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Strategies for the Scientific Progress of the Developing Countries in the New Millennium

The case of Serbia in comparison with Slovenia and South Korea

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Abstract

The underlying premise of this essay is the hypothesis that quality and significance of scientific research in any given society could be used as mirrors reflecting its true prosperity. By comparing the two cases of comparatively prosperous scientific management of South Korea and Slovenia, with the example of Serbia, illustrating the poor scientific and industrial productivity typically faced by the developing countries, a few general guidelines for the evolution of a society towards higher scientific and social prominence are outlined. It is argued that the most favourable pattern of growth should be based on the parallel progress in control of scientific policies on one side and the excellence of scientific and basic education on the other. The "leapfrog" tactics, according to which the less developed countries should learn from the natural cycle of alternate progressions and regressions that the developed countries experience, is especially highlighted. Applied research is demonstrated to be most productive when it is carried out on top of already established and prolific infrastructural and industrial bases. Examples are given in favour of the fact that the technological design and industrial solutions shown as successful in the context of a developed society, often turn out to be impractical and inefficient when straightforwardly transformed to less developed social settings. As a result, the strategy of adjustment of production capacities to local needs is advised to be considered when implementing a new technology on different social, political and economic grounds. Finally, it is concluded that to provide conditions for effective transfer and implementation of advanced know-how and novel technologies, embedment into international science and engineering networks is required as much as strong and sustainable local scientific and technological bases.

"There is something within me that might be illusion as it is often case with young delighted people, but if I would be fortunate to achieve some of my ideals, it would be on the behalf of the whole of humanity. If those hopes would become fulfilled, the most exciting thought would be that it is a deed of a Serb." (Nikola Tesla, Address at the Belgrade Train Station, June 1, 1892)

1 Introduction

Innumerable studies have been conducted in support of the view that quality and significance of scientific research in any given society could be seen as mirrors of its long-term prosperity. Scientific excellence looped with high levels of industrial productivity and openness to innovation has been considered as grounds for thriving global economies (Inter Academy Council 2004). An OECD report has concluded that "links to science are more important than in the past" and called for an inevitable "intensification of industry–science relationships in the knowledge economy" (OECD 2002). Fig. 1 nicely illustrates that knowledge- and technology-intensive economies create well paid jobs, contribute to the local economy with a high-value output, and ensure economic competitiveness, which shows that knowledge-intensive industries have grown exponentially in the past decade and more rapidly than other segments of economic activity. A continual rise in the science and engineering occupation share of total civilian employment has thus been evident in the US and other developed countries of the world (NSB 2004).

On the other hand, we seem to live in a world in which inequalities and ill distribution of wealth present some of the crucial social factors of its instability and non-sustainability. To illustrate this, Fig. 2 demonstrates the disparity between rich and poor countries of the world by the champagne-glass shaped distribution of the global income, showing that the poorest 20 % of the human population hold less than 1 % of the global wealth, whereas the richest 20 % are associated with more than 85 % of the world GDP (UNDP 1999, Watkins 2006). The aim of this report is to provide a perspective on some of the essential relationships that could be used in directing the planetary growth towards amelioration of the problem of inequality and finding the ways to fruitfully incorporate the cutting-edge scientific practice into less developed regions and countries of the world.

The implicit assumption that the following discourse will be based on is that science, seen as fundamentally underlying the prosperity of a society, can be used as the most direct tool in levelling the disparity in development between wealthy and poor countries of the world. Two cases of comparatively prosperous management of science and technologies (S&T), that is, of South Korea and Slovenia, are thus presented with the aim of finding the principles that would help to outline the convenient policies and progressive directions for the developing countries, the example of which is in this work taken to be Serbia.

Figure 1: Global value added of knowledge- and technology-intensive industries for the time period of 1995–2007. Source: NSB 2010.

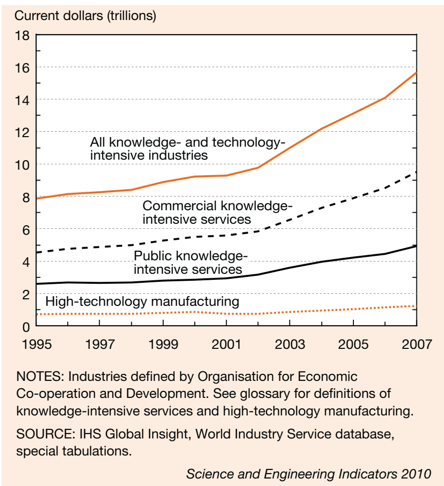
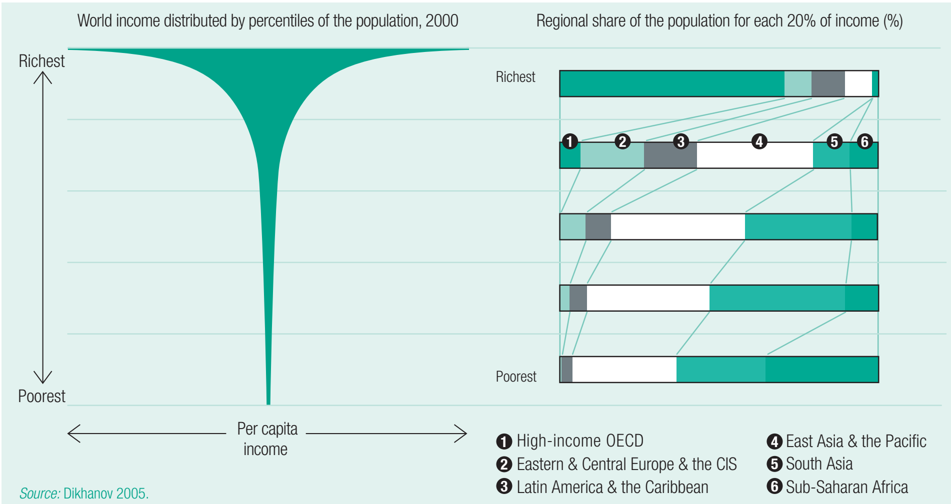


Figure 2: The disparity between rich and poor countries of the world demonstrated by the champagne glass shaped world income distribution in percentiles of the population (left), and shares in the world wealth held by populations from different regions of the world (right). Source: Watkins 2006



Methods

In this work we provide a few systemic guidelines for the design of science policies for underdeveloped countries, while referring to some of the basic criteria for the evaluation of progress in all scientific disciplines. The chosen parameters for this assessment partly belong to the S&T Indicators for European Research Area (STI-ERA) and have been regularly used for this purpose (European Commission 2007; Turlea et al. 2010). Serbia is going to form the central element in the discourse at hand. South Korea and Slovenia were chosen to provide a constructive contrasting comparison with the case of Serbia on the one hand, because Eurostat has provided annual statistic comparisons with South Korea, and on the other hand because of the increasing social prosperity that has been connected to appropriate S&T policies. As countries that enabled this path, after eras of economic and public safety turmoil, they may demonstrate how to substitute the downward path of warfare, poverty and international isolation with that of scientific prominence, economic prosperity and worldwide recognition. What makes Slovenia and Serbia comparable is the fact that they once shared a common political system within the former Yugoslav constitution. The funding and management in their R&D sectors once conformed to the same practices, and after the dissolution of the former Yugoslavia they also inherited the same educational traditions.

This paper also presents an analysis of various statistical and bibliometric indicators of progress in research. Such analyses have been a widely accepted tool for assessing the quality of the scientific output of countries or institutions (Alik 2008, Gupta/Dhawan 2009, Csajbók et al. 2007). Several such analyses were carried out with the aim of assessing the scientific productivity of Serbia and other former Yugoslav countries (Jovanović et al. 2010, Lewison/Igic 1999, Igić 2002, Bencetić Klaić/Klaić 2004, Sambunjak et al. 2008, Lukenda 2006, Andreis/Jokić 2008). Details regarding the bibliometric analysis method that we have used are given in the Appendix.

2 The case of South Korea

Many developing countries are nowadays facing similar challenges as the ones faced by South Korea prior to setting forth an aim to transform its society from the war stricken society of the 1950s, to the one marked with scientific and technological prominence of today (Oh 2007). South Koreans have demonstrated that with appropriate social and scientific policies, an extraordinarily high rate of development could be attained. As such, South Korea sets an example for numerous countries in the embryonic stages of scientific development.

2.1 Investments in R&D

The South Korean science policy has been typified by exceptionally high investments in R&D. By investing 3.5 % of its GDP to research, South Korea is a world leader in the governmental support of R&D (DESTATIS 2009) (Fig. 3). Although South Korea was considered a poor country in the early 1960s, it increased the per-capita GDP by 7 % by 1990, mostly owing to an export-oriented economic strategy and investments in innovative industrial production (Rodrik 1995). In the early 1990s, connections between academia and private industries were established, endowing the universities with a more entrepreneurial role and transforming them from primarily teaching-oriented to research-oriented centres, which resulted in the rise in research productivity (Eom/Lee 2010).

