. Finally, the 'Incentives from CERN' factor wants to identify a connection between the researcher and the specific organization into which s/he works and to which s/he is under contract. An additional factor was identified as being the 'Individual's character', but it was taken as a given.

In order to test what factors correlate to entrepreneurial behaviour of researchers, a questionnaire was handed out to the selected population. Perceived entrepreneurial behaviour at the level of CERN, but always from the point of view of the researchers, was defined as a) a series of activities that are presently done by the organization with industry, about which the researcher was asked to express a judgement on the opportunity of the Lab engaging in such activities and the perceived impact of such activities on the Lab environment; b) a series of activities with industry that – according to the researcher – CERN should engage into.

Entrepreneurial behaviour at the level of the researcher was identified as expressing what career alternative he/she would choose outside working at entrepreneurial behaviour CERN.

Statistical analysis on the questionnaires results can be summarized as:

- The hypothesis that there is a positive relation between recognition by peers and EB by researchers can not be confirmed or rejected;
- The hypothesis that there is a positive relation between network's assessment of EB and the researcher's desired EB is confirmed at all levels for general networks, but is rejected for CERN network as not being coherent;
- The hypothesis that there is a positive relation between the researcher's prior knowledge and his EB is confirmed in case of consulting experience, but is rejected in case of prior experience in business;
- The hypothesis that there is a positive correlation between the type of field of research and EB is confirmed, but in the case of prototyping;
- The hypothesis that incentives are positively correlated to EB is confirmed for general incentives, but not for CERN incentives.

On these bases, it can be maintained that there is evidence of EB by researchers. Prior knowledge and field of research, and general networks and incentives are correlated to entrepreneurial behaviour, whereas CERN networks and incentives do not show coherency.

The research questions can now be answered. Concerning the first issue, researchers do show an interest towards entrepreneurial behaviour both at the individual and at the organizational level. Moreover, they do not see these research and entrepreneurialism as conflicting activities. On the contrary, they do see them as complementary activities that could be carried out at the individual level in form of consulting (which should be encouraged by the organization) and the Laboratory level (which would not be swayed from its mission by closer collaboration with industry). Finally, there are incentives that might encourage researchers to engage in technology transfer activities, and those are mainly, but not only, financial incentives.

The questionnaire showed that collaboration with industry is an activity that researchers do find desirable. The results of the questionnaire on CERN staff are in accordance with a trend that has been theorized upon and recorded by a number of authors. And the fact that CERN-related factors were not significant allows interpreting the results in a wider perspective.

At the organizational level, the center's engagement in technology transfer can be described as an intertwining of the multiplicative and the industrial relations, thus taking into account the absorptive capacity given by also engaging in TT activities and the selection costs effect. In terms of sharecropping, it was demonstrated that researchers feel that technology transfer outcomes should be shared between themselves and the organization, at which moment they are will to engage in TT activities, thus up-holding the proposition that TT process might be described as a form of sharecropping. Basic research centers could also absorb the concept of "patching" organization, by making use of "mobile" human resources to co-operate in various forms with industry as needs arise. In this way, researchers could be seen as resources which are stitched and re-stitched as required on a case to case base.

Researchers' interest towards collaborations with industry, drove me to infer that, from the point of view of science policy research, a partial revival of the linear model, integrated by a reshaped reward system allowing scientists to get credit also for entrepreneurial activities, may be proposed. In the case of basic research, there are problem domains that have no current overlap with practical purposes, but the means for exploring these domains, however, are very likely to have overlaps.

This means that the concept of "entrepreneurial university" by Etzkowitz could be borrowed and applied to knowledge-seekers institutions, which could now be interpreted as institutions that can emphasize a 'third' mission of contributing to the economy, as much as their research and knowledge diffusion missions,.

In these terms, the 'commodification' of knowledge can be seen as a category of scientific activity and boundaries can be examined between this activity and the activities devoted to accumulating status (standing) within the scientific community. The willingness and ability of the scientific community to accept claims of priority that are covered by IPR protection or that are exploited on the market is a potential evolution of the norms of the scientific community in Mertonian terms.

