PhD Thesis Proposal - On the role of engineering schools on the process of technological change: A comparative analysis 1985 - 2000

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Abstract

Knowledge increasingly replaces capital and labor as the key factor for economic development. Universities face increased knowledge production and diffusion sites competition resulting from an accelerated technological rate. Furthermore, the emergence of the interactive innovation model and triple helix institutional models show adaptation attempts to deal with a widening skill gap between society needs and knowledge production/diffusion institutions, namely, universities.

The aim of this study is to analyze how engineering schools adapted to emerging forms of knowledge production, diffusion, institutional relationships and societal demands. Four dimensions are used to specify the research question: 1) knowledge production, 2) knowledge diffusion and enterprise competitiveness, 3) scientific culture 4) autonomy and the role of the State.

The data will be gathered using quantitative and qualitative methods. Statistical data will be retrieved from engineering schools and secondary sources such as OECD datasets, complemented by qualitative methods - case studies and documental content analysis.

State of the Art

After the 1950s and 1960s economic growth, the 1970s oil shocks and productivity slowdown showed the need to rethink the relationships between science, technology and economy. There was the need to rethink the S&T role in a way beyond considering technology a black box (Rosenberg 1982) and innovation a linear process. As a result, the traditional approach to economic growth explained through capital, labor and technological change was replaced by the new theories of economic growth. Other result

was the emergence of the chain-linked model (Kline and Rosenberg, 1986) considering innovation a complex process rather than a linear one, and the awareness of national systems of Innovation, thus framing innovation in the specificities in national socio-economic structures. More recently, the emergence of newer knowledge production forms (Gibbons, 1994) and institutional triple helix models (Etzkowitz et al, 2000) of institutional relationships to deal with increasingly changing techno-economic paradigms were presented.

The new theories of growth consider knowledge endogenous to social and economic development, and not restricted to technology, realizing also that continuous interaction between ideas and skills, supported by capital generates productivity gains leading to economic development. Thus, processes of knowledge accumulation and learning, - strongly present in the university, are key elements in economic development. The university is a repository and provider of knowledge accumulation through formal learning processes, such as education (Lucas, 1988), research (Romer, 1990) and professional networks (Foray and Lundvall, 1996). Furthermore, the innovation system is rooted both in R&D and in the human resources (Lundvall and Christensen, 2003) However, nowadays, universities are facing increasing demands from society that are overwhelming their response capacity (Neave, 1998).

The classic university research organization is based on a disciplinary structure – thus specialist - withholding a set of research and teaching rules that offer meaning and identity to its practice and outcomes (mode 1). This organization is being challenged by the emergence of a mix knowledge production mode (figure 1) as knowledge creation becomes increasingly complex and less self-contained. Furthermore, the emergence of learning organizations (Nonaka and Takeuchi, 1995) brought new knowledge producers, diffusers and regulators into the system, creating an overlay of linkages that originate internal and external dynamics of change among the system actors.

	Traditional University research	Emerging research questions
CONTEXT	specific community	application

SCOPE	disciplinary	transdisciplinary
SKILLS	homogeneity	heterogeneity
ORGANIZATION	Hierarchical & Static (preserved)	Transient & Dynamic (changing)
	MODE 1	MODE 2

Figure 1 – Gibbons knowledge production taxonomy (Gibbons et al, 1994)

Within the university system, engineering schools represent major poles of scientific advancement and innovation, due to their emphasis on applied research and technical expertise. The society technological complexity increasingly demands engineering schools to adapt their curricula and research to engineering systems, widening the scientific scope on approaching problems, rather than specializing it, thus reducing the existing gap between what is required to engineering schools and what is provided.

Furthermore, engineering schools are still challenged to adapt its structures to students' demands for training for non-academic careers and face an eminent crisis regarding the decreasing number of students (EC, 2004) after suffering a massification effect. Moreover, the institutional diversity of higher education (van Vught, 1996) and its increased autonomy are needed to increase student and faculty mobility, respond to market and student needs and promote excellence.

Objectives

The primary goal of this research is to analyze the engineering schools adaptation forms to an accelerated technological changing world. This will be done regarding its research function and its relation with an increasingly complex, uncertain, and technologically dependent society. This question is specified along four dimensions:

One relates to the mechanisms of knowledge production, namely whether and how engineering schools' knowledge production is changing from the traditional to a mixed mode of knowledge production. The second is concerned with the diffusion of knowledge and enterprise competitiveness, specifically, the science industry relationships between engineering schools and enterprises. The third will deal with the dependency between the

level of technological culture of the local or regional population and the impact of the schools in the socio-economic development. The fourth addresses the universities autonomy and its relationship with the State. The second and the fourth dimension are related to the increasingly interwoven institutional set of relationships between academia, enterprises and the State and the university organizational change derived from those relationships.