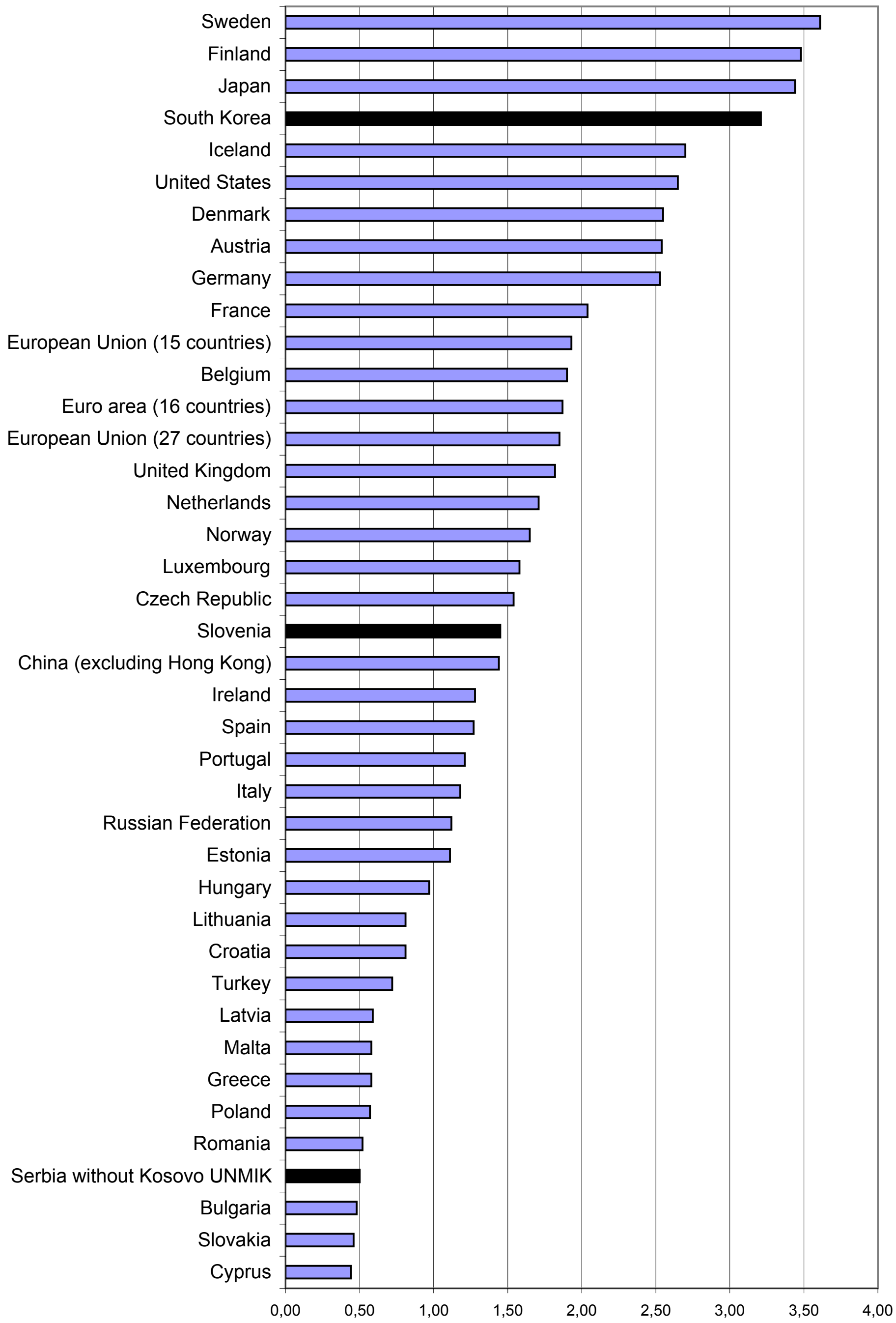
Patenting of scientific inventions has been equally encouraged, and South Korea currently ranks first on the list of the number of patents per GDP worldwide (Mahlich 2007). The 1997 crisis was blamed on the dependence of the South Korean economy on only a few key industries, and since then the industrial diversification and the development of a broad range of high-tech projects and activities has been incentivized by the government (Tearse 2008). Also, in 1967, a special governmental agency was created with to attract outstanding South Korean scientists from abroad. Excellent job opportunities for college graduates were provided too, so that nowadays more than 80 % of high-school graduates decide to enrol in one of the colleges (Hyeon 2007).

2.2 Adverse effects

However, each pattern of growth in its wake inevitably produces a set of adverse effects, which, on the other hand, provide opportunities for further research and growth (Uskoković 2009b). In view of that, a few detrimental consequences of the progressive path of the South Korean scientific society should be mentioned as well. One of them is the strong pressure for scientists to publish in order to maintain and strengthen their faculty positions. The number of publications is, thus, frequently regarded as more important than their quality, which spurs scientists to publish their works prematurely and in less prominent journals, resulting in low citation frequency of South Korean researchers when normalized to the total number of publications in comparison with other scientific powers of the world.

Another side effect of the South Korean S&T policy has been placing too much emphasis on applied research and too little on the fundamental. In fact, only 10 % of all grant applications in basic sciences are approved with the overall spending also at ~10 % of the total R&D budget. This is in spite of the fact that as of 2009, 3.5 % of the state budget is allocated to research, and by 2012 South Korea plans on reaching 5 % and becoming the world's leading country in terms of the amount funding normalized to GDP (Tong-Hyung 2009). Furthermore, with the government share in research investments of 25 %, the portion of basic science projects funded from the budget is only 2.5 % of the total. Communication between de-

Figure 3: Total R&D investments for different countries expressed in GDP percentages. Sources are given in Table 4.



partments within any given research institution is said to be low, and they mostly function in isolation from each other, which presents an obstacle for multidisciplinary research. Competition for funds has, just as in many other academic institutions in the developed world, left scientists without a broad technical and administrative support (Oh 2007). Promotion and compensation mechanisms at South Korean universities are still largely based on the number of years spent in service, although some institutions have adopted salary schemes based on the number of published papers and their impact on the national economy (Nature Materials 2007a). Finally, only 10 % of the South Korean faculty members and less than 15 % of all the researchers are women (Fig. 11), which indicates that the intellectual potential of the country has not been exerted to its full capacity. The results of a SWOT analysis of the South Korean R&D sector are presented in Table 1.

3 The case of Slovenia

Slovenia is regarded as a country with one of the most impressive combinations of GDP, life standard, economic prosperity and scientific productivity among the members of the EU that joined the latter in 2004. Its current growth rate with respect to technological performance is above the EU average, and it is the only accession country that spent more than 1.5 % of its GDP on research and development in early 2000s, and the only one that produced more than 415 publications per million inhabitants (Nature Materials 2004). Despite the fact that shrinkage of the local market that followed the collapse of the Yugoslav constitution forced many industries to undergo restructuring, downsizing or even bankruptcy, with proper revitalization incentives from the government level and an openness of academic research to cooperation with industry, an ascending trend in S&T performance has been made possible.

3.1 Strategies of growth

Promotion of academic research partnerships with various national and international industries has been seen in Slovenia as the most important incentive for scientific productivity and

Table 1: SWOT analysis of the South Korean R&D sector.

Strengths	Weaknesses	Opportunities	Threats
One of the highest rates of state investments in science and engineering in the world	Lack of openness to integrate foreign researchers in local academia and industry	Pushing the industry-academia partnerships, which are already one the leading in the world, to a new level	Too little of emphasis placed on fundamental research versus the applied one
Excellent level of industry-academia partnership	Low level of interdepartmental communication and interdisciplinary collaborations	Benefiting from promotion of cross-disciplinary research	A period of stagnation may follow the actual period of intensive growth, as they have alternated in the past
Well-developed industry-based research with a large share of the global market	Low technical and administrative support	Bringing in foreign talented students and postdocs and integrating them in the Korean science system	“Publish or perish” pressure may lead to publication quantity being given greater importance over their quality
Being one of the most technologically advanced countries, a leader in electronic communications	Low percentage of female scientists	Introducing a salary scheme based not only on the number of published papers, but on their impact on the national economy too	Uncompetitive promotion and compensation mechanisms may lower scientific productivity
High levels of international research cooperation activity, including both academic and private scientific centers	Low citation frequency of publications originating in Korean scientific institutions	Introducing innovative programs to attract students to science careers, such as Brain Korea 21	Weak technical and administrative support may hinder the research efficiency

technological success (Kornhauser 2000). For example, a single department within Jožef Stefan Institute, Department of Advanced Materials, with less than 20 employees, has maintained a persistent cooperation with a dozen of national and international industries in the past decade.

Among business corporations, smart innovation policies resulted in the public company, Gorenje, becoming one of the eight largest European manufacturers of white goods with a 4% share of the European market in 2006. In 2004, as part of the efforts to extend its links to R&D domain, it contributed as one of the industrial cofounders of the Jožef Stefan International Postgraduate School.

As early as 1985, Slovenia launched the 2000 Young Researchers programme with the aim to promote graduate studies in science and engineering and form a strong research basis that would satisfy both academic and industrial needs. To improve the ratio of industrial versus academic doctoral degrees (only 20 % in 1995), in 1995 the Ministry of S&T decided to subsidize the salaries for the first three years of newly employed scientists with master and doctoral degrees in industrial research departments.

Other legislative incentives were brought forth with the purpose of supporting business enterprises in technological development and strengthening their R&D potentials. Knowing that public knowledge institutions are usually not the main source of innovation, the Centres of Excellence were established at the major academic research institutions with the aim to integrate basic research with the stages of prototyping, testing and production in selected cooperating companies.

Table 2: SWOT analysis of the Slovenian RTDI system.

Strengths	Weaknesses	Opportunities	Threats
Well-developed and financially stable educational system	Low mobility from academic to industrial research sector	Increased public and private investments in RTDI	Failing to increase public and private investments in RTDI
Large interest in higher education studies	Low citation index and patenting performance	Raising research excellence through competition and strengthening of academic-business links	In the implementation of S&T policies, individual interests could prevail over national ones
EU average in the number of researchers per capita, and no significant "brain drain"	Scientific excellence limited to few disciplines and mono-disciplinary approaches	Enhanced internationalization of higher education, science, technology and innovation	Initiating "brain drain" by an openness to the international community
Well-developed research and communication infrastructure	Low level of research and innovation management skills	Fiscal policy measures	Failing to establish a policy making process that would flexibly follow the research innovations
High levels of innovational capacity in some industrial sectors, e.g. telecommunications, electronics, pharmaceuticals	Underdeveloped venture capital market and low market share of high-tech products	Establishment of intermediary knowledge-transfer institutions and networking (e.g. technology platforms)	Employees inflexible to the trans-disciplinary demands of globalization
Well-developed international scientific relationships	Insufficient funding of industrial R&D	Increased concentration of public funds in priority S&T areas	Prioritization of large integrated projects within Framework Programs

3.2 Pitfalls

However, despite the traditionally developed international and regional scientific cooperation and relationships, Slovenia comprises a comparatively small gross scientific network. Even though, as of 2008, it was involved in 850 bilateral scientific projects with countries from all continents of the world with the exception of Australia, the small number of Slovenian project coordinators is often quoted as a sign of incapacity to support the development of this solid networked basis for cooperation.

