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Knowledge diffusion social network is fundamental for efficient science policy

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Abstract

Development of a coherent science policy is a complex issue, especially within the strategic framework that has an ambition to build up the development of economy and society based on knowledge-intensive activities. The basis of such a policy is development of a dynamic (innovation) knowledge diffusion social network. Development of such a network require redefinition of the system of research careers and instruments for its development, modernization of public research institutions, investments in innovation diffusion mechanisms through alignment of educational policies and lifelong learning strategies, and development of policies and instruments for bidirectional technology transfer (from university to industry and vice versa). In this contribution, the elements of a knowledge diffusion social network in Croatia and Croatian innovation capacities are discussed from the perspectives of policies and instruments for development of research careers.

INTRODUCTION

Many European countries are developing strategies in order to respond to the Europe 2020 agenda. Alignment of policies is based on the open method of coordination, which is a fundamental instrument for harmonization of science policies in the EU. Thus, it is of fundamental interest for Croatia to adjust its policies in order to make the system comparable and complementary, and to create a platform for equal opportunities for Croatian scientists to function in the European Research Area (ERA).

The ERA environment is highly competitive and, thus, Croatian science environment should be competitive as well. Certainly, some research areas, especially in social sciences and humanities, bear lower competitiveness in international arena but present special interest for Croatia.

The national science policy should be aligned with national strategic documents and decisions and have to be incorporated in the national strategic framework. Unfortunately, the framework still does not exist and, thereby, reshaping of the science policy is not a simple task. In addition to national strategic framework, the science policy should also be aligned with EU policies, which is outlined in the Action plan to encourage investments into science and research (so called the Action plan 3%, adopted by the Government of the Republic of Croatia in April 2008) *(1)*. Although the document exists and is accepted by the

Government, it has not fostered reshaping of the national science policies.

National science policies in broader sense usually deal with many issues, including development of research grant schemes and promotion of individual researchers, funding instruments for development of research groups and research careers, development of doctoral studies and Graduate (doctoral) schools, development of centres of excellence and research infrastructure, technology transfer instruments, publication systems etc. However, they should also consider national network of research institutions, institutional polices at universities, instruments for collaboration with industry etc.

Although many different approaches towards development of national science policy are possible, and are existing within the ERA, from my point of view it seems that systematic development of research careers, attraction and rewarding talents, and development of a productive social network for knowledge diffusion is baseline for all policies, either national or European. This is especially important in time when new national strategy for development of research sector is under discussion and when still there is a debate about strategic research fields and research priorities. From my perspective, for small country such is Croatia every talent, especially innovator or leader within the research system, is precious, irrespective of the field of sciences and arts. Thus, this contribution will focus on proposal how national policies in the framework of the Croatian research area should be developed.

FUNDING MODELS

A key question that should be decided is identification of an appropriate model of funding allocation and respective policy.

In general, the delegation model can be used to explain the relationship between the state and scientists (research institutions) *(2)*. Policy-makers, representing the state, delegate to scientists to do something that they cannot accomplish by themselves *(3)*, and establish relations aiming to reduce risks associated with research investments. These relations are continuously challenged by two potentially conflicting issues: "to guarantee maximum welfare benefits, without violating the independence of scientists and their organizations" *(3)*. The risks can be minimized either by creating institutions that will guarantee high research performance, or by changing career patterns, or by using intermediary bodies that will guarantee the trust (i.e. research councils), or by delegating certain controlling functions to funding agencies with a high autonomy *(4)*. All above issues are not solved and systematically incorporated into the Croatian science policy at model level, although all elements can be found in existing public research sector: existing institutions cannot guarantee high research performance due to the enormous fragmentation of the research system, intermediary bodies cannot guarantee the trust due to the improper selection procedure, career system does not recognize high research performance and the funding agency is not empowered to take over buffering role.