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ANNEX I – QUESTIONNAIRE

CERN ENTREPRENEURSHIP SURVEY 2006

A. PERSONAL CHARACTERISTICS

1. Please state your nationality:

   ____

2. Please state your age (in years): ☐☐

3. Please indicate your gender

   M ☐ F ☐

4. Please state the highest academic qualification you have achieved

   Ph.D. ☐

   Postgraduate (Master or specialization) ☐

   Graduate (e.g. BSc, BA) ☐

   Other (please specify) _____ ☐

5. Please state what is your academic background (e.g. physics, nuclear engineering, administration, etc.)

   ____

6. Please state what is your field of research at CERN and your unit and division

   ____

7. How many publications (articles, presentations to congresses, etc.) do you do per year?

   ____

8. Which category best describes your current job classification

   Fellow ☐

   Staff (temporary position) ☐

   Other (please specify) _____ ☐

9. Have you previously been employed in a full-time position outside CERN?

- No previous experience ☐
- Administration ☐
- Manufacturing ☐
- Consulting ☐
- Public sector (NOT university) ☐
- University ☐
- Other (please specify) _____ ☐

B. PREVIOUS ENTREPRENEURIAL EXPERIENCE.

10. Have you:

- Family members who own/owned their own business? ☐
- Ever started or ever owned your own business? ☐
- Ever worked within a big business? (> 50 employees) ☐
- Ever worked within a small business? (< 50 employees) ☐
- Other (please specify) _____ ☐

C. ACADEMIC ENTREPRENEURSHIP ACTIVITIES

11. Since joining CERN have you had any direct contact with industry? (You may tick more than one answer)

- Yes - I approached an industrial organization for procurements ☐
- Yes - I approached an industrial organization for R&D outside procurement ☐
- Yes - an industrial organization approached me for consultancy ☐
- No ☐

12. If yes, which of the following activities have you been involved with: (you may tick more than one box)

	With CERN	Without CERN
Participating in research projects with industry	☐	☐
Patenting / licensing research results	☐	☐
Consulting / provision of personal expertise	☐	☐
Teaching to non-university individuals (ex.: continuing education)	☐	☐
Spin-off: the formation of a new organization to exploit research results	☐	☐
OTHER – please specify _____	☐	☐

D. SUPPORTING ENVIRONMENT

13. How would you describe CERN environment towards its staff getting involved into:

	Development of entrepreneurial activities	Contract research with industry
SUPPORTIVE	☐	☐
NO EFFECT	☐	☐
PREVENTING	☐	☐

14. Are you aware of the industrial liaison (Technology Transfer) service within CERN?

YES ☐ NO ☐

15. If yes, have you used this service in developing external links or to protect your intellectual rights?

YES ☐ NO ☐

16. Did the creation and existence of the Technology Transfer service change your interaction modalities with industry?

YES ☐ NO ☐

17. Would you be motivated by financial incentives to transfer technology?

YES ☐ NO ☐

18. Has your attitude changed since a proactive Technology Transfer policy was introduced at CERN??

YES ☐ NO ☐

19. On average, how are time and effort of individual staff in your unit (group) currently distributed among the following categories?

Today	**%**
Basic research	
Applied research for R&D development	
Prototyping	
TOTAL	100%

E. WHAT DO YOU THINK?

20. According to you, how much research credit for tenure and/or promotion is given to a researcher for patentable inventions?

Greater than or equal to a refereed journal articles	☐
At least equal to a refereed journal articles	☐
Equal to a non-refereed publication	☐
No research credit	☐
I don't know	☐

21. Personally, do you think that CERN today is working too closely (or not closely enough) with industry in transfer and commercialization of CERN research?

Too closely	Quite closely	Don't know	Closely	Not closely enough
☐	☐	☐	☐	☐

22. In your view, how likely an impact may a close CERN-industry collaboration for technology transfer and commercialization have on the following aspects of CERN life?

	Almost certain	Likely	Possible	Unlikely	Most unlikely
Displacement of CERN mission	☐	☐	☐	☐	☐
Loss of CERN freedom and autonomy	☐	☐	☐	☐	☐
Pressure for short-term research	☐	☐	☐	☐	☐
Reducing basic research activities	☐	☐	☐	☐	☐
Conflict of interest (research and business)	☐	☐	☐	☐	☐

23. In your view, CERN should ….

	Strongly agree	Agree	Indifferent	Disagree	Strongly disagree
Commercialize its research by more strongly support its technology transfer office	☐	☐	☐	☐	☐
Set up its own incubator to help start up new technology-based businesses	☐	☐	☐	☐	☐
Encourage staff to provide consulting services to private firms	☐	☐	☐	☐	☐

24. Which of these reasons would push you to do any entrepreneurial activity

	Very important	Quite important	Indifferent	Not very important	Not at all important
Pay/salary	☐	☐	☐	☐	☐
Shares in success using bonuses	☐	☐	☐	☐	☐
Shares in success using variable payment shares	☐	☐	☐	☐	☐
Self-realization	☐	☐	☐	☐	☐
Additional qualifications	☐	☐	☐	☐	☐
Gather experience for entry into industry/business	☐	☐	☐	☐	☐
Start and expand personal, career-supporting relationships	☐	☐	☐	☐	☐

Finally, we would like to learn about your work-related and life-related values.