The questions on future prospects of the impressive economic growth of Slovenia – so far still provided more by large infrastructural investments, and less by the targeted development of "knowledge-based" products – are also often posed in view of more open scientific, social and immigration policies adopted by the majority of other EU countries.

Small market size naturally limits the efficiency of translation of research findings into the commercial domain. As much as the small size of Slovenian R&D sector could lead to smooth collaboration among scientists and engineers, its detrimental potentials may become obvious in the evaluation of research proposals, during which grant approvals could become based on social and scientific prominence rather than on true scientific excellence. It is only during the past three years that the practice of an international review of scientific project proposals has been noticed. By promoting conditions for an unbiased competition for research funds, a more efficient expenditure of public funds could be expected. The results of a SWOT analysis of the Slovenian Research, Technological Development and Innovation (RTDI) system (Komac 2005), are presented in Table 2.

4 The case of Serbia

In comparison with the example of South Korea, a country that has raised its economic and scientific performance and prestige in the past few decades, Serbia illustrates a country that lived through the opposite path (Benson 2004).

Neutral with respect to the Cold War, Yugoslavia was considered one of the freest countries of the world, acting as an excellent bridge for scientific communication between the East and the West prior to the fall of the Iron Curtain. For example, in the period between 1969 and 1989, Yugoslavia was the permanent host country of the World Conference on Sintering (Kuczynski et al. 1987, Palmour et al. 1990). As a founder of the largest union of third-world countries, it also provided possibilities for their successful integration into hopes and promises of the developed world.

Breaking away from the Stalinist central planning system immediately after the end of World War II, Yugoslavs designed a more humane system which provided conditions for an open participation of the workers in conducting the management of their companies (Estrin 1993; Lynn et al. 2002), and the UN Economic Commission found in the early 1960s that Yugoslavia had the highest rate of expansion in Europe (Schultze 1962). The first large-scale foreign investments in Eastern European countries were found in Yugoslavia: Murata/EI Niš, Philips/EI Niš, and Sandvik/Prvi Partizan were some of the research-intensive industrial partnerships.

However, the breakup that began in 1991, slumped the Serbian life standard. In less than a few years, Serbia shifted from a relatively prosperous path to a scenario facing international sanctions and isolation, the relocation of resources to fund the war, and 1027 an overall hyperinflation impact rate between 1990–1994.

4.1 The education system

One of the positive aspects of the Serbian science, preserved even during the harshest times, has been the rigorous and comprehensive education system. However, an overly ample education takes its toll as well. For example, the annual transience rate at the Faculty of Physical Chemistry, one of the most prestigious colleges at Belgrade University, has been as low as 10 %, whereas the average duration of studies is at 8 years almost twice longer than the anticipated 4.5 years.

The perception that science careers are reserved only for superbly talented ones is thus widely present in the society, which detracts many young scholars from careers in research and science colleges in general. Consequently, with ~10,000 researchers (0.13 % of the overall population), Serbia has ~10 times lesser population of researchers per capita compared to the EU average (Yucht 2005), and is rated low on the scales of scientific talent and creativity indices. The educational system is also blamed for its lack of flexibility, as most colleges pursue only general study programs, without offering options to begin with professional specialization at an early undergraduate stage. In Slovenia, in contrast, all science students are obliged to spend at least six months at one of the external research institutions prior to graduation.

The recent adoption of the study management in accordance with the Bologna declaration is expected to increase flexibility and diversity of the teaching system. However, despite having been enacted in 2003, the Bologna declaration targets the transience rate of 80 %, and yet at the University of Belgrade as a whole, it is currently as low as 16 %. In general, only 25 % of high-school graduates enrol in one of the colleges in Serbia, whereby 70 % of the admitted subsequently drop out.

4.2 Missing links

Another major demerit of the college education is that it occurs in isolation from the S&T needs of the society. Previous studies have shown that efforts from the higher education sector need to be explicitly linked to the rate of innovations and fields of expertise on which this innovation depends in order to positively influence the growth in labour productivity (Aghion/Howitt 1998). Still, many people oppose an education system that would be less comprehensive and more optimized for the demands of the society, referring to certain fields, such as information technologies (IT), in which a drop in the quality of knowledge that students gained was observed following a high demand for IT engineers.

The lack of coordination between the study programmes and the actual labour market as a result leaves 95 % of fresh graduates unable to find a job without an additional training. Furthermore, there is a consequent disparity between close to a million of unemployed adults and about 50,000 permanently open positions due to the lack of appropriate qualifications and skills (Šekeljić 2007).

Instead of engaging students in projects of real-life importance for their social environment, their professional training typically deals with comprehensive theoretical calculations and laboratory exercises which are rarely tied to outcomes of an immediate R&D significance. Freshly graduated students thus have little awareness of how their knowledge could be implemented in the "real world", and the most talented graduates decide to pursue their subsequent studies abroad. 90 % of the graduates of the Faculty of Electrical Engineering in Belgrade from 1992 to 2000 thus continued their careers abroad, whereas the general trend estimated among natural science students at Belgrade University is slightly less drastic: 33 % find positions in foreign countries after the graduation.

4.3 Brain drain – brain gain

The number of Serbian emigrants in the world is estimated to be more than 3.5 million, which is a number that is equal to 50 % of the current population of Serbia (MDRS 2010, SORS 2010). A large portion of these emigrants are highly educated individuals that left the country during the harsh economic era of the past two decades (UNDESAPD 2005). In comparison, the majority of Slovenian doctoral scientists leave only for short-term postdoctoral stays in foreign laboratories. The positive side of the "brain drain", however, is that it could provide a crucial impulse in the networking of local R&D infrastructure with international institutions and associations. As such, it has a potential to be renamed into "brain gain" under certain conditions.

In 2010, the Serbian Ministry of Science has begun the process of collecting information about Serbian scientists based in foreign labs with the aim to promote their collaboration with the domestic R&D sectors. According to the report given by the Serbian Ministry of S&T, an international refereeing system will be established using the capacity of the Serbian science community in exile and possibilities will be opened up for Serbian researchers living abroad to be part of national projects (MSTDRS 2009).

Fostering a more official recognition and integration of small foreign-based islands of experts into science policy making through common research projects, transfers of technologies or expert consultations is thought to be an excellent step forward. The contemporary electronic communication systems can significantly facilitate the process of seeking partnerships as the society strives to unfold the positive potentials of the "brain drain". The results of a SWOT analysis of the Serbian R&D sector are presented in Table 3.

4.4 Breaking walls

The Yugoslav Materials Research Society has through its annually held YUCOMAT conferences proven that the intellectual Diaspora can attract renowned scientists from abroad and provide a local forum for exchange of ideas and formation of collaborative networks (Usković D. 2007). Such meetings have also provided an excellent opportunity to initiate collaborations with scientists from the neighbouring states, many of which belonged to the former Yugoslav constitution.

Somewhat similar to Serbia, South Korea has struggled with a tenuous past in relations with its neighbours. In its case, it has been shown that scientific connections established by universities and industries, owing to the traditionally more open-minded and cosmopolitan nature of intellectuals, could present the first steps in breaking the walls of mistrust held in place in people's minds by remembering the historic events (Park/Leydesdorff 2010).

Unlike the relations between North and South Korea, which have exceptionally slowly improved and are still filled with tensions (Cumings 1998), Serbia revitalized its economic and political relations with all the former Yugoslav republics, now independent states, promptly after the 1990s wartime period. The number of cooperation projects between the successor states of the former Yugoslavia has been increasing ever since (Jovanović et al. 2010). With 100 such collaborations in 2007, Serbia has doubled their number compared to the pre-civil War state of affairs (55 in 1990 and 50 in 1991). However, with 1.75:1 as the calculated ratio of the dominance factors between Slovenia/Croatia and Serbia, as of 2007, Slovenia and Croatia tend to be the dominant partners in these cooperative projects (Jovanović et al. 2010).

Table 3: SWOT analysis of the Serbian R&D sector.

Strengths	Weaknesses	Opportunities	Threats
Broad research experience	Lacking well structured strategy and vision of scientific development	Using worldwide connections provided by Diaspora to form international collaborations	Failing to increase the already low public and private investments in R&D sector
Long tradition of high-quality basic education	Insufficient modernization of the research equipment within scientific centers	Taking full advantage of modern communication networks and infrastructure	Monopolization of private sector and the threat that short-term individual interests may prevail over the long-term national ones
Comparatively high number of publications in journals with high reputation	Investments in research from the budget stagnating despite the 6-fold increase in GDP in the same time period	Formation of collaborative multi-disciplinary networks around centers of excellence	Initiating even more of the "brain drain" by the increased openness to the international community
High research efficiency reflected in comparatively low cost per publication	Discrepancy in research excellence between academic and industrial sectors	Appropriate fiscal policy measures that would promote partnerships with companies, academic spin-off and startup projects	Failing to define a clear vision of scientific progress and enable sustained funding for R&D sector
High rate of economic recovery, resulting in more than 6-fold increase in GDP in the 2000-2008 period	Low interest in higher education studies and significant level of "brain drain"	Broad demand for marketable research products, such as in biotechnology, agriculture, medicine, energy sectors and ecology	Fragmentation of research due to lack of collaboration interests and/or communication skills
Respected and well established scientific Diaspora	Weak academic-business links and underdeveloped venture capital market	Provision of outsourcing services	Possibility that a rise in political nationalism may destabilize the trend of economic recovery
Well balanced gender population among researchers	Low levels of innovational capacity in most industrial sectors and a lack of impetus for their investing in research	Creation of the National Innovation System with looped Governance, Human resources, Science base, Business R&D and innovation, and Economic and market development	Failure to focus on a few national priorities that would bring major economic benefits
Joint work between the Ministry of Education and Ministry of S&T Development on optimizing R&D system	Little developed mechanisms to attract and support talented young researchers as well as promote social affirmation of scientists and innovators	Possibility of successful participation in the Lisbon agenda and alignment with EU research priorities	Continued superficial evaluation of scientific performance at the academic level
Links with institutions leading FP7 projects with participating Serbian scientists	Low critical mass of researchers within scientific centers (only 4 institutions with more than 100 researchers)	Approved project of development of centers of excellence, academic research centers and IT infrastructure	Continued social marginalization of prominent scientists internationally established in their fields

4.5 Increasing output

Although without any official nanotechnology initiative, around 700 research papers arising from Serbian scientific centres and relating to the field of nanoscience have been published in the 1996-2009 period (Ševkušić/Uskoković 2009). These papers were cited 5.1 times on average and their Hirsch index is equal to 26. They contribute to 5-6 % of the scientific works published and originating from Serbian scientific institutions, which is comparable with many developed countries of the world.