The development of research policies should also recognize the evolution of funding models. Five delegation models were identified by Braun *(2, 3)*. The "blind delegation" model characterized period until 1980s, where state allocated funding to a researcher or a research institution without external validation. It was up to the scientist to decide what to research and the quality was assessed by "*ex-ante*" evaluation, often peer-review based on scientific publications. With the growth of research system and financial constraints (after 1980s), this model was supplemented with the "incentive model", characterized by extension into conditional scientific program funding, without additional constraints maintaining *ex-ante* and peer review evaluation (austerity delegation). In the 1990s, two additional models were introduced: (a) relational contract between the state and a scientist (contract delegation) or (b) relational contract with a research institution, where the state defines the content of the contracts and "*ex-post*" evaluation conditions, often based on measurable outcomes. Finally, in the recent decade the "network delegation" model emerged, which promotes development of funding networks of research institutions with companies and the state generally controls functioning of networks.

The research policy should recognize that "different delegation models can coexist" and "science policy-makers have to deal with an increasing heterogeneity of actors and networks making it more difficult to impose their own goals on the research system" *(4)*. In the context of the Croatian research sector, this would mean that goals and objectives of science policy should be aligned with the overall strategy, and funding instruments should be heterogeneous, aligned with these goals or objectives. In other words, it is impossible, with exception of "blind delegation" mode, to implement the same funding instruments to all researchers, research institutions and research fields.

RESEARCH FUNDING VS. DEVELOPMENT OF INNOVATION CAPACITIES

A key problem for policy makers will be to decide whether to construct science policy and research funding instruments that will gradually develop the existing research system (low scale goals) or innovation capacity of the entire society (large scale goals). This decision should be made in the political arena, and policy-makers will have to align objectives of the political system and the science system that follow different roles. Both approaches can follow the same roles; however, the scale is different. In this discussion I would like to propose such science policy that will accelerate diffusion of innovation (knowledge) into the entire society.

Development of innovation capacities of the society requires sufficient number of people with research competence, social network for diffusion of innovation (knowledge), innovation leaders, career system for their selection,

and knowledge-generation centres. For policy-makers a critical political decision is whether the innovation system will be developed by public or private funding instruments, or both. Private resources may present a significant background for enhancement of innovation capacities; however, private investments have limited outreach, especially in Croatian environment. Thus, development of the innovation capacity is a public responsibility and should be funded by public funding instruments. A major role of science system is to orchestrate diffusion of innovation (knowledge) with significant technology transfer toward the industry and to cause societal changes. For successful society, it is essential to maintain vivid social networks and drive social evolution. Both are responsibility of science system and political system and have to create a platform for public and private investments, often in the hybrid form.

WHAT IS REQUIRED FOR DIFFUSION OF INNOVATION?

Successful diffusion of innovation (knowledge), including scientific innovations, depends on the volume of the innovation network (i.e. number of people with research competence) and proper balance of key players that maintain this network. Understanding of this network, its composition and internal relations, requires extensive and sophisticated research, which is, to my knowledge, still not developed. Thus, for the purpose of this discussion we can use a simple model established 50 years ago by Rogers *(5)* and modified by many others over the five decades *(for review see 6)*, which describes the roles of diffusion of innovation within a community. According to this model four main elements influence the spread of a new idea: the innovation, communication channels, time, and a social system. In a community several categories of adopters can be distinguished: innovators, early adopters, early majority, late majority, and laggards *(5, p. 150)*. The frequency of innovators is 2,5% and early adopters 13,5%, and for adoption of innovation it is essential to reach 16% of creators (innovators and early adopters) to overcome so called 16% chiasm *(5-12)*, a critical mass essential for social networking *(8)*. Efficient diffusion of innovation requires such social network which allows productive relations between creators, early majority and late majority *(11, 12)*. Similar roles may be expected also for diffusion of the scientific innovation and within the social system that depends on diffusion of knowledge, including research community *(11)*.

