ISSN 1330-3651
UDC/UDK 001.894/.895(4-69)

CAPITALIZATION OF KNOWLEDGE - INNOVATION PROCESSES IN TRANSITIONAL COUNTRIES

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Original scientific paper

Capitalization of knowledge is the driver of knowledge economy. These processes are implemented through management and innovations embedding scientific research with technological innovation and patents and their commercial exploitation. The capitalization of knowledge in transition countries is analyzed through: a) the number of patents, b) the rate and structure of financing scientific and developmental research and c) the human resources in the sector of science and technology. The comparisons are made with developed European countries and global trends within leading countries of the world. Furthermore, the position of transition countries and Croatia is defined. Finally, systematic solutions are proposed.

Keywords: *capitalization of knowledge, innovation processes, patents, research and development, transition countries*

Kapitalizacija znanja kroz inovacijske procese u zemljama tranzicije

Izvorni znanstveni članak

Kapitalizacija znanja je pokretač ekonomije znanja. Ti se procesi odvijaju inovacijama uključujući znanstvena istraživanja s tehnološkim inovacijama i patentima i njihovom komercijalnom eksploatacijom. U radu se razmatra kapitalizacija znanja u zemljama tranzicije putem: a) broja patenata, b) stope i strukture financiranja znanstvenih i razvojnih istraživanja i c) ljudskih resursa u znanosti i tehnologiji – uspoređeno s razvijenim europskim zemljama i globalnim trendom s vodećim zemljama svijeta. Utvrđena je nepovoljna pozicija tranzicijskih zemalja i Hrvatske te su predložena sistemska rješenja.

Ključne riječi: *inovacijski procesi, istraživanje i razvoj, kapitalizacija znanja, patenti, zemlje tranzicije*

1 Introduction
Uvod

Capitalization of knowledge is the driver of knowledge economy. These processes are implemented through management and innovations embedding scientific research with technological innovation and patents and their commercial exploitation [1] - [4]. This article considers the capitalization of knowledge in transition countries through: a) the number of granted patents and patents application, b) the rate and structure of financing scientific and developmental research (R&D) and c) the human resources in the sector of science and technology - all comparisons have been made with developed European countries and leading countries of the world.

A patent is a device used to protect the intellectual property of a person who designs, invents or cultivates an original work of special value. While it is mainly considered an intellectual property protection, the patent will also express the real property described in the document. In most cases, patent protection is a key part of any new invention [5].

There is no unique world database of patents. Patents are registered on a national patent office level and on the international level. The most important databases are the US Patent & Trademark Office (USPTO), the European Patent Office (EPO) and the Japan Patent Office (JPO).

2 Patent applications and granted patents
Prijavljeni i registrirani patenti

USPTO data refer to patents granted from The United States Patent and Trademark Office. Data are recorded by year of publication. Patents in the US are only published once they are granted. Patents are allocated to the country of the inventor using fractional counting in the case of multiple inventor countries [6].

EPO data refer to applications filed directly under the European Patent Convention or to applications filed under the Patent Cooperation Treaty and designated to the EPO. Patent applications are counted according to the year in which they were filed at the EPO and are broken down according to the International Patent Classification. They are also broken down according to the inventor's place of residence, using fractional counting if multiple inventors or IPC classes are provided to avoid double counting [6].

2.1 USPTO granted patents
Registrirani USPTO patenti

Developed countries have most patent activities. The USA and Japan have almost 3 times more patents per capita than the EU-27. Here it is necessary to point out that the number of patents per million inhabitants in the EU-27 is reduced by the new members - transition countries, so that the EU-27 falls behind the leading countries of the world (Fig. 1).

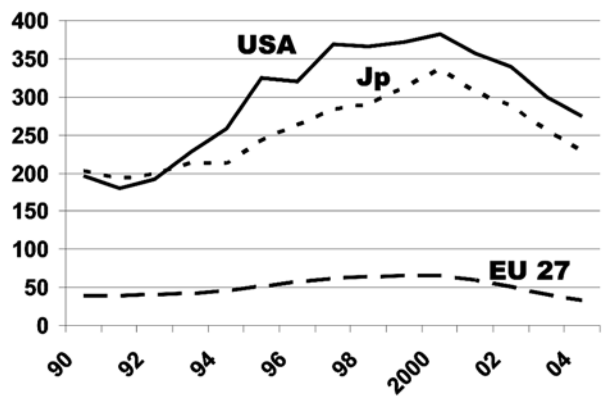

Figure 1 *Patents granted by the USPTO, source* [6]
Slika 1. *USPTO registrirani patenti, izvor* [6]

Tables 1 - 4 and Fig. 2 show the number of granted patents per million inhabitants in large, middle-sized and small developed European countries (DEC) and European transition countries (TEC). DECs are grouped according to the number of inhabitants: large countries = 11 and more million inhabitants, middle-sized countries = 7,5 to 11 million inhabitants, small European countries = 5 million and less.