There is also an increasing trend in the annual output of such publications. Hence, from 1998 to 2002, around 20 nano-prefixed papers affiliated with Serbian institutions were published annually, after which an exponential growth took over, resulting in 65 papers in 2005 and 154 in 2007 (Ševkušić/Uskoković 2009). Materials Science Forum, the series that published the highest quality works presented at the YUCOMAT conferences from 1996 to 2006, is by far leading in the number of the papers published: 13 % of them. This signifies a major role that an international meeting such as YUCOMAT may play in promoting dissemination of locally conducted research in compliance with the highest quality standards.

4.6 Missing infrastructure

Only a spinning windmill can mill the wheat, and any grains thrown into a still mill are predestined to go rotten. The same happens to human knowledge in the deficiency of an intellectual infrastructure within the society. In a country like Serbia, the major problem behind the scientific inefficiency in both research and application domains is associated with an inability of scientific research to find a fertile ground at the local level.

That Serbia is far from being a knowledge-based economy is supported by the fact that the professionally creative part of the overall population (2.6 %) accounted for creating only 1.1 % of the country's GDP in 2005 (Komnenić/Mikić 2008). This explains why the current R&D investments relative to GDP are at 0.5 % extremely low in comparison with other European countries and with the range of 2–3.5 % existing in the developed countries on average (cf. Fig. 3 on page 37 & Table 4, column 4).

As high-quality research stands at the basis of competitive and innovative industrial sectors, the vice versa argument applies too, that is, low investments in research can be used to explain the undersized and internationally uncompetitive economy. The recent program of S&T development in Serbia designed by the Ministry of S&T has thus concluded that

"Serbian science, despite improvements in the past few years, is still on an unsustainable path; investing in S&T is, for Serbia, the only way to create a sustainable economy and society" (MSTDRS 2009).

As shown in Fig. 3, the results from 2007 suggest that Serbia is still at the very bottom in terms of R&D investments with respect to GDP.

Fig. 4 shows that although government expenditures on S&T have been increasing in the past decade in absolute numbers (Fig. 4a), they have been stagnating in terms of their relative amount with respect to the GDP (Fig. 4b). In terms of absolute funding, in 2008 the best subsidised research field in Serbia was chemistry with €7.5 million, which is a minor amount in comparison with the average US National Institutes of Health monetary grant size of $400,000, and the total budget of the NIH that stands close to $30 billion (Giles/Wadman 2006).

4.7 Underdeveloped academia-industry links

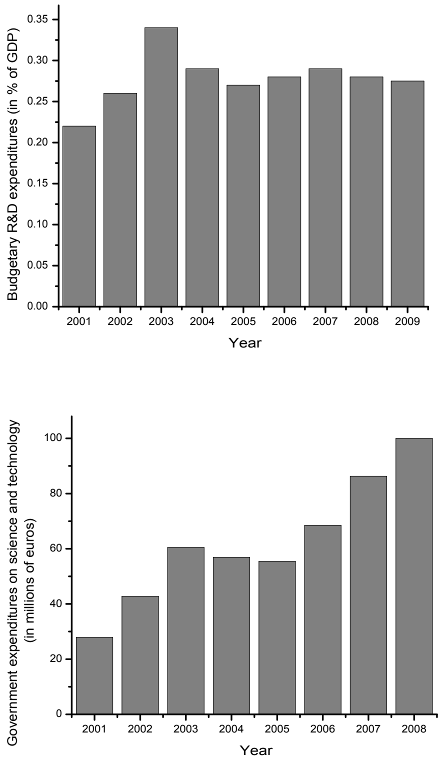
Low investments have naturally corresponded to negligible levels of scientific productivity on average. According to our bibliometric analysis,

Table 4: Scientific and technological R&D parameters for different European counties, European Union, US, China, Japan and South Korea as of 2007

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Country	Population in millions	2007 GDP per capita in 1,000 EUR	Total research funds and funds from the budget in % of GDP		Total research funds and funds from the budget per capita (EUR)		Total research funds and funds from the budget in millions of EUR		Total GBAORD as a % of total general government expenditure	ISI publications	Number of ISI publications per one million residents	Average costs per single ISI publication from total and budget funds (1,000 EUR)		Patent applications to the EPO at the national level per one million inhabitants	High-tech export of total export (%)
			Total	Budget	Total	Budget	Total	Budget				Total	Budget		
European Union (27 countries)	495.2	24.9	1.85	0.23	462.4	58.5	229014.63	28961.21	1.55	393000	793.62	582.73	73.69	118.37	15.97
European Union (15 countries)	319.8	29.2	1.93	0.24	694.6	84.6	222138.93	27063.52	1.60	357000	1116.32	622.24	75.81		
Euro area (16 countries)	325.2	27.6	1.87	0.26	516.9	71.5	168103.69	23259.01	1.62	260000	799.51	646.55	89.46	:	
Belgium	10.6	31.5	1.9	0.15	600.6	48.5	6356.93	513.28	1.25	13252	1250.19	479.70	38.73	141.22	6.63
Bulgaria	7.7	3.8	0.48	0.28	18.2	10.6	139.61	81.62	0.66	2078	269.87	67.18	39.28	3.97	3.49
Czech Republic	10.3	12.3	1.54	0.32	190	39.6	1955.04	407.21	1.36	6640	644.66	294.43	61.33	13.44	14.13
Denmark	5.4	41.6	2.55	0.08	1064.6	34.9	5798.95	190.06	1.56	9065	1678.70	639.71	20.97	216.08	11.69
Germany	82.3	29.5	2.53	0.35	746.9	103.8	61481.98	8540.20	1.76	74106	900.44	829.65	115.24	301.95	12.99
Estonia	1.3	11.6	1.11	0.10	129.4	11.2	173.65	15.04	1.43	891	685.38	194.89	16.88	14.14	7.81
Ireland	4.3	43.5	1.28	0.09	564.4	39.7	2434.20	171.00	1.36	6394	1486.98	380.70	26.74	67.84	25.73
Greece	11.2	20.2	0.58	0.12	117.4	25.1	1311.40	280.68	0.67	8884	793.21	147.61	31.59	11.94	4.74
Spain	44.5	23.5	1.27	0.22	300	52.8	13342.37	2348.84	2.74	33312	748.58	400.53	70.51	36.99	4.24
France	63.6	29.7	2.04	0.32	608.1	96.1	38689.79	6113.21	1.42	51668	812.39	748.82	118.32	137.13	15.57
Italy	59.1	26.0	1.18	0.17	308.3	44.7	18231.40	2644.30	1.34	41881	708.65	435.31	63.14	88.79	6.00
Cyprus	0.8	20.3	0.44	0.11	90.4	21.8	70.38	16.99	1.00	378	472.50	186.18	44.96	30.35	14.64
Latvia	2.3	9.3	0.59	0.14	55.1	13.4	125.60	30.46	0.83	341	148.26	368.32	89.34	11.94	4.62
Lithuania	3.4	8.5	0.81	0.17	68.7	14.3	232.59	48.48	0.96	1248	367.06	186.37	38.85	2.95	7.34
Luxembourg	4.8	78.1	1.58	0.21	1242.4	165.9	591.60	79.00	0.92	236	49.17	2506.78	334.75	245.87	32.40
Hungary	10.1	10.1	0.97	0.23	97.1	23.5	977.49	236.07	0.78	4829	478.12	202.42	48.89	15.15	21.36
Malta	0.4	13.3	0.58	0.02	78	2.0	31.82	0.82	0.47	74	185.00	429.97	11.07	40.14	47.83
Netherlands	16.3	34.7	1.71	0.22	594.6	77.0	9726.00	1259.00	1.52	23810	1460.74	408.48	52.88	205.52	18.28
Austria	8.3	32.6	2.54	0.14	829.1	44.3	6867.82	367.30	1.34	9006	1085.06	762.58	40.78	201.42	11.11
Poland	38.1	8.2	0.57	0.20	46.3	16.4	1763.62	624.92	0.75	13314	349.45	132.46	46.94	3.65	3.04
Portugal	10.6	15.4	1.21	0.11	186.1	17.4	1972.73	184.48	1.70	6159	581.04	320.30	29.95	15.46	6.52
Romania	21.6	5.8	0.52	0.18	30.3	10.3	652.82	221.62	1.03	3333	154.31	195.86	66.49	1.87	3.50
Slovenia	**2.0**	**17.1**	**1.45**	**0.35**	**249**	**60.9**	**500.51**	**122.49**	**1.23**	**2220**	**1110.00**	**225.45**	**55.18**	**64.57**	**4.62**
Slovakia	5.4	10.2	0.46	0.16	46.7	16.5	252.10	89.13	0.62	2164	400.74	116.49	41.19	6.55	5.00
Finland	5.3	33.9	3.48	0.29	1183	100.1	6242.67	528.28	2.05	8463	1596.79	737.64	62.42	250.59	17.52
Sweden	9.1	36.9	3.61	0.17	1310.3	62.9	11940.84	573.62	1.54	16624	1826.81	718.29	34.51	287.03	13.84
United Kingdom	60.8	33.5	1.82	0.16	610.9	53.8	37150.25	3270.27	1.49	77605	1276.40	478.71	42.14	84.81	16.17
Croatia	4.4	9.7	0.81	0.21	78.4	20.0	348.00	88.72		1916	435.45	181.63	46.31	6.81	6.61
Turkey	69.7	6.7	0.72	0.08	48.9	5.2	3409.56	359.83		15065	216.14	226.32	23.89	3.37	1.74
Iceland	0.3	48.0	2.7	0.48	1303	232.2	400.90	71.46	1.95	473	1576.67	847.56	151.07	:	1.64
Norway	4.7	60.2	1.65	0.25	996.5	152.6	4664.94	714.51	1.86	7099	1510.43	657.13	100.65	122.78	3.28
Switzerland	7.5	42.0	:	:	:	:	:	:	:	17374	2316.53			453.08	20.15
Russian Federation	142.2	12.5	1.12	0.33	74.5	21.7	10596.75	3083.67	:	23627	166.15	448.50	130.51	2.69	1.23
United States	301.1	38.4	2.65	0.29	902.6	97.9	272231.30	29524.99	2.76	346000	1149.12	786.80	85.33	120.67	20.34
China (excluding Hong Kong)	1338.6	4.5	1.44	0.28	27	5.2	35614.43	6849.94		97736	73.01	364.39	70.09	1.77	28.13
Japan	127.4	25.0	3.44	0.27	861.9	67.0	110115.97	8554.23	1.88	72411	568.38	1520.71	118.13	166.50	17.96
Korea (Republic of) (South)	**49.0**	**21.8**	**3.21**	**0.37**	**507.4**	**59.1**	**24588.88**	**2866.03**	**2.92**	**29281**	**597.57**	**839.76**	**97.88**	**139.88**	**28.15**
Serbia (without Kosovo UNMIK)	**7.4**	**3.9**	**0.50**	**0.30**	**18.1**	**11.6**	**143.9**	**86.30**	**1.13**	**2112**	**285.41**	**68.14**	**40.86**		