In the Croatian society, as it is so in other societies, the knowledge diffusion social network should include active researchers in public research institutions, non-research public institutions, public and private enterprises, and research non-active people with research competence throughout sectors. Translated into the model of Myong-Hun and Harrington *(12)* innovators generate ideas, imitators learn from innovators and regular agents learn from imitators (Fig. 1A). Much better outcome is predicted when strong mutual interaction between innovators and imitators is established (Fig. 1B). Imitators have

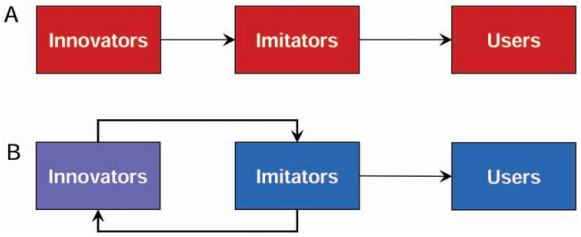

Figure 1. *Architecture of social network for diffusion of innovation into market (A) and for diffusion of knowledge into community (B).*

special role in the social system due to their ability to integrate dispersed knowledge in the social system and due to their role as the repository of knowledge *(12)*. Thus, translated into the policy language, the science policy and funding instruments (mechanisms) should be designed in order to construct such a network.

Given that the basic mission of the public research institutions is to maintain the knowledge-base and to organize diffusion of the knowledge, public research sector is a primary stakeholder of the knowledge diffusion social network, especially in the situation when public research system is significantly growing and public and private research activities taking place out of the public research institutions is diminishing. Thus, the entire knowledge diffusion social network can be expected to have Roger's distribution and 16% role can be applied to the entire network. Considering the public research system as a basic component of the network, the 16% creators within public research system cannot be sufficient to maintain the network and the entire distribution curve should be shifted to the left – the more to the left the lower is research activity outside the public research institutions. Therefore, successful research policy aiming to develop and maintain the innovation capacity of society should carefully sustain the knowledge diffusion network. This means that in the public research institutions the percentage of creators should be significantly increased at the expense of laggards, and this distribution can be achieved by continuous selection. In the system where the selection pressure is too low, only natural distribution can be established. This distribution within public research institution is not sufficient to maintain the knowledge diffusion network and cannot provide sufficient innovation capacity of the society.

Insufficient architecture of the knowledge diffusion social network can be expected in a major part of the Croatian research system due to long-lasting low selection pressure. Thus, the entire innovation diffusion social network can hardly generate the 16% critical mass. Accordingly, for enhancement of the innovation capacity within the entire innovation system and a public research institution, it is essential to develop selection procedures which will shift the architecture of the innovation diffusion social network at public research institutions to the left: i.e. to increase proportion of innovators and early adopters and to reduce the proportion of laggards (Fig 2, dashed curve).

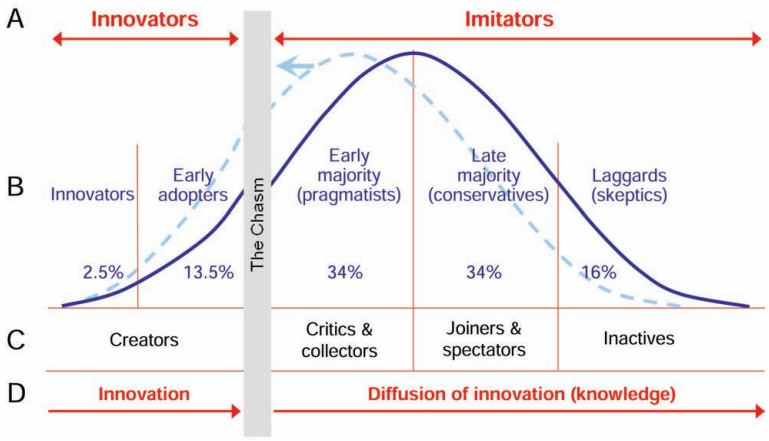

Figure 2. *Composition of the innovation (knowledge) diffusion social network. The distribution (blue solid line) is based on the first description of Rogers (B and C) (5) and modified according to Moore (7), Gewin (8), Gladwell (9), and Myong-Hun and Harrington (11,12) (A and D). Blue dashed line represents the proposed shift in the composition of the social network in public research institutions.*