Among large countries, Germany had the largest number of patents per million inhabitants, while Italy had the smallest number of patents. The average number of patents in this group of countries increased from 53 (1990) to 86 patents (2000), which then dropped to 43 (2004) (Tab. 1).

Table 1 *Number of patents granted by USPTO in large European countries - per million inhabitants, source* [6]
Tablica 1. *Broj registriranih USPTO patenata u velikim europskim zemljama – na milijun stanovnika, izvor* [6]

Time	1990	1994	1998	2002	2004
De	91,3	106,5	156,4	125,0	83,3
Fr	52,2	59,5	77,6	55,1	37,6
GB	47,5	55,7	75,4	54,7	32,4
It	22,4	23,9	33,5	28,9	18,1
Average	53,3	61,4	85,7	65,9	42,9

Compared to large countries, middle-sized countries claim a greater average number of patents increasing from 82 (1990) to 139 (2000) and then decreasing to 60 (2006). The largest number of patents was generated by Switzerland and the smallest number by Austria (Tab. 2).

Table 2 *Number of patents granted by USPTO in middle European countries - per million inhabitants, source* [6]
Tablica 2. *Broj registriranih USPTO patenata u srednjim europskim zemljama – na milijun stanovnika, izvor* [6]

Time	1990	1994	1998	2002	2004
At	45,4	54,9	75,0	70,2	44,9
Be	35,2	64,1	78,6	60,7	38,0
Ch	177,4	183,2	217,6	164,3	103,5
No	61,1	71,2	98,0	86,5	57,7
Se	92,2	135,4	200,7	123,8	56,8
Average	82,3	101,7	134,0	101,1	60,2

The average number of patents in small European countries increased from 42 (1990) to 105 (2000), and then declined to 55 (2004). Finland had the largest number of patents, whereas Norway had the smallest number of patents (Tab. 3).

Table 3 *Number of patents granted by USPTO in small European countries - per million inhabitants, source* [6]
Tablica 3. *Broj registriranih USPTO patenata u malim europskim zemljama – na milijun stanovnika, izvor* [6]

Time	1990	1994	1998	2002	2004
Dk	49,9	75,1	108,4	72,8	45,5
Ir	16,5	24,2	46,0	42,7	38,8
Fi	73,2	124,5	195,1	146,8	104,3
No	28,7	45,3	67,4	51,8	32,7
Average	42,1	67,3	104,2	78,5	55,3

The number of patents per million inhabitants in transition countries was smaller than in DEC. The average number of patents in TEC ranged from 2,1 (1996) to 3,8 (2000) and then dropped to 2,5 (2004). Slovenia ranked first with the number of patents, while Bulgaria had the smallest number of patents. Croatia was in the middle of this rank list with 2 (1996) and 5,8 (2000) granted patents, but then dropping to 2,3 patents in 2004 (Tab. 4).

The basic relation of these four groups of countries is shown in Fig. 2.

Table 4 *Number of patents granted by USPTO in European transition countries - per million inhabitants, source* [6]
Tablica 4. *Broj registriranih USPTO patenata u europskim tranzicijskim zemljama – na milijun stanovnika, izvor* [6]

Time	1996	1998	2000	2002	2004
Bg	0,3	0,8	0,4	0,7	0,6
Cz	3,1	3,8	3,8	4,9	4,8
Ee	3,2	2,8	2,4	0,4	2,8
Lv	0,6	1,8	4,2	1,8	0,9
Lt	0,3	0,2	1,6	2,3	5,5
Hu	4,6	3,5	7,2	5,8	3,9
Pl	0,8	0,5	0,9	1,0	1,0
Ro	0,3	0,3	0,3	0,4	0,6
Sl	7,3	13,9	15,6	12,6	4,2
Sk	1,0	1,3	1,7	1,4	1,1
HR	**2,0**	**3,5**	**3,9**	**5,8**	**2,3**
Average	2,1	2,9	3,8	3,4	2,5

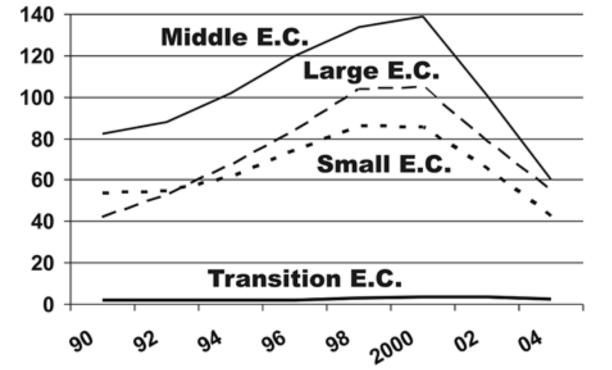

Figure 2 *Average number of patents granted by USPTO in large, middle, small and transition European countries - per million inhabitants, source: tab. 1 - 4*
Slika 2. *Prosječan broj registriranih USPTO patenata u velikim, srednjim, malim i tranzicijskim europskim zemljama - na milijun stanovnika, izvor: tab. 1 - 4*

The illustration of this large gap between transition and developed countries is shown in Fig. 3. During the observed period from 1990 to 2004, 14 developed European countries were granted 1180 USPTO patents per million inhabitants, in contrast to 11 European transition countries which were granted only 34 patents during the same period of time.

