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POSTGRADUATE STUDENTS OF ENGINEERING IN THE CZECH REPUBLIC-THE FUTURE OF SCIENCE OR A DYING SPECIES?

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Abstract: Basic economic data about the Czech Republic present a picture of a relatively deep recession, especially in heavy industry, following the political changes in 1989. Growth did not start again until a few years ago, and even now the country is only approaching the level of GDP that it had at the beginning of the 1990s. In future the Czech Republic will need new highly qualified young people, both for academic institutions and for applied research and development. Especially in technical, information and natural sciences, we can anticipate a need for tens of thousands of new PhD graduates in the next decade. The key question is whether highly specialized PhD courses and careers in science are still attractive for some young people. The aim of our paper is to summarise the experience already gained and the measures put forward to improve the attractiveness of PhD studies, and to point out unsolved problems, in order to form a basis for future discussions.

INTRODUCTION

The education of highly qualified graduates, who represent a reservoir of human power for research and development, has a long and deep tradition at the technical universities in the Czech Republic, and especially at the Czech Technical University in Prague (CTU). During communism the system leading to a PhD degree was replaced by the more or less equivalent Russian-influenced system leading to the degree of "candidatus scientiae (CSc)", which was also based on creative scientific work carried out by a student. The change of political system brought a change of titles and a change in the position of a student at the university, but no change in the effort to produce highly qualified young people, prepared to carry out research in scientific institutes and in the research departments of industrial companies.

However, the social environment has changed, and has brought some new issues that the technical universities now encounter. Namely:

- How many scientists and researchers does our society need?

- What is the correct proportion between general and specialised education?

- Is enrolment in PhD courses still attractive for young people, having in mind the competition from high incomes offered by private companies?

- Is it possible to make traditional technical disciplines more attractive?

- What are the reasons for the high proportion of students who fail to complete their PhD studies?

Some answers can be provided from the experience of recent years at the CTU, and some measures to improve the situation are being accepted by the university. Nevertheless, there are still many uncertainties in all estimates of future developments. The aim of our paper is to summarise existing experience and the measures that have been taken, and to point out unsolved problems, in order to form a basis for future discussions.

How many scientists and researchers does our society need?

Basic data about the Czech Republic, as summarised in (HN, 2001), provide a picture of a relatively deep recession in the country after the political changes in 1989 **(see Table-1)**. The decrease is understandable, as the political changes have been accompanied by deep structural changes in the economy. However, there have been unpleasant consequences for the Czech research and development infrastructure. The figures clearly indicate that growth started again only a few years ago, and even now the country is only attaining the level of GDP that had been reached at the beginning of the 1990s.

This situation has been reflected in the number of employees in research and development and the financial flow into research and development, where there was a very significant decrease at the beginning of the 1990s **(see Table-2)**, and many research institutions were closed down. The biggest cuts were in applied research at institutes under various ministries, and also in industrial research. The research infrastructure in the Czech Republic is still adversely affected. The institutes of the Academy of Sciences have been reduced, and now employ only half as many researchers as they did at the end of the 1980s. The universities have suffered less damage to their research teams and have the best preserved research capacities, partially due to the funding of PhD students and their participation in research projects, using part of budget earmarked for education. Moreover, the number of university students has increased rapidly **(see Table-3)**, partially due to political pressures (low ratio of university educated population compared with some developed countries and compared with the targets set by the EU), but mainly due to economic causes (most of the money allocated to the universities is tied to student numbers).

There is a strong feeling that the decrease in research capacities (and also funding) should not be too long-term, and that intellectual potential is the main resource of our country, which has very limited natural resources. Almost co-inciding with the document "Towards a European Research Area" (EU, 2000), issued by the EU, a national document defining its policy on research and development was published by the Czech government (VĈR, 2000). These two documents both have the same thrust: to increase the research and development potential, to increase scientific production, to improve the organisation of research, to strengthen the transfer of R&D results to potential end users, especially to industry.