Source - Eurostat
Source: Statistical Office of the Republic of Serbia
Source: Scientific and Technological Development Strategy of the Rrepublic of Serbia
Source: CIA World Factbook
Web of Science® with Conference Proceedings or calculated according to data provided by Web of Science® with Conference Proceedings
estimation
Calculated according to data provided by Eurostat and Web of Science® with Conference Proceedings

Figure 4: Government expenditures on S&T in Serbia in the period of 2001–2008 (a), and budgetary R&D expenditures in terms of percent of GDP for the same period (b).



in a five-year period, 2000–2004, only 25 % of scientists funded by the Ministry of Science had at least one article published in one of the ISI Journals. Furthermore, the average research costs per article were at €33,000 by an order of magnitude lower in comparison with the averages for the second-wave members of the EU.

Although Figs. 5–6 demonstrate that scientific output stands in direct proportion with the amount of investments, it is uncertain whether simple increases in investments in science without a well-coordinated action of other governmental, fiscal and industrial sectors, and the long-term prospect of the local economy, present an optimal solution. A classical analysis of national systems of technical innovation has shown that factors involved in shaping an effective innovative performance include high-quality education and training on one side, and stable and facilitative economic and trade policies on the other (Nelson 1993).

Therefore, any progressive social policies would need to place more emphasis on the significance of science in Serbia, since scientific productivity presents a strong indicator of the

Figure 5: Number of ISI publications per million residents as a function of research funds from the budget in EUR per capita for most European countries, including China and the US.

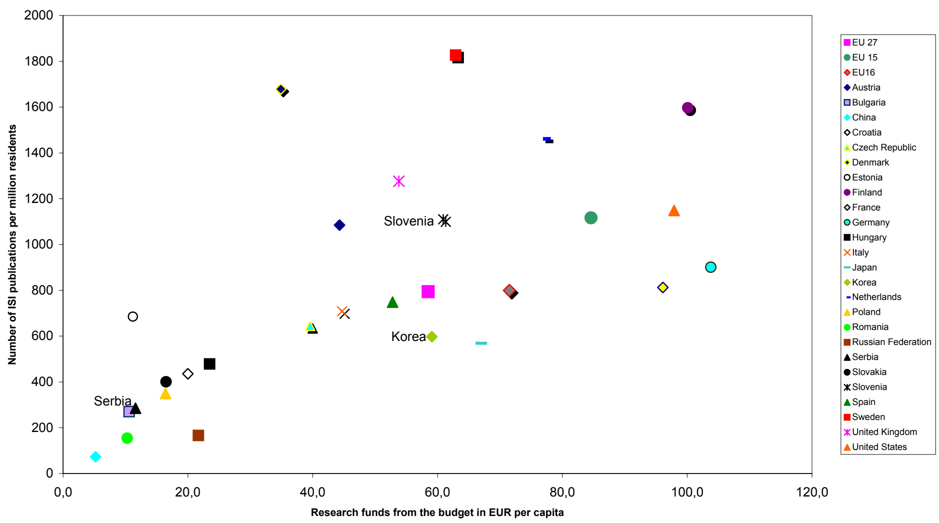


Figure 6: Number of ISI publications per million residents as a function of research funds in EUR per capita for most European countries, including China and the US.

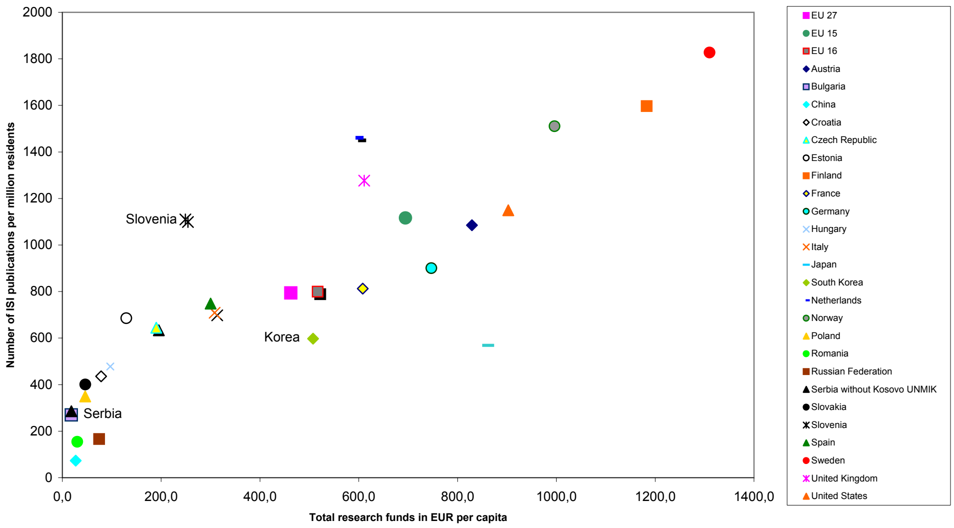
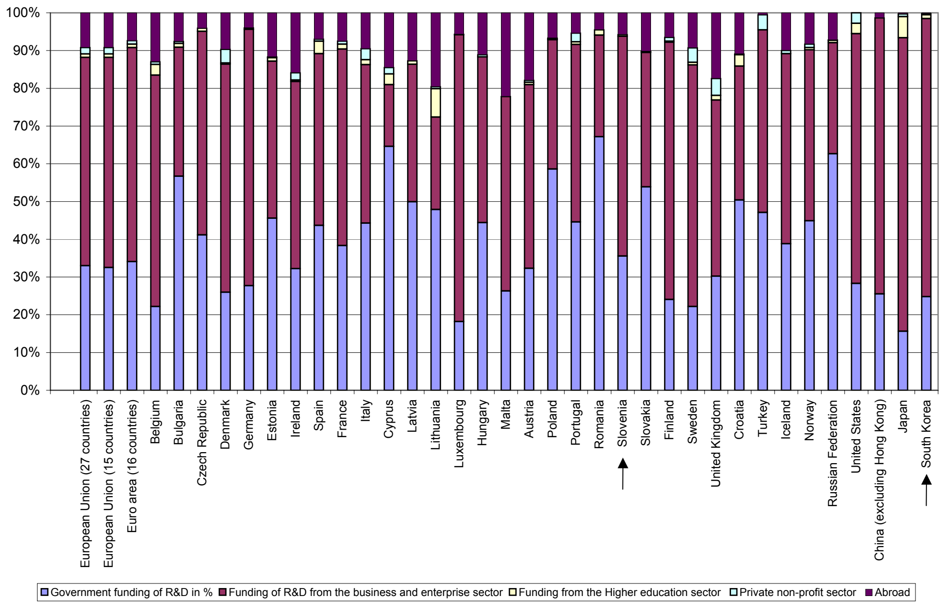
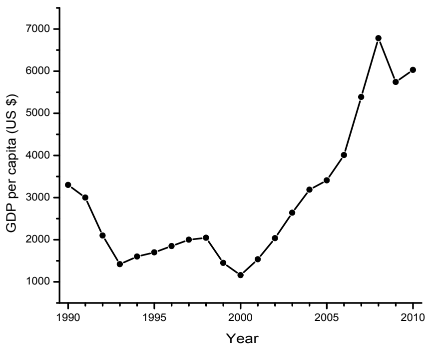


Figure 7: Proportions of R&D funding that come from governments, business and enterprise sectors, higher education sectors, private non-profit sectors and abroad for different European countries, including the US, China, Japan and South Korea.



overall social welfare. An awareness that parallel investments in basic research and in the improvements of the existing infrastructure and technological bases of the society are needed has been spurred and along with the projected growth in the funding of research, €400 million are said to have been allocated for investment in several key infrastructural projects for S&T in Serbia, through a joint loan with the European Investment Bank, World Bank and other international financial institutions and donations (MSTDRS 2009).

Figure 8: GDP per capita for the Republic of Serbia without UNMIK/Kosovo in the 1990–2010 period. Sources: IMF 2008, World Bank 2010, Aleksić 2001, UNECE 2000.

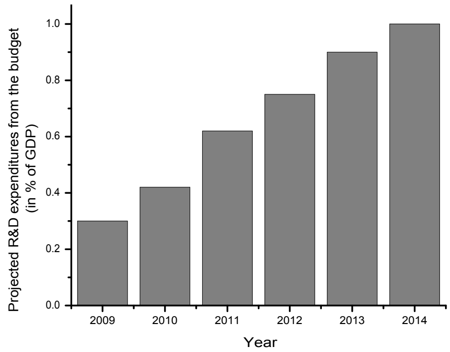


Diversification of R&D funding sources could thus be used as an indicator of how balanced scientific policies are in terms of the implementation capacity of discoveries and innovations produced at either academic or industrial levels, and one such comparison of funding sources is displayed in Fig. 7. The average funding for research coming from the business and entrepreneurial sectors equals ~ 70 % worldwide; in view of that, 60 % of funding for research related to the university sources in Serbia could be used as an indicator of underdeveloped academia-industry links.