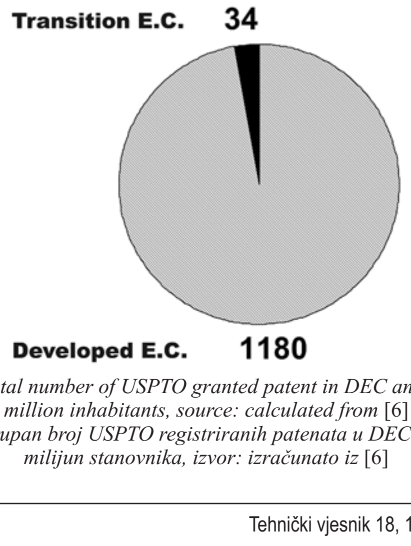

Figure 3 *Total number of USPTO granted patent in DEC and TEC - per million inhabitants, source: calculated from* [6]
Slika 3. *Ukupan broj USPTO registriranih patenata u DEC i TEC – na milijun stanovnika, izvor: izračunato iz* [6]

2.2 EPO patent applications
Prijavljeni EPO patenti

In order to obtain a more realistic view of the circumstances of knowledge capitalization in transition countries, the number of applications to the EPO should be taken into consideration. Fig. 4 shows the number of patent applications of developed European countries. Switzerland ranked first with 250 (1990) patent applications, which increased to 429 (2007) per million inhabitants. Sweden and Germany followed with 300 applications, while Spain had the least recorded patent applications – only 33 per year. The average number of patent applications in this group of countries increased from 81 (1990) to 187 (2007).

Transition countries had a significantly lower number of patent applications and some of these countries did not have any applications in the first years.

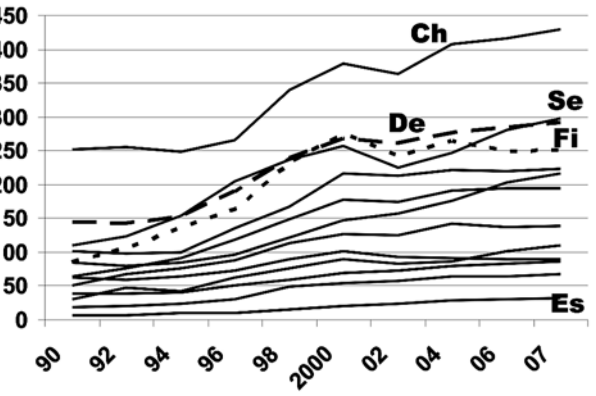

Figure 4 *Number of EPO patent applications from developed European countries – per million inhabitants, source* [6]
Slika 4. Broj prijavljenih EPO patenata iz razvijenih europskih zemalja – na milijun stanovnika, izvor [6]

The best performing transition country was Slovenia with 2,5 (1990) increasing to 52,5 (2007) patent applications, followed by Hungary, Estonia and the Czech Republic. With only 1 application per year (2004-2007), Romania had the smallest number of patenting activities. There is an increase of the number of patent applications in Croatia from 1,7 (1992) to 7,2 (2007). The average number of patent applications in transition countries moved from 1 (1990) to 12,4 (2007) (Fig. 5).

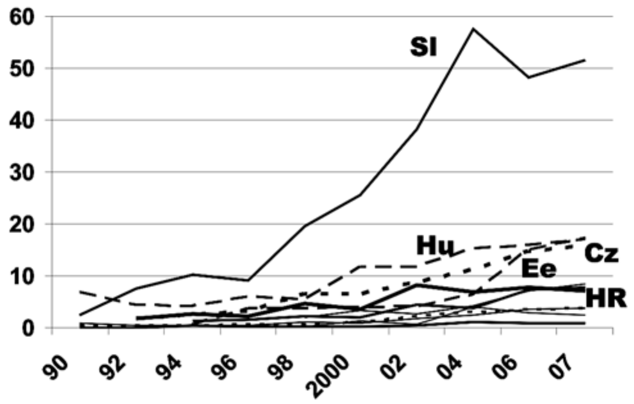

Figure 5 *Number of patent applications of transition countries to EPO - per million inhabitants, source* [6]
Slika 5. Broj prijavljenih EPO patenata iz europskih tranzicijskih zemalja – na milijun stanovnika, izvor [6]

Fig. 6 presents the large gap between developed and developing countries. In the period from 1990 to 2007, 14 developed European countries applied for 2412 patents to the EPO, in contrast to 11 transition countries which had only 97 patent applications during the same period of time.