What does this mean for the perspectives of future graduates of PhD programmes? Our scientific community is nowadays weaker than advisable, and both European and national policy will tend to reinforce it. Moreover, in recent years the Czech scientific community has grown older, and is now threatened by the retirement of aging researchers. All the greater is the need for a new generation of highly-qualified young people, both in academic institutions and in applied research and development. Nobody is able to give a good estimate of the numbers of researchers that will be required, but especially in technical, information and natural sciences tens of thousands of new PhD graduates will surely be needed in the next decade, if the Czech economy is to flourish. This gives an excellent perspective to young people who would like to enrol in PhD studies in these technical fields. The key question is whether young people are aware of the opportunities, and whether they do not prefer the immediate profits offered in softer specialisations.

What is the correct proportion between general and specialised education?

Extensive discussions have taken place between supporters of general university education, on the one side, and specialised university education, on the other. These have been reflected in many conferences on education, e.g., (GCEE, 1998). However, the opinion of industrial managers should be the main source of information, and the concepts for study programmes should be based more on their opinions and requirements than on the ideas expressed by iygeneralistsls or irspecialistsls from the academic sphere.

The opinions of the "captains of industry" are sometimes surprising. In the Central European area, university education is traditionally based on programmes at MSc level, with engineering programmes usually taking from 4 to 6 years. It is quite easy to prepare syllabi with a good mixture of general and specialised subjects for such long programmes. As far as general subjects are concerned, it is clear that modern engineers need to know something not just about mathematics, physics and the other hard sciences, but also about economics, law, the environment, a foreign language, psychology, etc. All this can be included in a MSc programme. Nevertheless, for many positions in industrial companies, such graduates are considered overeducated. Their knowledge and ambitions lead toward research, or toward higher-level management. More specialised, more applications-orientated graduates are needed for posts in lower management, e.g., for heads of large workshops in factories, and also as sales representatives, etc. Graduates at BSc level are suitable for such posts, provided the programmes are not too theoretical (German "Fachhochschule" have been successful in offering such programmes).

Studies at BSc and MSc level, however, are not the subject of this paper. What is the place of PhD courses from the point of view of acceptance in industry? PhD graduates are particularly interesting for large companies that have their own research and development departments. For them, the ability of an engineer to deal independently with complicated problems, to think creatively and express himself scientifically are irreplaceable. The same is valid for young people taking up posts at universities or research laboratories. In order to educate such graduates, rather specialised study programmes are needed. The most general part of university education should be at MSc level. PhD studies deal with a large-scale project, usually with close links to the ihreal worldly, and are always highly specialised. It is not important whether the graduate finds employment exactly in his field of specialisation. His specialised

studies and research experience at a high scientific level have taught him a way of thinking that can be applied quite broadly. The position, which we sometimes meet, that such PhD studies in engineering are "irrelevant" or "obsolete" and discouraging students, cannot be accepted. No number of small projects can replace the traditional three-year project from the point of view of forming a scientific approach. The question remains, however, whether highly specialised studies and careers in science are still attractive for young people, in an age when superficial ideas spread by the mass media and by Hollywood movies have gained wide popularity.

Is enrolment in PhD courses still attractive for young people, having in mind the competition from high incomes offered by private companies?

Another problem of the attractiveness of PhD studies is the comparative attractiveness of jobs outside the academic world. Probably all over the world, the material conditions of PhD students are worse than those of their colleagues who took a job after graduating at MSc or even BSc level. This situation is very marked in the Czech Republic, where the level of scholarships of PhD students and the salaries of young scientists are much lower than in, e.g., most EU countries. The basic scholarship (which may be raised by a decision of the university, or supplemented by a research grant, etc.) is only slightly higher than the officially announced poverty line. This means that the decision to take up a scientific career involves accepting a life of poverty for several years. Only an enthusiast for some branch of science can make such decision. Even those who start out on such a mission can find their enthusiasm tempered by marriage and the arrival of children.