4.8 Trends of recovery

An encouraging feature of the Serbian economy has been its exceptional recovery following the economic breakdown that followed the collapse of Yugoslavia and the times of the socialist regime that pushed the country into a decade permeated with wars and international isolation. This is illustrated in Fig. 8, which shows from 1994 on an almost continual rise in the country's GDP, with the exception of the 1998–2000 period, when the NATO bombing campaign and the Kosovo war left devastating traces on the local economy, and 2009 due to the effects of the global economic crisis.

Figure 9: The projected growth of governmental R&D expenditures on S&T in the 2009–2014 period.



The funds dedicated to research from public sources have thus been in increase during the past decade. Hence, the absolute amount of investments added up to €18.1 per capita in 2007 (cf. Table 4), €7.5 per capita in 2004, and only €1.5 per capita in 2000, which accounts for a 12-fold increase in the 2000–2007 period . However, as already mentioned, the relative amount of investment in science with respect to the GDP has not improved in the past decade. The current plan outlined by the Serbian Ministry of Science is therefore to establish annual increases in R&D expenditures from the state budget over the next five years, as shown in Fig. 9, and reach the goal of 1 % of GDP by 2014. This plan seems particularly positive with

Figure 10: Number of scientific publications affiliated with domestic institutions for Serbia (-∆-) and a few countries in the region, including Slovenia (-o-), Croatia (-□-), and Bulgaria (-◊-).

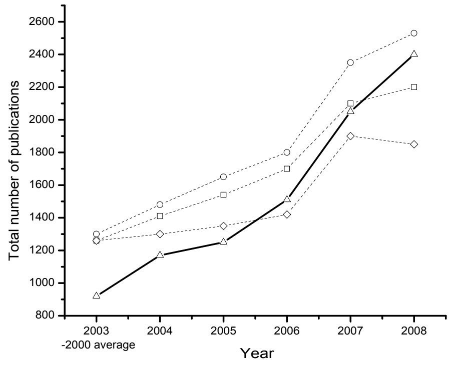
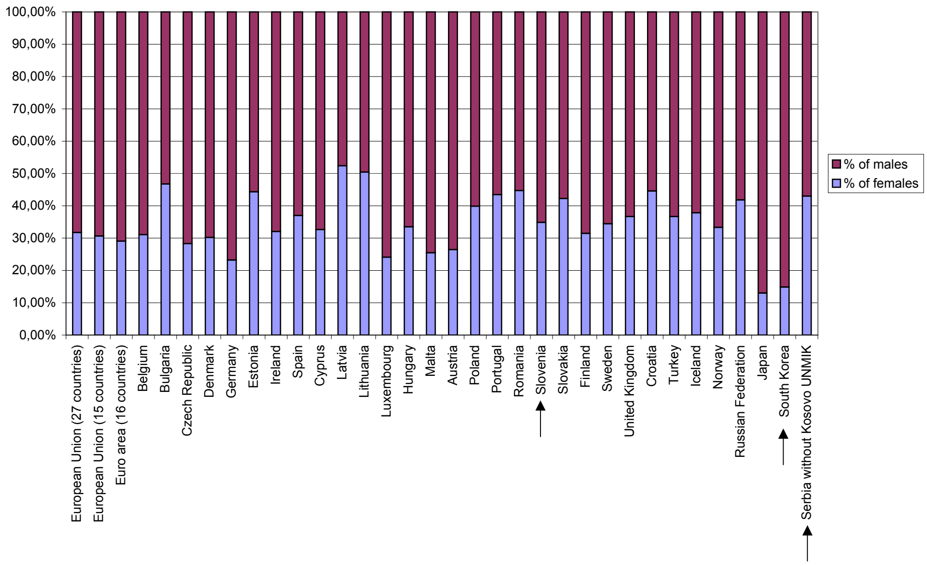


Figure 11: Gender structure among research population for different European countries, including Japan and South Korea.



regard to the opposite trend that some of the former Yugoslav states are undergoing; for example, investments in R&D from the budget in Montenegro have been in constant decline: 0.83 % in 2001, 0.30 % in 2004 and 0.13 % in 2006 (Vukćević 2009).

4.9 Other indicators

Also, as could be seen from Fig. 10, the number of papers published and originating in Serbian institutions has doubled in the period of 2004–2008, which is a significantly higher rate of growth compared to most countries in the region. Also, the overall costs per publication are lower than the European average. In the research group led by one of the authors, 48 ISI publications were produced in the period between 2005 and 2009, during which the funding was equal to €1 million, resulting in costs of €21,000 per publication, which is significantly less than the European Union average of approximately €74,000 per publication. The latter value was averaged for funding from the state budgets only; averaged for the total funds this cost would be equal to about €600,000 per publication, as can be seen from Table 4, column 13. In fact, if costs per publication could be used as a measure of research efficiency, as of 2008, with the average costs per publication of €39,000, Serbia surpasses both Croatia (€121,000) and Slovenia (€178,000) in this respect (MSTDRS 2009).

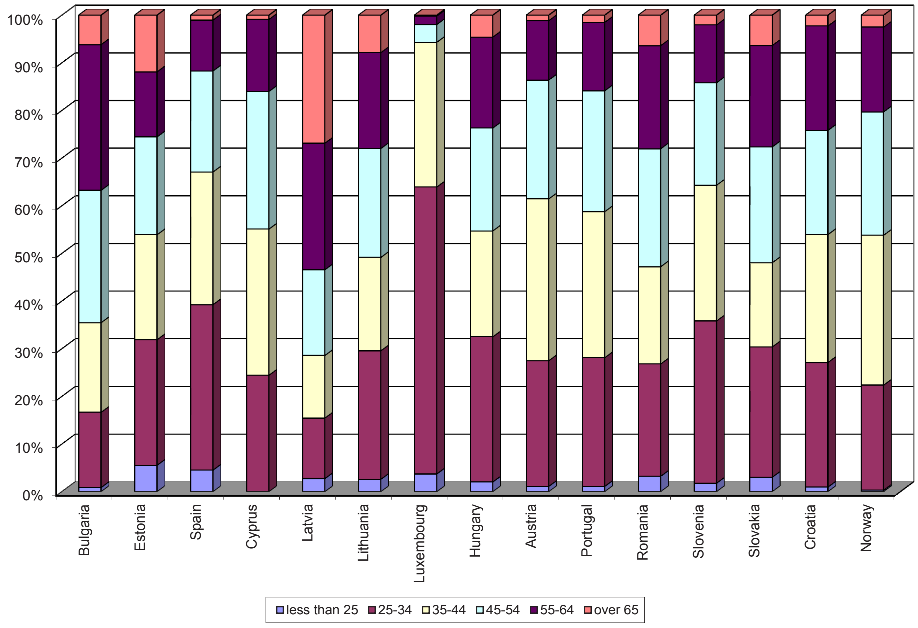
With more than 40 % of female researchers, Serbia also represents a well balanced research population in terms of gender, and finds itself much ahead of the European Union average (~30 %), as shown in Fig. 11.

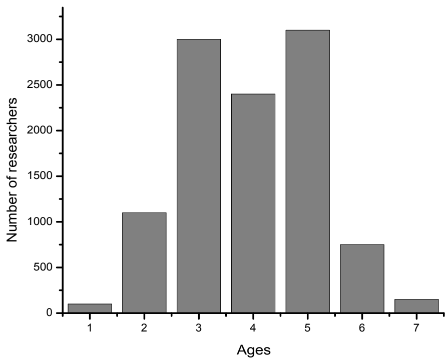
Finally, despite the significant brain drain, which certainly diminishes the quality of local research excellence, the age pyramid of the scientific community in Serbia does not show a significant lack of young researchers and is comparable to most other European states, as can be seen from Fig. 12.

5 Systemic set of strategies for the progress of developing countries

In order to reach the levels of development that typify rich countries, the developing countries should ideally use the "leapfrog" tactics (Barro/Sala-i-Martin 1997, Bernard/Jones 1996b, Bernard/Jones 1996a). There are many factors that lead to the leaders' "stumbling" along the road of their

Figure 12: Age structure of the research population in different European countries (top) and in Serbia (bottom).





progress, enabling their followers to catch-up, including rigid dependence on old-fashioned technologies (Lazonick 1994), declining social welfare, political turmoil, ecological recklessness and other mistakes that threaten their sustainability, typically resulting in a cycle of periods of ascension, growth plateau and fall (Olson 1984).

Accordingly, the developing countries are instigated to keep their eyes on the natural cycle of alternate progressions and regressions that the developed countries experience, and discern the reasons behind these soars and slumps. As in accordance with the classical Schumpeter's theory of creative destruction (Schumpeter 1962), it is the unending need to embrace new innovations and discard obsolete methods that hinders the progress of the leaders and gives a chance to the followers to reach the same level of development (Aghion/Howitt 1992). Studies have shown that more than 50 % of long-term economic growth is connected with timely introduced technological innovations (Goldsmith 1970). Development and adoption of new technologies is thus crucial in sustaining the international competitiveness and economic growth (Kim/Dahlman 1992).

5.1 Catching-up the developed countries

Mistakes and opportunities

Thereupon, instead of going through the same mistakes that the developed countries have committed, the developing countries would be able to circumvent them by implementing the right solutions even before immanent problems occur in the their own systems or by thinking ahead and coming up with original innovations that would boost the local economies and increase the international competitiveness. It has been shown that during the past three decades, a number of late industrializing countries have sufficiently increased their levels of innovative productivity to compete with the former leaders in innovation, with South Korea, Taiwan, Ireland, Israel and Singapore being some of the examples (Furman/Hayes 2004).