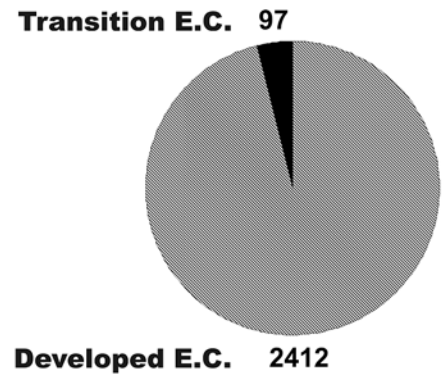

Figure 6 *Total number of patent EPO applications in DEC and TEC during 1990-2004 – per million inhabitants, source: calculated from* [6]
Slika 6. Ukupan broj EPO registriranih patenata u DEC i TEC – na milijun stanovnika, izvor: izračunato iz [6]

2.3. High technology patent applications
Prijave patenata visoke tehnologije

Analyzing the patent applications of high technology to the EPO, EU countries ranked lower with respect to the exposed activity on the patent. Japan generated the largest number of patent applications per million inhabitants, followed by the USA, Canada, and the EU with almost half the number of applications generated by Japan. We point out that the average of EU-27 is reduced by transition countries (Fig. 7).

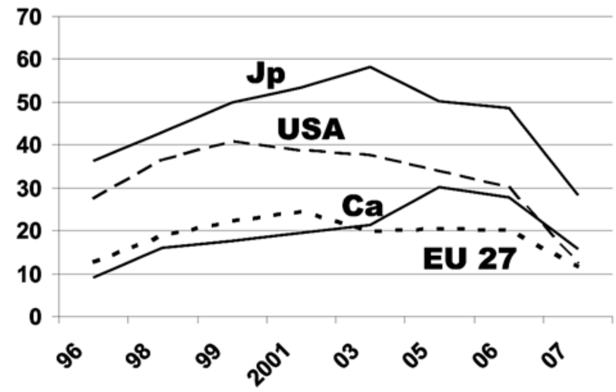

Figure 7 *EPO high-technology patents applications on the world level – per million inhabitants* [6]
Slika 7. Broj EPO visoko-tehnoloških patentnih prijava na svjetskoj razini – na milijun stanovnika [6]

Among developed European countries a lot of patent applications were registered in the Netherlands, followed by Switzerland, while Spain and Italy ranked lowest (Fig. 8).

Considering the high-tech patent category, European transition countries fell far behind the developed European countries. A lot of patents were from Slovenia and Estonia, followed by Hungary and Croatia at the bottom with less than one patent each year (Fig. 9).

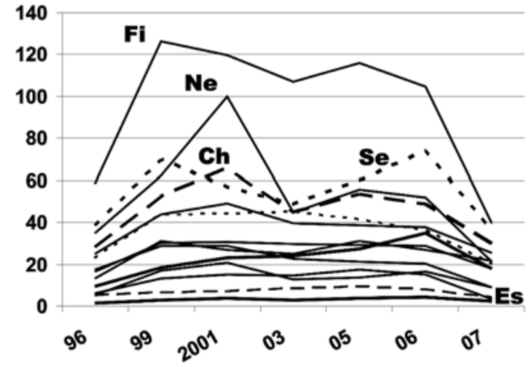

Figure 8 *EPO high-technology patent applications in DEC – per million inhabitants* [6]
Slika 8. Broj EPO visoko-tehnoloških patentnih prijava u DEC – na milijun stanovnika [6]

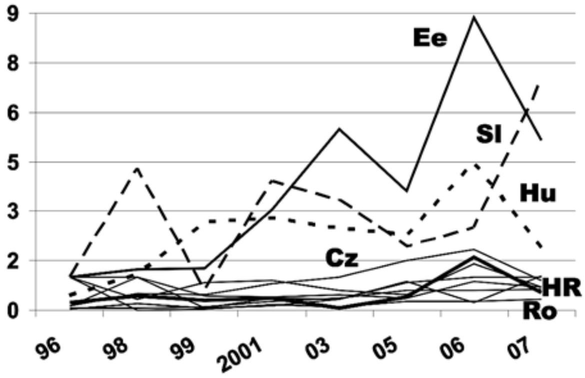

Figure 9 *EPO high-technology patent applications in TEC – per million inhabitants* [6]
Slika 9. Broj EPO visoko-tehnoloških patentnih prijava u TEC – na milijun stanovnika [6]

What is the cause of the unfavorable situation in transition countries? Surely, there are several causes like: a) concept of organization of research in technical sciences, b) development level of industry, c) level of technical and innovation culture in these countries. The above noted reasons are better in developed European countries. Our further analyses primarily focus on organizational concepts of research in technical sciences: (a1) rate and (a2) financing structure of scientific research, (a3) the number of researchers and (a4) employment of researchers by sector.

3 Research and development expenditures
Razvojno-istraživački rashodi

Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the knowledge stock, including individual knowledge, culture and society and the use of this knowledge to obtain new applications. R&D expenditures include all expenditures for R&D on the national territory during a given period. [6]

From 2000 to 2006 EU-27 had a GDP of 13,7 % rate of growth in real terms and R&D expenditures increased to 14,8 % in real terms (Fig. 10). This process indicates a development trend for transition countries regarding the investment in the R&D sector.