On the other hand, Czech PhD students do enjoy some financial advantages. Up to the age of 26, they are officially treated as students, which means lower taxation for their parents. They can have relatively cheap accommodation in one of the university dormitories (the quality of which is variable, and often low), they can take subsidised meals in student canteens, and qualify for discounted monthly tickets for municipal transport. Last but not least, some (especially the most able) are accepted as the part-time assistants by the university or by some collaborating research institution. Even so, the life of a student has become expensive, especially in Prague, which is considerably more expensive than the regional university centres.

Though the current level of unemployment in the Czech Republic is about 9%, it falls mostly on employees with lower qualifications. Only a few fields are saturated with university BSc and MSc level graduates, e.g., law and economics. Few graduates even have to accept what they consider to be "non-graduate" employment. In particular, technical and information specialists are constantly sought, and are sometimes offered financially attractive positions. Most graduates from technical universities have good skills in the use of computers, and various private companies, such as banks and consulting firms, offer an income three or four times higher than the graduate would receive as a PhD student or a young scientist at a university or in a research institute. If, as is often the case, a graduate working in the private sector is required to undertake mainly routine, unspecialised work, within a few years it will be difficult for him to return to an academic position. The following are a few examples of jobs taken by MSc graduates from the Faculty of Nuclear Sciences and Physical Engineering and by students abandoning PhD studies: selling computers, making replicas of old glass and classic cars, working in the communications department of a tobacco company, heading an advertising agency. In this context we should not be too angry with one of our PhD students, who, after graduating with excellent results, fulfilled his childhood dream by becoming a truck driver. It should be pointed out that, at the same time, the Faculty of Nuclear Sciences and Physical Engineering is not able to satisfy the demand for its graduates from institutions working in the fields that the faculty specialises in.

The key question is whether salaries for the most highly qualified university graduates will improve in the near future, and stop the trend for good graduates to turn away from specialised professions and prefer better paid but less specialised jobs. Many of these highly qualified graduates are needed in institutions financed partially by the state (universities, the Academy of Sciences, research institutes), so the whole question of the gulf between salaries in the private sector and in the public sector arises.

Is it possible to make traditional technical disciplines more attractive?

There has been some movement away from the traditional technical disciplines in recent years. The reasons are both objective and subjective. Objectively, the structure of production has been changing toward more sophisticated products and technologies. Steel production figures are no longer an index of industrial development. Computers have entered even into such classical mechanical engineering products as the family car, and they are used not only in its design but also in its operation. It seems improbable that a talented technician will in future be able to build the kind of industrial empire established by, for example, Emil Ŝkoda in the 19th century in Bohemia, Henry Ford at the beginning of the 20th century in U.S.A. or Soichiro Honda after World War II in Japan. These empires were based not on money, but on technical knowledge, experience and ability.

What can a technical university do, facing this changing world? Many universities, including CTU in

Prague, have attempted to solve the problem by rapidly introducing information sciences into their programmes (see, e.g., (Musílek and Ŝkoda, 1997)). This is an effective way to keep the number of students approximately constant or even to raise student numbers gradually, because computers and information sciences are still very popular among potential university students. It is not, however, an effective way to keep an acceptable number of students learning civil, mechanical, electrical, or even nuclear engineering. These traditional branches of technical science must change their approach, and become more interdisciplinary, making visible their links with information sciences, environmental sciences, biology and medicine, etc. (see, e.g. (Musílek and Mareš, 1998)). As an example of this approach, one of the most popular study programmes at the Faculty of Nuclear Sciences and Physical Engineering deals with radiation physics in medicine. Various branches of biomedical engineering are also successful at the other faculties of CTU.

Another important issue in propagating technical studies is to spread the idea that computers need not necessarily be a student's primary field of specialisation: they can be successfully applied in a wide range of fields. Students should consider using computers in the design of technical artefacts, rather than being a computer specialist who serves other fields of specialisation.

Paradoxically, such interdisciplinarity can lead to deeper specialisation. A graduate in radiation physics in medicine is well fitted for work in a hospital, in radiotherapy as well as in diagnostics and nuclear medicine. On the other hand, he is far removed from other, non- medical applications of radiation physics. Nevertheless, this is the price we should be prepared to pay for attracting students to technical universities.