Leapfrogging strategies

One such opportunity for developing countries to leapfrog a problematic development and thereby catch up with the developed states, are the ecological flaws committed by the developed societies (Grubb 1990, Raufer/Li 2009). Thus, instead of repeating the same instances of ecological recklessness that have occurred in the developed world (UNEP 2005), the less developed countries could apply the policies for their prevention before the ecological problems become evident in reality (Biello 2007). In the past decade, an awareness of the challenges to balance a continued economic growth while satisfying the requirements of sustainability has been increased in the developing world. he retardation of the progress that this challenge will inevitably bring along, is seen as a great opportunity for the countries in developing stages to draw alongside the developed ones (Blinc et al. 2006).

Riding waves

It has already been suggested that as technological and scientific development follows a similar sinusoidal path driven by the stages of conception, expectation, hype, saturation, over-hype and backlash, the ability to predict rises and surges of interests in given ideas or technologies is crucial in learning how to smoothly ride on these waves (Pearton 2007).

South Korea experienced alternate waves of soars and slumps in terms of R&D after gaining independence, and one such negative period of growth in manufacturing between 1960 and 1987 was ascribed not only to a lack of investment in R&D, but also to increasing reliance upon imitation, capital deepening, and scale economies to increase output (Park/Kwon 1995).

The "leapfrog" tactics in general presents a convenient mechanism for the gradual bridging of large gaps in prosperity that exist between the developed and the underdeveloped societies. In addition, this gap is considered as one of the brakes of an efficient and prosperous globalization in terms of preventing the possibilities for a convenient transfer of advanced know-how and new technologies (Olson 1996). Implementing policies for its remission may thus turn out to be crucial for sustainability of the entire humanity.

Detrimental aspects

To satisfy the ideals of leapfrogging, a clear view of disadvantageous aspects of a scientific policy of growth has to be formed in parallel with the prosperous ones. A few of such detrimental aspects were selected for both the South Korean and the Slovenian case. For example, although South Korea indeed invests a relatively high percentage of its GDP to R&D, these high investments have required a sufficiently propitious basis (including up-to-date equipment, productive industrial sectors and a thriving economy) in which they would find a fertile ground to be able to induce truly productive research.

Another drawback of the rapid streaming to achieve extraordinary scientific productivity and secure one's place in the field in the South Korean model has been the tendency to publish prematurely and in journals with less intensive peer-review process and lower prestige. Yet, a study has shown that authors whose records weighed quality over quantity tended to be associated with more prestigious institutions (Haslam/Laham 2010).

On the other hand, science develops incrementally and a timely feedback from the scientific society is an important drive for a successful research. It is, therefore, essential to find the right time to publish, and thus avoid both premature announcements of one's accomplishments and retardation of the progress of the field by their prolonged concealment. To succeed in that, softening up the attitude that fosters competitiveness between individual research groups and selflessly seeing scientific achievements as products of the scientific society and mankind as a whole may be required (Laband 1985).

Intellectual freedom

Yet another one of the mentioned drawbacks for the South Korean case was the tendency to neglect fundamental research on the account of the applied one. Many modern professional settings, including those that have traditionally fostered uptight and disciplined creative approaches, such as industries, are nowadays changing towards balancing the emphasis on sheer productivity with cultivating more intellectual freedom. Genentech, the company celebrated for its pursuance of innovation and seven times selected as the "top employer in the biopharmaceutical industry" by Science magazine, most recently in 2009, has adopted the merits of curiosity-driven research (Bonetta 2009).

"No one from management can ask what a postdoc's work has to do with the mission of the company. They are free to work on whatever intrigues them", a company's executive said (Kaplan 2009).

Still, science remains an issue of public interest because social values inevitably underlie scientific thinking and because even the most fundamental scientific studies are carried out while keeping an eye on how the findings could be applied for the sake of elevating the quality of life.

However, the links between scientists and the governmental and corporate funding agencies in the developed world, which includes South Korea, have become so tight that the basic science that yields fundamental and long-term benefits often becomes depreciated in favour of applied research that is meant to bear fruits in short terms. Yet, as basic research is the substratum of the applied one (Braben 2008), the results of the former often lead to unforeseen but incredibly versatile ways of utilizing them. The cases of quantum mechanics, which was first used decades after its invention in the design of microelectronics, and molecular biology, the basic principles of which are nowadays applied in drug discovery and other biotechnologies, may illustrate this point.

Commercialized science?

Still, in many developed countries university research projects with a higher chance of commercialization are preferred in the funding selection processes. However, too much focus on creating spin-offs without careful prior analyses of their true potentials can be detrimental for the overall research quality (Nature Materials 2006). In enforcing policies that instigate pushing academic research to the commercial level, another extreme may be reached, wherein corporate spirit would begin to pervade the freedom of thought that universities have fostered for centuries (Washburn 2005).

As an example the case of the Yale University and the pharmaceutical company Bristol-Myers can be cited. Yale was generously funded by Bristol-Myers, giving the exclusive manufacturing rights of the AIDS drug D4T in return. It turned out that Bristol-Myers was not able to produce D4T at a price affordable for the third world. But although competing pharmaceutical companies could produce the drug at a considerably lower price, Yale claimed its hands were tied by an agreement signed with Bristol-Myers. This practice is covered by the Bayh-Dole Act adopted in 1980, which gave universities intellectual property rights to federally funded research in the US.

Lack of transparency

Failing to encourage smart and competent methods for the allocation of research funds has been shown as another main threat for S&T policies of the developing countries. In Serbia, for example, the general lack of transparency is reflected in the fact that governmental committees are partly involved in nomination and selection of heads of the research organizations, which similarly to other social domains indicates that fulfilling political interests might be more important than claiming scientific or other types of professional excellence.

In view of the largest concentration of scientists at or around the academic and independent research institutions rather than within industrial centres, a novel and multidimensional method for financing research is needed. A recent analysis of the innovational character of S&T in Eastern European countries in transition has confirmed the role of universities and existing national knowledge bases complemented by R&D commitments from both public and private sources as the main drivers of their innovative output (Krammer 2009). Tax benefits and other incentives promoting partnerships between industry and academia also present a vital feature of scientific and technological progress of a developing country (Etzkowitz 1998).

Cycle of productivity

Applied research is, as the name itself suggests, most productive when it is carried out on the basis of an already established infrastructural and industrial prosperity. The first stage in the example of South Korean development corresponded to technological and industrial improvements spurred by the cycle of export-oriented economy, promotion of international recognition and attraction of foreign investors (Chen/Sewell 1996). Only under these circumstances the scientific productivity can be increased.

On the other hand, the success of basic research nowadays similarly depends on expensive high-tech equipment. Even though a general consequence of the post-World War II division to abundant funding of research in the West and poor funding in the East has predisposed researchers in the former regions to become more oriented towards experimentation and the latter to attain strong theoretical capabilities (Nature Materials 2007b), theoretical research nowadays frequently requires expensive computational equipment to satisfy the needs for competitive, high-quality simulations and modelling (Johnson 2009).

However, this is not to say that there is no hope for basic research in less developed countries (Salam 1984). Quite contrary, the recent breakthroughs in simple and yet very efficient soft chemical methods of synthesis provide the opportunities for competition of low-cost experimental setups with expensive lithographic techniques, at least when the aspect of materials science is concerned (Uskoković V. 2007; Masala/Seshadri 2004).

5.2 Systemic guidelines for sustainable management

Global trends and local needs

Hence, a systemic guideline for developing countries would be to follow the steps of the developed world, and yet to be active and ready to implement actions to prevent the mistakes made in the very same developed world in due time. Based on economic predispositions and cultural and geographical background, each society requires a unique internal organization, while at the same time a certain level of similarity of the patterns of growth is to be expected among individual societies. As observed by the Brazilian scientist and policy maker, José Goldemberg,

"We in developing countries should not expect to follow the research model that led to the scientific enterprise of the US and else-

where. Rather, we need to adapt and develop technologies appropriate to our local circumstances, help strengthen education, and expand our roles as advisers in both government and industry. In this way, we can prevent the brain-drain that results when scientists are not in touch with the problems of their home countries or when they face indifference – and poor financial support – from their governments." (Goldemberg 1998)

The nationwide decision to switch from gasoline to ethanol, obtainable from sugarcane, the traditional crop in Brazil, as the major fuel can be used as an example of one such eco-technological idea created by focusing on local needs rather than on copying the trends existing in the developed world (Clendenning 2006).

Top-down and bottom-up

It is an old cliché that the correct approach in helping underprivileged societies is not to hand people their fish, but to teach them the art of fishing. Instead of a passive servitude promoted by the former approach, sustained social benefits could be fostered by the latter approach. Hence, instead of investing in tops of the frequently corrupt governments of the poor countries, the attitude of providing a high-quality education and a fertile ground for the locally sustained economic growth should become more pervasive.

Consequently, the route to development occurs at the intersection of two directions: top-down and bottom-up. Whereas the former corresponds to the management of social relationships by means of policies brought about from centralized hierarchical levels, the latter belongs to improvements of the society at its fundamental organizational levels, including the provision of educational opportunities and generation of productive academic and industrial bases upon which scientific research would find a fertile ground.

This perspective may be said to fit the concept of the learning economy coined by Bengt-Åke Lundvall. It encompasses both, the idea that high-quality education is rooted in productive and sustainable social organizations, and the core of the "leap-frogging" approach, which implies an incessant orientation towards innovation that narrows the gap between the followers and the leaders (Lundvall 1999, 1992, 1995).

Good education is oftentimes considered the general recipe for social prosperity (Uskoković 2009a). When society invests in high-quality education, which includes not only professional trainings, but general knowledge, ethical teaching and upbringing in childhood as well, it gains an ability to live through hard times without reaching the states of civil anarchy. In accordance with the circular causal nature of physical phenomena in general (Bateson 1972), the attempts to improve the rate of development of a given society in a politically hierarchical, top-down fashion sooner or later encounter complex circular causal chains in which each cause presents an effect and vice versa (Beer 1967).

It can thus be noted that in order to solve the problem of poverty, stable political and security bases should be set, which requires good educational foundations, for which the solution of existential poverty becomes the necessary precondition (Churchman 1968). Sustaining a productive society can be thus said to lie in the coalescence of smart policies that descend down from the top levels of governmental regulations, and promotion of valuable education that extends from the invisible foundations of the society up.