Globally speaking, EU-27 was not a leader among large economies with respect to the investment in the R&D sector. In 2006 the R&D intensity in EU-27 stood at 1,85 (as a percentage of GDP). In the same year the US stood at 2,59 %, South Korea reached 3,23 and Japan 3,39 %. Unlike China which showed an increase in R&D intensity, EU-27, as well as Russia showed a downward trend after 2003 (Fig. 11).

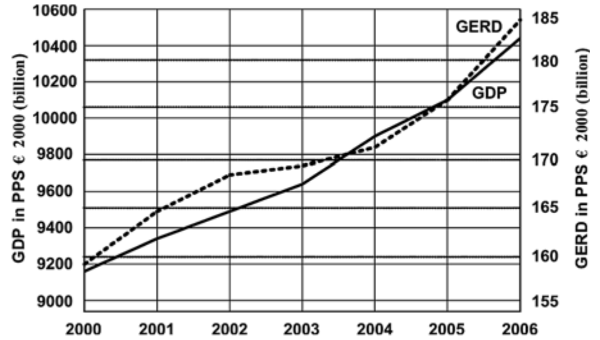

Figure 10 *Evolution of EU-27 GERD and GDP, 2000-2006; in real terms* [7]
Slika 10. Kretanje ukupnih istraživačko-razvojnih rashoda i BDP, u EU-27 - 2000-2006; u stvarnim cijenama [7]

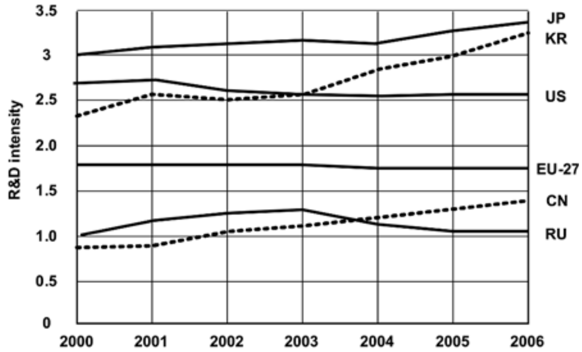

Figure 11 *Evolution of R&D intensity (% of GDP) in leading world economy-countries, 2000-2006* [7]
Slika 11. Kretanje istraživačko-razvojnog intenziteta (% BDP) u vodećim zemljama svijeta, 2000-2006 [7]

During the period from 1990 to 2009, the R&D intensity in developed European countries varied: 1,02-1,27 % in Italy, 3,58-3,67 % in Sweden and 3,17-3,96 % in Finland (Fig. 12).

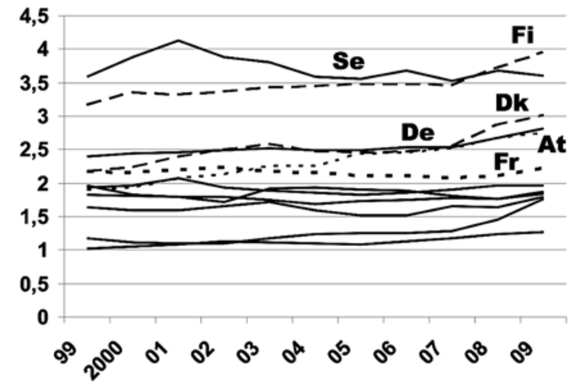

Figure 12 *R&D intensity (% of GDP) in European developed countries* [6]
Slika 12. Istraživačko-razvojni intenzitet (% BDP) u europskim razvijenim zemljama [6]

During the same period the R&D intensity in transition countries varied from 0,4-0,48 % in Romania, 1,14-1,53 % in the Czech Republic to 1,37-1,86 % in Slovenia. Croatia stood at 0,96-0,84 % (Fig. 13).

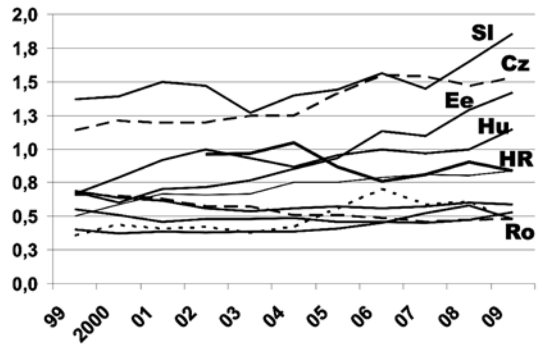

Figure 13 *R&D intensity (% of GDP) in European transition countries* [6]
Slika 13. *Istraživačko-razvojni intenzitet (% BDP) u europskim tranzicijskim zemljama* [6]

3.1 R&D expenditures performed within the business enterprise sector
Rashodi istraživanja i razvoja u privrednom sektoru

Business enterprise expenditure on R&D (BERD) includes expenditures for R&D performed within the business enterprise sector on the national territory during a given period. R&D expenditure in BERD is shown as a percentage of GDP (R&D intensity) [5].