Similar to the adoption of innovation, the development of innovation can occur through the social network created by the members of a community. In other words, institutional organization, culture and roles are key elements for adoption as well as for development of innovation. It is hard to believe that outside influences can facilitate innovation, but outside influences can disrupt the capacity for innovation. Translated to the language of policy-makers and research institutions in Croatia, especially universities, improper funding instruments for research activities may highly reduce innovation capacity. This was the case in the last two decades with the funding scheme of research projects, which is constructed on the leadership paradigm and facilitated fragmentation. This, in many cases, disabled collaboration and "social networking" in research activities, and made development of institutional research policies and networking almost impossible.

WHAT IS A BASIS OF INNOVATION CAPACITY OF CROATIA?

Every science policy should be an integral part of a national strategy of development. In a system without strategy, the science policy is being set up every year, or every political cycle, in line with the annual fiscal policy. In other words, the policy framework allows the development of science system in accordance with the redistribution capacity of the State budget and with predicted growth of the Budget. Usually, this growth is minimal, especially in a system where most of the budgetary allocation is confined to wages. In general, such science policy aims to maintain steady state and does not allow significant improvement of the science system. Accordingly, capability of such a policy to systematically develop knowledge diffusion social network, which is based on systematic development of wide range of research careers, is very limited and confined to the maintenance of existing institutions and research landscape, including also existing research groups and research focuses. Needless to say that such a policy cannot address a question: why do we need development of a wide range of research careers.

Contrary to the steady state policy, strategic approach to the development of research careers means addressing a baseline question: why do we need development of research careers. In principle, all policies dealing with this issue are focused on innovation capacity of the existing research system and extension of the innovation capacities towards the society and business. It should be clear to the policy makers that the term "innovation capacity" means a number of networked people having research skills, trained for innovation and collaboration, working in public or private research institutions and in non-research public sector and private enterprises. Innovation capacity, thus, primarily depends on the number of people with research competences and secondarily on their social network i.e. innovation initiatives. Clearly, innovation is not confined solely to development of a commercially attractive product, but also to improvement of every activity that increases the productivity and social cohesion.

Innovation policy, and consequently innovation capacities, should be focused to promote innovation initiatives at every sector: public administration (i.e. ministries, municipalities, cities, agencies, etc.), public institutions (i.e. hospitals, health promotion institutions, schools, universities, theatres, museums, etc.), and small and medium size enterprises. In other words, innovation is required almost at every place and, in fact, it should be developed as innovation culture that is immersed in every activity. This is a long-lasting goal which requires systematic transformation of the educational system and huge public campaign. In this contribution we will not discuss that issue, although it should be the most important part of the national development strategy. Thus, further discussion will be focused only to the "immediate" innovation policy (capacity) which is dependent to trained people with innovation skills that should be "leaders" in development of wider innovation culture. Clearly, it is hard to believe that these people can be found outside the cohort

of highly educated people. It is quite clear that innovation in the 21st century should be driven as research--based activity; consequently, the innovation leaders' cohort is confined to those that are trained for research skills: people that complete PhD training. Thus PhD training is critical milestone for development of innovation capacities in a wider meaning, and should be in the centre of any science policy. In the broader sense, innovation capacities should be depend by development of a ladder of research careers with the aim to increase capacities for research-based and well-structured PhD training: in order to increase supervision capacities, to provide highly competitive research and to organize research for the needs of industry and social changes. In that case, science policy should be concentrated on the development of instruments for selection of leaders and organization of bigger research groups.