25.

	Very good	Good	Indifferent	Bad	Very bad
If I became an entrepreneur, my colleagues (in- and outside CERN) would consider it to be…	☐	☐	☐	☐	☐
If one of my colleagues became an entrepreneur, my colleagues and I would consider it to be…	☐	☐	☐	☐	☐
My colleagues and I would consider entrepreneurship as a career alternative for people with our professional background to be…	☐	☐	☐	☐	☐
I know many people (in- and outside CERN) who have successfully started up their own firm and I consider it to be…	☐	☐	☐	☐	☐
We consider the increasing importance of the industrial sector as a potential employer for people with my professional background to be…	☐	☐	☐	☐	☐

26.

	Strongly agree	Agree	Indifferent	Disagree	Strongly disagree
At CERN, people are actively encouraged to pursue own ideas in application of research	☐	☐	☐	☐	☐
At CERN, you get to meet lots of people with good ideas for young firms	☐	☐	☐	☐	☐
The international officer status holds back people at CERN from engaging in entrepreneurial activities	☐	☐	☐	☐	☐
I am aware that CERN has a clear policy regarding the intellectual ownership of ideas developed during research	☐	☐	☐	☐	☐
There is a well functioning infrastructure in place to support technology transfer	☐	☐	☐	☐	☐

27. If you could choose an alternative career, you would find attractive or not attractive:

	Highly attractive	Mightily attractive	Attractive	Not very attractive	Not attractive
Corporate career (working for a large, established, private sector company)	☐	☐	☐	☐	☐
Civil service career (working for a government agency or other public sector agency)	☐	☐	☐	☐	☐
Entrepreneurial career (starting up and managing your own firm / business / consultancy)	☐	☐	☐	☐	☐
Academic career (working at a university or at a research institution)	☐	☐	☐	☐	☐

[Send it back to me]

THANK YOU VERY MUCH FOR YOUR HELP AND KINDNESS

ANNEX II – Some general data on scientific researchers at CERN

People at CERN

People on CERN payroll are divided in the following categories:

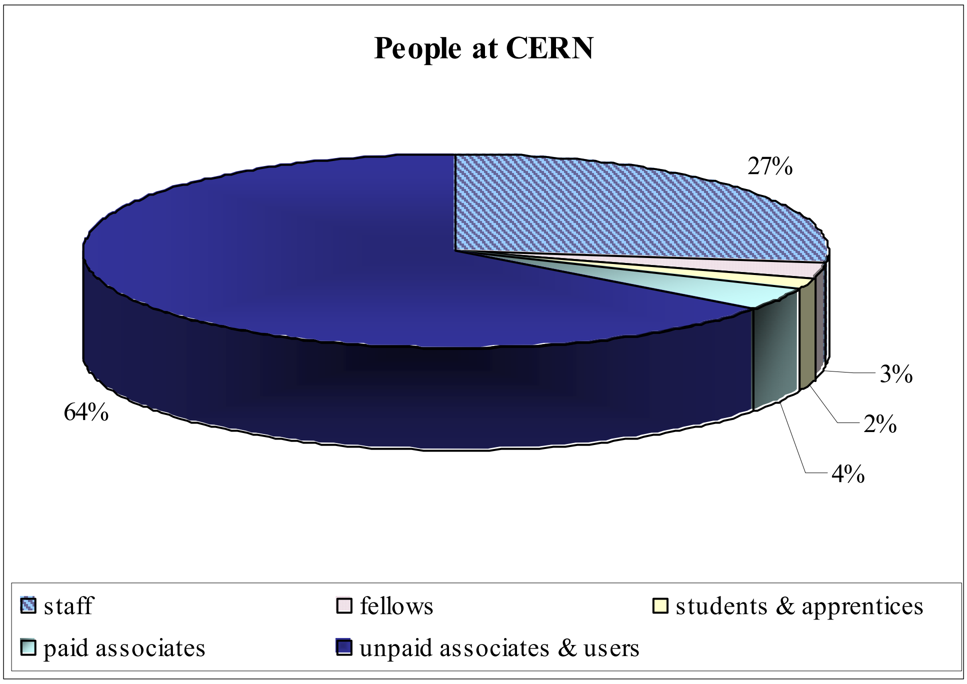
- Staff – who are divided in permanent staff, staff with Limited Duration (LD) contracts and staff with Fixed Term (FT) contracts;
- Fellows – who are selected via a call and normally are young researchers;
- Students – who are at CERN in order to complete their studies and typically write their dissertation (either to graduate or to get their Master on PhD title) on the project they are working at;
- Apprentices – who are at CERN with a contract for professional training;
- Paid Associates – who are from external institutions, but their professional activity is entirely at CERN and therefore they are partly sustained by it.