In the world leading large economies BERD increased in Japan 2,14-2,687 % (2007) and oscillated with very small growth in the US and EU-27 (Fig. 14).

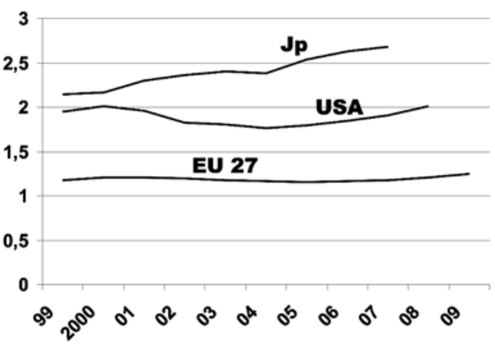

Figure 14 *BERD in world large economies (% of GDP)* [6]
Slika 14. *Istraživačko-razvojni rashodi u privredi u velikim zemljama svijeta (% BDP)* [6]

BERD intensity in developed European countries in the same period fluctuated from 0,5-0,65 % in Italy to 2,66-2,54 % in Sweden and 2,16-2,84 % in Finland (Fig. 15).

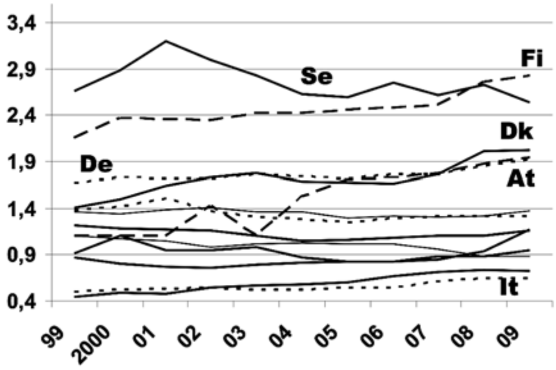

Figure 15 *BERD in developed European countries (% of GDP)* [6]
Slika 15. *Istraživačko-razvojni rashodi u privredi razvijenih europskih zemalja (% BDP)* [6]

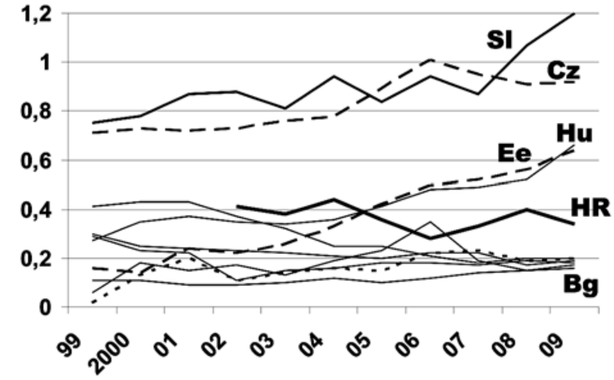

Figure 16 *Transition countries BERD (% of GDP)* [6]
Slika 16. *Istraživačko-razvojni rashodi u privredi europskih tranzicijskih zemalja (% BDP)* [6]

BERD intensity varied in transition countries from 0,11-0,16 % in Bulgaria to 0,71-0,92 % in the Czech Republic and 0,75-1,27 % in Slovenia. Croatia stood at 0,41-0,34 % (Fig. 16).

4 Human resources in science and technology
Ljudski kapaciteti u znanosti i tehnologiji

Human resources in science and technology (HRST) in techno-economic analyses count as a percent of the economically active population aged 25-64, i.e. having either successfully completed education at the third level in S&T field of study or being employed in occupation where such an education is normally required. [6]

During the period from 1998 to 2009, HRST percentage in developed European countries was on the constant increase. The highest growth was registered in Switzerland ranging from 44,7 to 54,7 % of total labor force, and was followed by Denmark, Sweden and Norway. The lowest HRST percentage was registered in Austria and Italy, with 34,37 and 25,9 % respectively (Fig. 17).

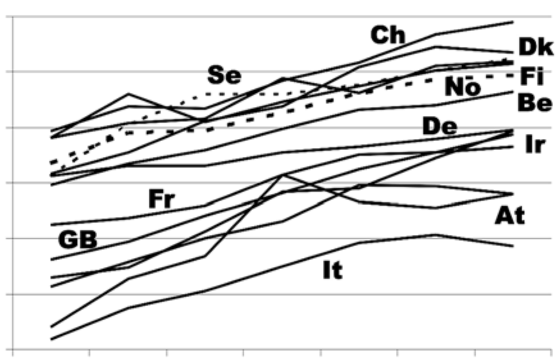

Figure 17 *HRST in European developed countries (% of total labor force)* [6]
Slika 17. *Udio zaposlenih u sektoru znanosti i tehnologije u ukupnom broju zaposlenih u dobi 25-64 u europskim razvijenim zemljama* [6]

European transition countries registered a smaller increase of HRST during the same period. The highest growth was in Estonia (40,6 – 44,67 %) and Slovenia, whereas the lowest growth of HRST was registered in Croatia 27,6 (2002) – 31,67 % and Romania 19,0 – 24,17 % (Fig. 18).