WHAT IS CROATIAN RESEARCH COMPETENCE-BASED INNOVATION CAPACITY?

"Doctoral graduates are key players for research and innovation. They have been specifically trained to conduct research and are considered the best qualified for the -creation and diffusion of scientific knowledge"*(13)*.

The precise number of PhD holders in Croatia is not available. Census 2001 *(14)* reported 7,443 PhD holders in Croatia, and 7,127 PhDs graduated at Croatian universities in the period 2000-2012 *(15-19)*. The number of PhDs exponentially increased in the last five years (Fig. 3). In 2011, 52% (5,600) PhD holders were employed at higher education institutions *(19)*. Thus, the number of PhD holders in Croatia can be estimated to 12,000. Although the increase in the last decade is dramatic and opens public debate about their future, recent report of the European Commission *(20)*, demonstrates that the overall number of PhD graduates in Croatia (0.9 per 1,000 population aged 25-34) is lagging behind EU27 (1.6) and especially behind Switzerland (3.6), Sweden (3.1) and Finland (2.9). Nevertheless, avoiding comments about research competences they acquired during PhD training, one can estimate that this number of graduates create potential research--based innovation capacity. This capacity is higher than i.e. Turkey, Latvia or Bulgaria, similar to Poland, Hungary, Lithuania and much behind Denmark, Austria or Portugal *(20)*. Thus, if we consider Finland, Denmark or Sweden as an example of best practices, Croatia should scale up the number of PhDs for at least 3 times in the reasonable period of time. This would mean that instead 12,000 PhDs, Croatia should have 30–40,000 PhDs. Current trend of PhD enrolment and graduation suggests that by 2025 Croatia will have 25,000 PhD holders. Although this increase is dramatic and opens many questions, especially associated policies that will provide employment opportunities for PhD holders outside public sector, it is clear that the Croatian innovation capacity remains behind many EU countries.

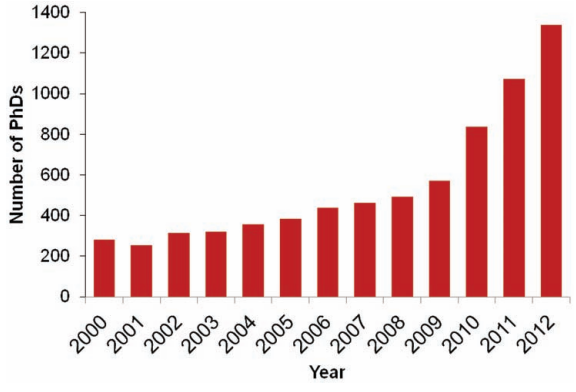

Figure 3. *Number of PhD graduates at Croatian universities (Source: Croatian Bureau of Statistics).*

The presented analysis is based on number of people with PhD. Additional, even more important, analysis should include analysis of research competencies acquired during PhD training, especially competencies required for development of the knowledge diffusion social network, in order to be able to increase the innovation capacities In other words, pure increase of number of PhD holders without redefinition of PhD training and competencies acquired does not make many sense, and cannot be kind of policy that is favourable. In addition, a policy of increasing the number of PhDs without alignment of other economic policies and active approach to them also does not make much sense. For example, active policy of promotion of investments, attraction of investors that will transfer technology due to a high number of highly qualified research-competences, development of start-up packages for entrepreneurial PhD holders etc., should parallel national science policy. Without this, most of PhDs will remain within academic public sector (universities and research institutes) and will put pressure on the State budget. This will provoke the discussion about "Where will these people work?" and end up with the conclusion "It doesn't make sense!" – resulting in the maintenance of the steady state.

HOW TO INCREASE NUMBER OF PEOPLE WITH RESEARCH COMPETENCE?