Status distribution at CERN	
Staff	2635
Fellows	246
Students	149
Apprentices	31
Paid associates	397
Total on CERN payroll	**3458**
Unpaid associates & users	6333
Total at CERN	**9791**

In 2005, there were 3.458 people on CERN payroll. In addition to them, in the same year there were 6.333 people that have been at CERN for periods of time that go from a few months to the whole year.

The following figure gives the percentage distribution of status at CERN. The fact that the majority (64%) of people working at CERN is not on its payroll is a clear sign of the scientific excellence and uniqueness of CERN. Such leading role is going to be even more important with the opening of the LHC in 2007. The LHC will be the largest and most advanced collider in the world, reason why so many countries are participating to its creation even though they are not Member States.

Figure A.1 – Status distribution of people at CERN



Source: elaboration on (CERN 2006e).

Distribution of personnel by job

Personnel and users tasks at CERN are coded from one to five according to the following definitions:

1 Scientific work (Experimental and Theoretical Physics) – researchers whose tasks are strictly embedded or connected with Physics research, both at the experimental level (e.g. interpretation of results) or at the theoretical level (e.g. theories development);
2 Scientific and Engineering work (other than Experimental and Theoretical Physics) – researchers whose tasks are normally those of designing, implementing and running the complex machines in place at CERN;
3 Technical work – support staff with technical competencies
4 Manual work, Crafts and Trades – support staff.
5 Administrative and Office work – staff with administrative tasks

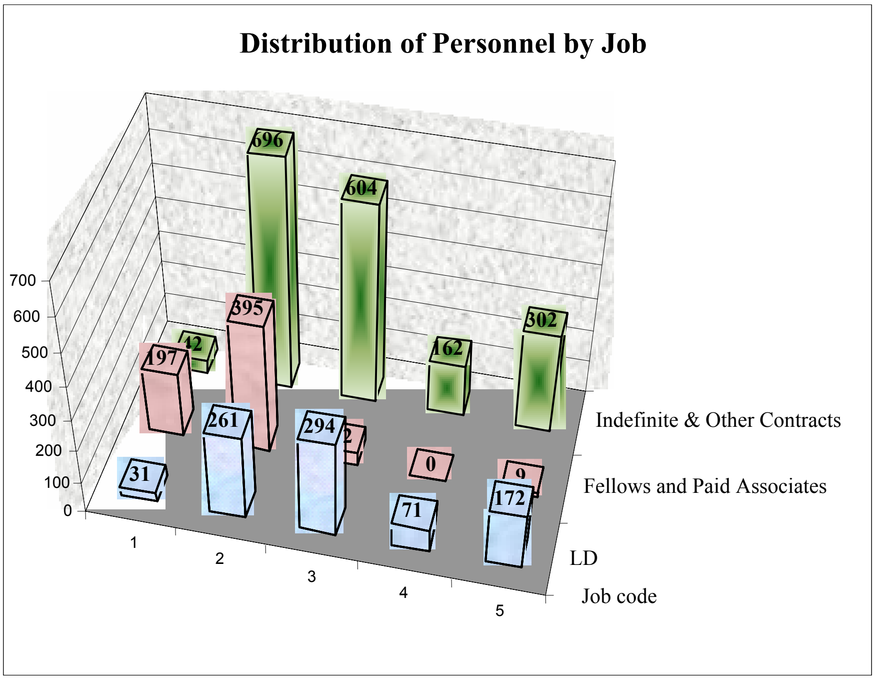
Table A.1 – Code and Job title description of people on CERN payroll.