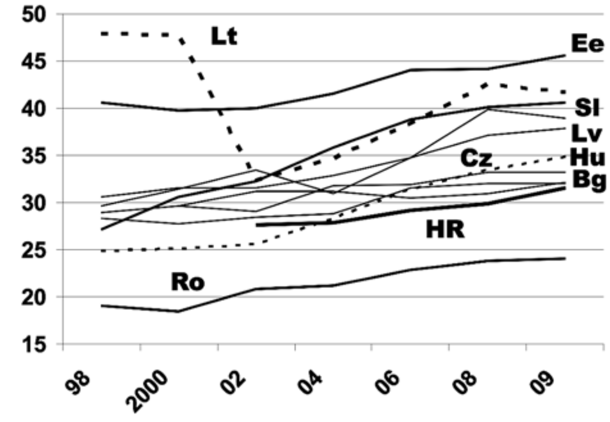

Figure 18 *HRST in European transition countries (% of total labor force)* [6]
Slika 18. Udio zaposlenih u sektoru znanosti i tehnologije u ukupnom broju zaposlenih (25-64) u europskim tranzicijskim zemljama [6]

4.1
Doctorate students in science and technology fields
Studenti doktorskih studija u znanosti i tehnologiji

Doctorate students as human resources in science and technology fields are important because innovation processes require highly educated personnel and teams. Students aged 20-29 following the second stage of tertiary education in science and technology fields (Science, Mathematics and Computing and Engineering, Manufacturing and Construction) were included.

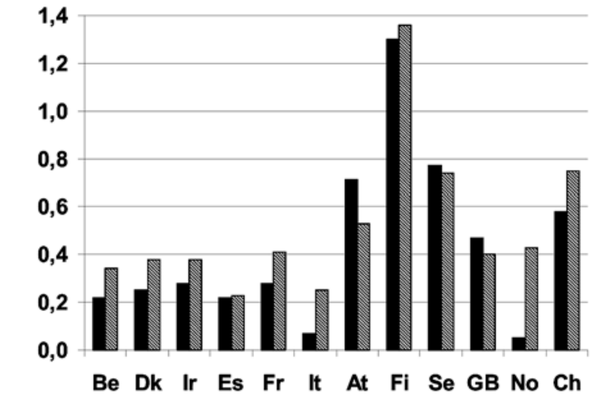

Figure 19 *Doctorate students in science and technology fields in developed European countries (% population age 20-29)* [6]
Slika 19. Studenti doktorskih studija u znanosti i tehnologiji u razvijenim europskim zemljama (% populacije 20-29) [6]

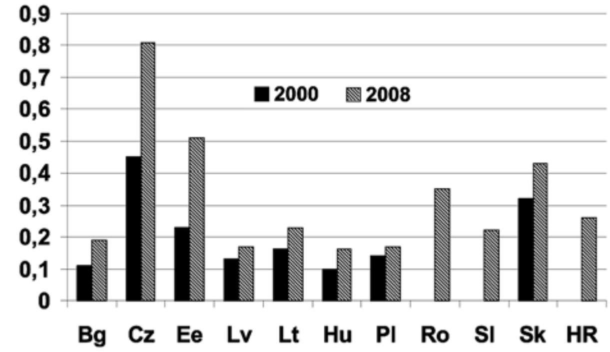

Figure 20 *Doctorate students in science and technology fields in transition countries (% population age 20-29)*[6]
Slika 20. Studenti doktorskih studija znanosti i tehnologije u tranzicijskim zemljama (% populacije 20-29) [6]

The largest percentage of doctorate students in developed European countries was recorded in 2008: Finland (1,36), Sweden and Switzerland (Fig. 19).

Among European transition countries the largest percentage was recorded in the Czech Republic (0,81), Estonia (0,51) and Slovakia (0,43), while Croatia reached (0,26) (Fig. 20).

4.2
Researchers by sector of employment
Istraživači prema sektoru zaposlenosti

Six developed European countries registered the highest percentage of researchers employed full-time equivalent (FTE) in the business sector - Sweden (69,2 %), Denmark (63,4 %), Finland, Ireland, the Netherlands and Norway. The second group of DEC like Great Britain (59,3 %), Spain, Belgium and Italy registered a higher portion of researchers employed in the higher education sector. Italy (43 %) and Great Britain (1,5 %) had the highest share of employed researchers in the private non-profit sector (Fig. 21).