To achieve scientific inference on the four dimensions, they will be operationalized on several engineering universities from different countries and regional social and economic frameworks. Quantitative and qualitative research methods will be used. Statistics will be gathered from a set of engineering schools and from secondary sources, such as OECD databases. Concerning qualitative methods, case studies and documental content analysis will be used as complementary to the statistical information.

Detailed Description

It has been acknowledged that intangible assets are of capital importance for the industrialized world economies, overwhelming the importance of capital, labor and technological change as unique contributors for economic development. For individuals, organizations or nations, non-codified assets are not easily learnt or transferable though necessary for understanding and creating complex codified knowledge. Therefore, the need to raise human capital and improve social capital mechanisms is essential in order to obtain optimal performance in competitive knowledge environments.

Although to a great extent skills result from the innate characteristics of an individual or from the history of an institution or country, they are also dependent on the learning processes in which these entities are involved. Complex learning processes and new ideas creation are generated in universities through the interdependency between research and teaching and its available physical resources to support them. Therefore, universities are regarded as drivers of regional and national economic performance facing increasing societal pressure concerning its contribution to economic development. However, it is

known that universities do not reform themselves as their foundations are based on secular sets of institutional and tradition rules that usually oppose change.

In face of this framework, the university faces several challenges: reinforce its autonomy and governance, stimulate excellence through selectivity and diversification promotion, reinforce its societal links, assure State's role as an evaluating financing entity and integrating itself into the European Research Area. Engineering schools as a part of the university sector face the same problems, but the nature of its research, linkages to society and the importance of engineers to the economy (Heitor, Horta and Conceição, 2002; FORFAS, 2003) places engineering schools as the focus of this research. Within this context, the following research question is proposed: **How are engineering schools adapting themselves to Gibbons proposed mix modes of knowledge production, triple helix institutional relation framework and constant demands of an increasingly complex, chaotic, and technologically dependent society?** Essentially it will deepened the argument that engineering schools should be more autonomous with a stronger governance model to enable them to act more closely with other societal actors, adopting a proactive dynamic through the promotion of different mechanisms of knowledge creation and diffusion, though preserving its institutional integrity (Conceição, Heitor, Horta, 2003; Heitor, Conceição, Horta, forthcoming).

Four dimensions specify the research question. The first is concerned with the engineering schools mechanisms of knowledge production, specifically, the project will investigate *if the adoption of Gibbons mix between mode 1 and mode 2 of knowledge production is dependent upon career and organizational incentives and/or constrains*. The policy implications that are to be drawn from this dimension are related to the need to reinforce academic career incentive schemes towards multidisciplinary research. The second is related to the diffusion of knowledge and the enterprise competitiveness. This dimension will study the relationship between the industry and university actors at two levels: a) *the adaptation of university activities to the regional social-economic environment* b) *the balance between answering to external demands and maintain institutional integrity and autonomy.* This dimension should provide policy implications

directed towards the arrangement of sustainable connections towards society, beyond short-term technological transfer contracts, which implicate new forms to finance innovation. The third is related to the diffusion of knowledge and the technological culture, namely answering *if the impact of engineering schools in the socio-economic development depends on the level of technological culture of the regional or local population*. Its results will possibly lead to the introduction of diffusion activities and promotion of the technological culture in the universities agenda, in order to form and guarantee its contribution to the enlargement of the knowledge base of the general population. The fourth dimension focuses on the relation between the State and universities autonomy, specifically, *the more the State incentive mechanisms (funding and career) focuses on activities rather than resources the more proactive and ready to change the university is.* The policy implications of this dimensions is related to the role of the State as a preserver of universities institutional integrity, through the use of new financing mechanisms based on activities instead of resources, and as an evaluator adding value to the results of the developed activities in the universities, namely at production, diffusion and knowledge transfer levels.

In order to test the dimensions, quantitative methods will be used through statistical analysis of countries and regions higher education, science and technology and economic datasets using OECD, Eurostat, CIS, and national statistics institutes sources. Statistical data will also be obtained directly from the engineering schools. Qualitative data will also be used, namely, case studies, which will allow greater depth and specificity, and documental content analysis. Four engineering schools from different European countries using US engineering schools as reference marks will be used as analysis units. The chosen European engineering schools are Instituto Superior Técnico (IST), in Portugal, University of Aalborg (UA), in Denmark, Imperial College (IC), in England and the Polytechnic University of Catalunya (UPC), in Spain. The US universities that will be used as reference marks are the Massachusetts Institute of Technology (MIT) and the Carnegie Mellon University (CMU).

The fact that each engineering school is placed within a different higher education system, science, technology and innovation system and regional socio-economic setup will enable to withdraw scientific inference. The justification for choosing these engineering schools is based on differences of: *scope* (regional, national, national/international influence and impact), *economic framework* (regional and national Industrial structure and technological intensity), *society characteristics* (Educational level, IT use, public understanding of science), *higher education structure*, *science and technology system* and *internal governance*.

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