What are the reasons for the high rate of students who fail to complete their PhD studies?

Tab. 4 summarises the number of PhD students and PhD graduates at CTU in Prague since 1995. The situation at the other Czech universities is similar. It can be seen that the ratio of the number of PhD graduates to the number of PhD students is catastrophically low. The reasons are twofold:

- Though the nominal length of the programme is 3 years, many students are not able to finish their thesis within this time and stay longer at the Faculty, using the possibility of extending their studies (after three years they no longer receive a scholarship).

- Many students do not finish their studies and leave the University, usually for a better paid position in a private company, or for an attractive offer from abroad.

We can exclude intellectual inability as a reason for failing to complete a PhD study programme. The students accepted into PhD programmes have generally graduated from rather demanding MSc courses without difficulty, and their abilities have been tested many times, including the doctoral entrance examination. Economic reasons are without doubt the main influence on the unsatisfactory situation. A certain increase in the number of graduates in the last three years may be only a statistical fluctuation, but we hope it will turn out to be a small but visible result of our effort to improve the attractiveness of PhD studies and the position of PhD students.

Conclusions

The reasons for some difficulties in the effectiveness of PhD programmes are apparent. They can be dealt with only by a joint effort by the universities and by the outside world, including the state authorities. The most important improvements are as follows:

- to extend the selection of attractive, especially interdisciplinary, research topics offered to students,

- to improve radically the social situation of PhD students, both by raising their scholarships and by more systematically offering them part-time positions at the university and collaborating institutions,

- to give PhD students a clear perspective of future appreciation of high qualifications, both in terms of social prestige and in terms of higher salaries.

Official documents seem to be indicating some understanding of the importance of supporting scientific research, though appropriate action in the form of radically increased funding is still limited by the general economic situation in the country. We may hope that the greater emphasis given to research and development in the EU countries will also improve the importance and attractiveness of PhD studies in the Czech Republic as the main source of highly qualified researchers.

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Tab. 1: Development of basic economic data about the Czech Republic

	1990[1]	1993	1995	1998	1999	2000
Population (in millions)	10.36	10.33	10.33	10.29	10.28	10.27
GDP (%)	100	88	95.2	96.7	95.9	98.5
Industrial production (%)	100	68	76	83	80	85
Building production (%)	100	80	94	88	81	86
Agricultural production (%)	100	78	77	73	73	70
Employees (thousands) [2]	5351	4848	5012	4869	4693	4610
Unemployed (thousands)	-	39	185	387	488	465
Real salary (%)	100	84.2	98.7	108.0	114.5	117.0

[1] The present-day Czech Republic was a part of former Czechoslovakia. Statistical data for 1990 are available both for the Czech part (the Czech Republic) and, separately, for the Slovak part of the country. Therefore these figures are fully comparable with the later data for the Czech Republic as a separate state.
[2] In the non-military sector.)

Tab. 2: Situation in research and development in the Czech Republic during the past decade

	1989	1991	1993	1995	1997	1999
Employees (thousands)	137.9	76.5	40.2	47.5	52.1	52.7
Operational Expenses (billions)	196	13.5	11.1	12.4	16.9	20.8
Investments (billions)	?	1.7	1.2	1.6	2.6	2.8

Tab. 3: Number of students at various levels of schools in the Czech Republic during the past decade (in thousands)

	1990	1993	1995	1997	1998	1999
Basic schools	1195	1061	1005	1092	1082	1071
Gymnasiums	111	122	133	126	126	127
Specialised high schools	191	219	259	200	192	180
Universities	118	127	140	166	174	184

Tab. 4: Number of students and graduates from PhD. courses at the CTU Prague

	1995	1996	1997	1998	1999	2000
Number of PhD. students	1183	1315	1215	1191	1241	1829
Number of PhD. graduates	41	44	40	57	94	76

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