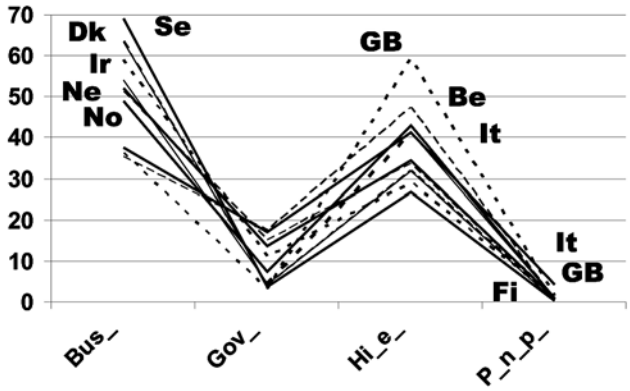

Figure 21 *Researchers by sector of employment (FTE) in European developed countries in 2008* [8]
Slika 21. Istraživači prema sektoru zaposlenja (puno radno vrijeme) u europskim razvijenim zemljama u 2008. [8]

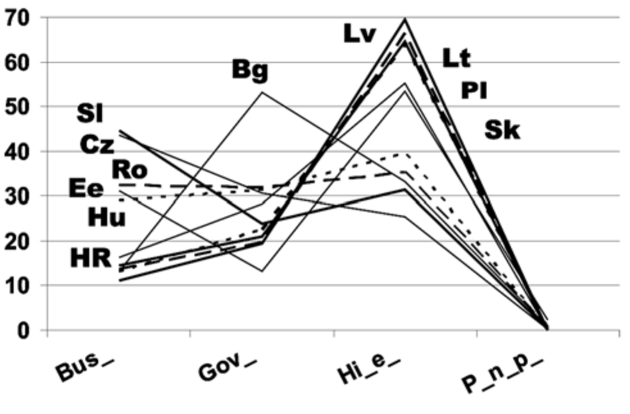

Figure 22 *Researchers by sector of employment (FTE) in European transition countries in 2008* [8]
Slika 22. Istraživači prema sektoru zaposlenja (puno radno vrijeme) u europskim tranzicijskim zemljama u 2008. [8]

European transition countries had a smaller percentage of employed researchers (*FTE*) in the business sector ranging from 11,1 to 44,5 %. The Czech Republic and Slovenia were ranked top with 44,5 % and 43,5 % respectively, while Croatia had 16,4 % of employed researches in the business sector.

Bulgaria (53,0 %) had the highest percentage in the governmental sector, unlike Latvia (69,4 %), Poland and Slovakia which had the highest employment of researchers in the higher education sector. Moreover, Estonia (2,2 %) and Bulgaria (0,7 %) had the second largest percentage of employed researchers in the private non-profit sector (Fig. 22).

5 Conclusion and proposals
Zaključak i prijedlozi

Based on the presented analyses one can draw a conclusion upon significant lag of transition countries compared to developed European countries regarding knowledge capitalization measured through: the number of registered USPTO and caveat EPO patents, R&D expenditures and human resources. This state highly influences industry and other production oriented firms resulting finally with low economy development, high foreign debt and low BNP of the transition countries.

Basic causes of this unfavorable status are found in scientific-technology policy and in finance of research and development activities. Low percent of R&D people is employed in business and remunerations for R&D from industry and government are marginal.

Other reasons of this state although not treated in the article are: a) underdeveloped innovation culture b) bureaucratic and non-functional organization of the R&D sector, c) unorganized and low demand for technology innovations – this market should be organized and deployed to neighboring transition countries. Our earlier studies resulted in partial solutions principally applicable for innovation activities in transition countries and in Croatia as well [10] - [17].

System solutions for the Republic of Croatia, starting from the civilization lag of transition countries, are quoted as follows:

1. Foundation of a university of technology – unlike developed countries, Croatia does not have a single university organization of this profile that can focus on economy and governmental efforts to technology improvement and thus give impetus in the country development policy.
2. Abandon pure education type of the university and develop research type of the university in the function of national resource development.
3. Criteria for scientific development of scientists should be based on economic and social relevance of their projects and scientific work.
4. Priorities of scientific and technology research (PSTR) should be based on national security and economy development of Croatia.
5. University institutes responsible for PSTR should be founded at universities intended for applied and development research and employing corresponding researchers with R&D references from relevant faculty and university departments. These researchers should be partly engaged in education and partly engaged on projects carried out for the economy.
6. Business firms and other business partners should be oriented toward relevant PSTR centers where they can negotiate and order specific applied and development research and subsidize these projects according to law regulated allotment (such as 50 %). Other potential business partners could also cooperate with universities outside the scope of PSTR according to different project arrangements with the Ministry of Science.
7. Foundation of spin-off companies initiated by professors and talented students should be promoted and primarily allowed. Furthermore, they should be permitted to use institute laboratories and equipment for intended R&D technology innovations.

Thus a series of beneficial effects would be realized, the most important among them being: (1) scientific and technology research would be more goal oriented and achievable and (2) national economy would gain benefit from science support gaining adequate technology for faster qualitative development. Science would not be recognized as a budgetary expenditure that has to be cut as much as possible but as a profitable development activity as exemplified in the developed European countries.

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