Code & Job title description	Staff				Fell. & Paid Ass.		Total	
	LD	Indef. & Other	Total	%	Nr.	%	Nr	%
1 - Scientific work (Experimental and Theoretical Physics)	31	42	73	3	197	31	270	8
2 - Scientific and Engineering work (other than Experimental and Theoretical Physics)	261	696	957	36	395	61	1352	41
3 - Technical work	294	604	898	34	42	7	940	29
4 - Manual work, Crafts and Trades	71	162	233	9	0	0	233	7
5 - Administrative and Office work	172	302	474	18	9	1	483	15
Total	**829**	**1806**	**2635**	**100**	**643**	**100**	**3278**	**100,00**

Source: elaboration on (CERN 2006e)

The highest percentage of indefinite contract personnel has scientific and engineering tasks, immediately followed by technical work and, at a greater distance, by administrative jobs. The same three tasks are the ones concerning most of the LD contracts, but with the difference that 294 of them have technical work tasks, compared to 261 of them with scientific and engineering work tasks. Finally, Fellows and Paid Associates are almost completely concerned with scientific work, both in terms of physics and engineering assignments.

Figure A.2 – Distribution of CERN personnel by job code

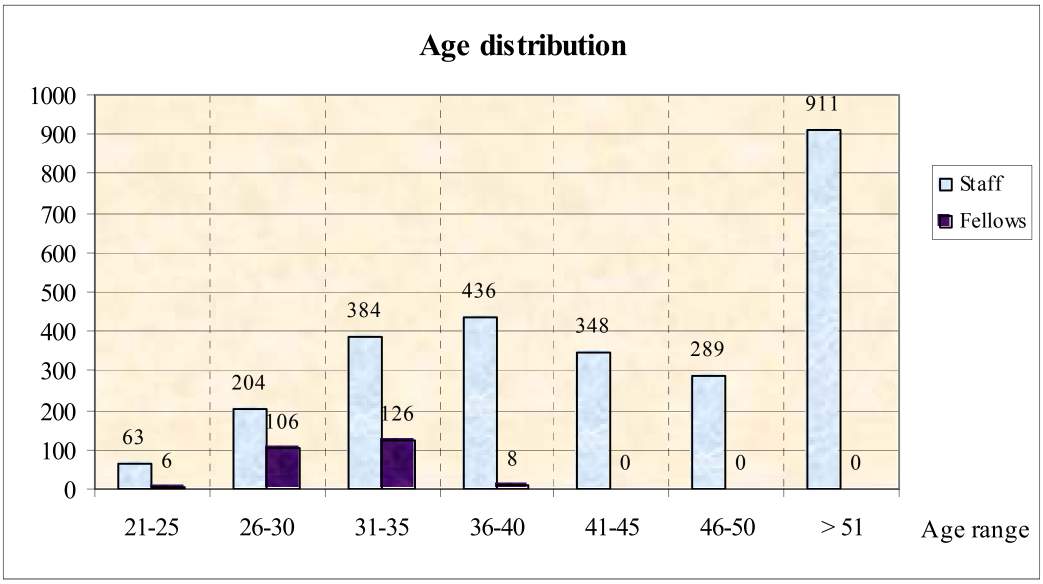


Source: elaboration on (CERN 2006e)

Age distribution of staff and fellows

In the following figure, we can notice that while the majority of fellows are between 26 and 35 years old, over 34% of staff is above 51 years old. This means that most of permanent staff is nearing retirement age, as LD and FT personnel are generally younger (their average age is 35 years old). Staff above 50 years old is generally in a good position relative to possible career path, in terms both of remuneration and responsibility.