Smart policies

Also, in the context of globalization and internationalization, a developing society should maintain the balance between preserving its cultural bases and fostering openness to information exchange with the rest of the world (Kelly 1995). Forms of openness to external influences that erase the cultural background of the society or closeness to international communication driven by fears that the national heritage would be diminished both deviate from the optimal, middle way approaches.

Openness that allows for facile transmission of technical information has been shown to encourage researchers and entrepreneurs to innovate and pursue the most up-to-date approaches and technologies (Grossman/Helpman 1993). It also broadens the market size and leads to reallocation of resources that may positively affect growth.

On the other hand, focusing on technological solutions that satisfy local needs rather than looking after competing on the international scene at every cost, even though the discoveries arrived at may never be implemented locally, may prevent futile dissipations of research creativity.

Human nature

This guideline is, in fact, consistent with both the nature of perception and biological constitution of human beings (Glasersfeld 1996). Firstly, perceptual experiences proceed from within the brain as much as they are being influenced by the sensual detection of physical features of the surrounding world (Uskoković 2009c). Secondly, biological creatures are intrinsically built on the principle of balancing thermodynamic openness and operational closeness (Maturana/Varela 1987).

Namely, whereas the former explains for the exchange of matter, energy and information with the environment, in which the living creatures need to be constantly engaged in order to maintain their physical structures, the latter is descriptive of closed metabolic loops that comprise biological entities and are essential in preserving their integrity and autonomy, preventing their disintegrative dissipation into the environment.

Naturally, we imitate others and primarily those who we admire and whom we aspire to become. Yet, without sanely being in touch with our own inner source of creativity, such an imitational approach would turn us into blind followers of leaders and authorities of the world, prone to manipulation and not living up to the fullest of our creative potentials.

Cultural diversity of societies

The same can be said to be valid for countries and societies of the world: the sense of respect would naturally yield a healthy dose of imitation, whereas a focus on building original and unique social bases of welfare and prosperity starting from the local scale and certainly comprising heavy investments in research would maximize fulfilment of the creative potentials of the given society and eventually promote cultural diversification of the planet instead of threatening it by the extensive imitation of the leaders. "Focus and Partner", the slogan given for the development plan for S&T in Serbia by the Ministry of S&T, nicely captures this balance between cooperative openness and operational closeness (MSTDRS 2009).

Local needs

It has been witnessed that technological design and industrial solutions shown as successful in the context of a developed society may turn out to be impractical and inefficient when straightforwardly introduced into a less developed society (Schumacher 2000). An example of innovation aimed at suiting primarily the local needs and yet open to international transfer of knowledge is given by a Slovakian team of scientists that commercialized a nanobiocomposite electrode for in situ analysis of wine components, thus linking nanotechnology with the traditional winemaking in an inexpensive and elegant way (Tkac et al. 2007).

Sustainable management

Adjusting the technological performance of a small country to its size and to local needs and capabilities should present only an aspect of a wider social plan of economically and ecologically sustainable management (Uskoković 2008). Considering the fact that rich countries have based their progress on an overall degradation of the underlying natural capital, the chance of the developing countries to overtake the developed societies lies exactly in timely adoption of progressive ecological policies.

In that sense, Serbia could learn a lot from Germany and the way in which it transformed its destructive nationalism of the World War II era into one of the most influential environmental conservation movements. With the right incentives from the international community and appropriate technological and educational policies, a similarly devastating nationalism, arising of which followed the breakdown of Yugoslavia, could be transformed into a truer and more productive "love of the land".

The opening passage by Nikola Tesla demonstrates one such balance between a locally oriented patriotism and a working dedication to the entire humanity. With such an approach, hopes remain that the Berlin Wall of international isolation that has taken an enormous toll on the intellectual potential of Serbia could be toppled down. The local political and social problems would thus become only remnants of the faint past of a society which is soon to be transformed into a vital member of the European science and economy.

6 Conclusion

By comparing the two cases of fairly prosperous scientific management, of South Korea and Slovenia, with challenges tied with poor scientific and industrial productivity, typical for the developing countries and illustrated on the example of Serbia, a few guidelines for the evolution of a society towards higher scientific and social prominence were outlined.

Establishing innovation-fostering academia-industry partnerships, which would promote research with high applicative potentials in addition to that pertaining to fundamental discoveries was laid out as a part of the solution. Prioritizing R&D areas through national research programs and reforming the higher education sector to follow the local demands of the society were also discussed as positive factors in integrating scientific potentials of a developing country within its total economic performance. The most favourable pattern of growth should be based on the parallel control of scientific and fiscal policies on one side and the excellence of basic education and scientific training on the other.

To succeed in this dream of raising a society with an average scientific and technological performance into clouds of excellence, embedment into international science and engineering networks is required as much as strong local scientific and technological bases. The former would be vital in maintaining up-to-date R&D interests and priorities, whereas the latter would provide a fertile ground for an efficient transfer and implementation of the foreign-based capital and knowledge.

Systemic nature of progress

Furthermore, the signs of healthy progress of any given society or natural system are evident in the parallel development of communicational complexity between their constitutive entities and of their intrinsic versatility. In their healthy states, natural systems are diversified and functionally differentiated as much as they are unified and well integrated. Once this systemic property of progress becomes openly recognized, both rich and poor countries would gain responsibility to promote it at their respective organizational levels.

The former should primarily reorient towards ensuring not only fair transactions in terms of short-term reciprocity, but primarily long-term socially, economically and ecologically sustainable interactions between the developed and underdeveloped countries of the world, which would foster the appropriate systemic balance between unity and diversity. The developing countries have the same task, which is to be carried out in far smaller domains.

And we, individual human beings, in accordance with the tradition of wisdom and ethics of our civilization, are responsible to pay attention to the importance of the invisible roots of science, thought and creativity as much as on the measurable welfare. For, in the end, what this paper has primarily aimed at is to provide a glimpse of a profound education as standing at the foundations of a truly sustainable society.

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This work has been dedicated to all the peoples of the former Yugoslavia and hopes that cosmopolitan spirits and optimistic gazes into the future in this region of the world will prevail over the past permeated with nationalistic intolerance and delusions of ethnic and religious disparity. The authors also thank Johannes Weyer, the STIs Editor, for useful suggestions during the preparation of this article.

7 Appendix: The bibliographic analysis method

The major part of the statistical data used in the analysis was drawn from various Eurostat databases available online. All the data are from 2007 because the statistics for 2008 and 2009 are incomplete. In case Eurostat (Eurostat 2010) did not provide data on a particular indicator, we used other primary sources like the CIA World Factbook (CIA 2010) and the databases of the Statistical Office of the Republic of Serbia (Statistical Office of the Republic of 2010b), and secondary sources, like the policy document of the Ministry of Science and Technological Development of the Republic of Serbia Scientific and Technological Development Strategy of the Republic of Serbia, 2010–2015 (Ministry of Science and Technological Development of the Republic of Serbia 2009). Estimations were made only when it was not possible to draw reliable data from the primary and secondary sources and they were calculated on the basis of the known parameters.

Bibliometric data, primarily related to the number of publications written by authors coming from a particular country or area and indexed by the International Scientific Institute (ISI), were drawn from the Web of Science® with Conference Proceedings, namely from the following databases: Science Citation Index Expanded (SCI-EXPANDED) – 1996–present, Social Sciences Citation Index (SSCI) – 1996–present, Arts & Humanities Citation Index (A&HCI) – 1996-present, Conference Proceedings Citation Index – Science (CPCI-S) – 2001-present, and Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH) – 2001–present. In order to draw relevant data, we performed a series of advanced searches limiting search parameters to the following document types: "Article", "Proceeding Paper" and "Review", and the time span "2007". Having in mind that search results usually include a number of documents from years before or after, though the time span is specified in the initial search, they were further refined using the "Publication Year" filter. In order to retrieve data for the United Kingdom, the terms "Great Britain", "England", "Wales", "Scotland", and "Northern Ireland" were included in the search, whereas for the Russian Federation we included the names of a dozen major cities as search terms. Since the number of documents retrieved in the searches related to the European Union (EU 27, EU 15 and EU 16) and the United States of America was beyond the search limit (100,000), it was necessary to make estimation. The estimations were made on the basis of data provided by the Web of Science: in a series of separate searches we established the number of relevant documents ("Article", "Proceeding Paper" and "Review") in the Social Sciences Citation Index (SSCI) – 1996–present, Arts & Humanities Citation Index (A&HCI) – 1996-present and Conference Proceedings Citation Index – Social Science & Humanities (CPCI-SSH) – 2001–present; and the number of Proceeding Papers and Reviews in the Science Citation Index Expanded (SCI-EXPANDED) – 1996–present and Conference Proceedings Citation Index – Science (CPCI-S) – 2001-present; having in mind that the share of Articles in the Science Citation Index Expanded (SCI-EXPANDED) – 1996–present and Conference Proceedings Citation Index – Science (CPCI-S) – 2001-present for other countries is about 70 percent (as we calculated it), it was easy to calculate the estimated number of Articles for the European Union and the United States of America and add it to the results of the performed searches.

The data related to the costs of a single ISI publication were calculated from the figures obtained from the Web of Science® with Conference Proceedings and those drawn from Eurostat databases. There are several parameters in Table 4 that have to do with the funds allocated to R&D. The idea was to give a multifaceted view of R&D expenditures by presenting absolute amounts (column "Total research funds and funds from the budget in millions of EUR"), by normalizing them per GDP and population (columns "Total research funds and funds from the budget in % of GDP" and "Total research funds and funds from the budget per capita"), and by highlighting the structure of R&D funding and the share of R&D expenditures in the overall government budget (column "Total GBAORD as a % of total general government expenditures"). Total research funds include funding from: (a) government; (b) business and enterprise sector; (c) higher education sector; (d) private non-profit sector; and (e) abroad, i.e., both the funds allocated by the government (a) and funding from other sources (b-e). Research funds from the budget (a) include merely the R&D funds provided by the government. This parameter is called Government Budget Appropriations or Outlays for Research and Development, abbreviated as GBAORD. According to the definition provided by Eurostat, it includes "all appropriations (government spending) given to R & D in central (or federal) government budgets". In Table 4, EPO stands for the European Patent Office.

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