Figure A.3 – Age distribution of CERN staff and fellows



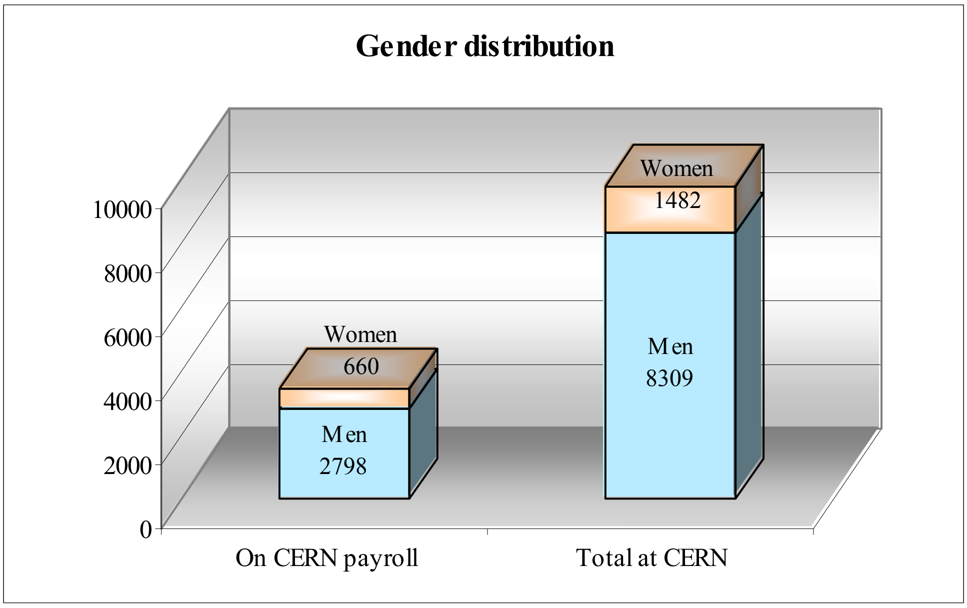
Source: elaboration on (CERN 2006e)

Gender distribution of people at CERN

The vast majority of people at CERN, both staff and users are males. Even if at CERN there is an equal opportunity policy, the number of women is still relatively small, although it is well known that worldwide women in fields such as physics and engineering are few compared to their male colleagues.

In any case, the percentage of women on CERN payroll (staff, fellows and paid associates.) is 23.6%, whereas of the total of people at CERN (including users and unpaid associates) only 17.8% of them are women.

Figure A.4 – Gender distribution at CERN

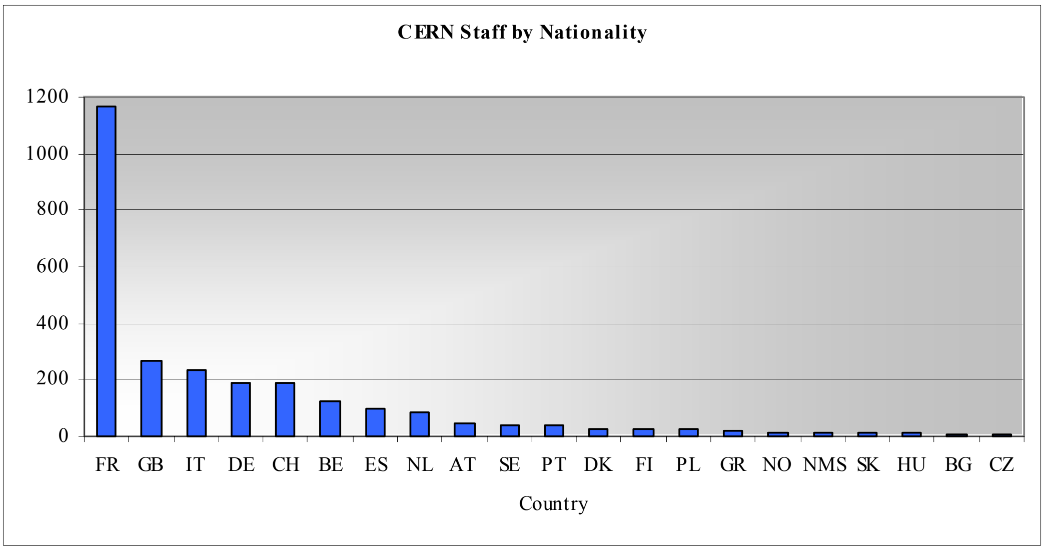


Source: elaboration on (CERN 2006e)

Nationality distribution

Over 44% of CERN staff (permanent, LD and FT contracts) comes from France, the remaining staff is distributed among the various Member States of CERN and only fourteen people are from Non-Member States.

Figure A.5 – Nationality distribution of CERN staff



Source: elaboration on (CERN 2006e).

The nationality distribution for the first four MS is in accordance with the fact that those same countries also provide the biggest shares of CERN budget. Thus, France, UK, Italy and Germany provide almost 71% of personnel as well as almost 65% of total budget.

The nationality distribution is skewed for French personnel, but this is understandable given the geographical location of CERN between France and francophone Switzerland. In fact, a large share of French personnel is local staff and is employed in support and administrative jobs.