If the policy sets up the goal of 25,000 PhDs by 2025, and if we decide to start with their organized training immediately, the existing PhD programs should be adapted (reformed) which will, assuming extremely optimistic conditions, require at least one year. With such extreme optimism, first PhDs can start training in 2015, and if training is equally efficient, it can end up in 2019. Thus, potential 25,000 PhDs can be distributed over the 6 years (if we want to reach the goal by the 2025), which means at least 4,000 PhDs per year. With such extremely high efficiency (i.e. 80% completion within 4 years), we should enrol each year 5,000 PhDs.

Annual enrolment of 5,000 PhDs would require also 5,000 supervision equivalents each year. If we further consider that the maximal supervision capacity of every active researcher is 3 PhD students over the period of 4

years, than we can easily calculate that in the most optimistic version we would need 6,000 supervisors. Clearly, a big question arises immediately: Has Croatia such capacity? The answer is: NO. It seems that such a calculation is too ambitious.

What is an alternative? To scale down ambitions and to increase efficiency. However, in that case we should estimate maximal number that can be expected by 2025 (i.e. 7,000 PhDs according to the current capacities), reduce it for those that will retire by 2025, and estimate the gain to 4-5,000 PhDs by 2025. The question that follows is: Is it sufficient? Yes, but not for establishment of the knowledge diffusion social network and for development of the knowledge-based economy. It is sufficient just to justify the demands of higher education sector.

DO WE NEED PhDs IN ALL RESEARCH FIELDS?

Another big issue is structure of PhDs. The question is whether we need to scale up PhD training in all fields, or we need to scale up i.e. natural sciences or engineering. Certainly, all fields are not of equal importance. In order to increase innovation capacity in production sectors we would certainly need more PhDs in engineering, biotechnology, natural sciences and biomedicine. However, the requirement to increase innovation capacity in the area of social sciences should not be underestimated. It is extremely hard to predict the structure and societal values that will be in place at 2025, especially considering the fact that information technology, Internet, transmedia communication, and social networking is growing exponentially by doubling or even tripling per year. This means that by 2025 some things will be enlarged 1,000 or even 5,000 times than today. Inevitably, the societies will be different and will require intensive research-based reactions. It would be better to think how to bridge the gap in methodology used by sciences from one side and humanities from the other side, especially the gap with social sciences that is historically formed in this area of the World.

REGIONAL IMBALANCE OF THE KNOWLEDGE DIFFUSION CAPACITIES

Many studies demonstrated that development of region is related to the level of education and R&D *(20, 21)*. The retention of graduates, or even attraction of talents, is one of the main approaches by which the cities and the regions can maintain development, innovation spirit, entrepreneurship and management capacity. Any insufficiency on these matters constitutes an obstacle for development *(21)*.

If we continue to envisage Croatia as highly competitive knowledge-based environment, all regions of Croatia should have a sufficient number of people with the research competence in order to create knowledge-diffusion network. Current distribution pattern of people with PhD in Croatian regions is not favourable for such a vision. Although the data about regional distribution of

Figure 4. *Doctors of science (PhDs) by county of usual residence that graduated in 2000-2012 at Croatian universities (source Croatian Bureau of Statistics). Surface area of the circles is proportional to the number of PhD graduates.*

all PhD holders are not available, the general conclusion can be drawn from available data on new PhD graduates during last 12 years. Most of PhD holders live and work in the Zagreb area (the County of Zagreb and the City of Zagreb). For example, out of 6,888 PhD holders that graduated in the period 2000-2012, 58,27% (4,014) live in the Zagreb area (Fig. 4) *(15-19, 22)*. The overall contribution to the labour active population of new PhD graduates in this period in Zagreb area was approx. 0.64% whereas, as an example of two relatively well developed regions, in Primorsko-goranska County and Istrian County was approx. 0.26%. Therefore, the knowledge-diffusion capacity of Croatia is concentrated in one region. Strategic thinking of the future of Croatia, thus, should also include long-term plan of development of knowledge-diffusion network in the entire Croatia, either by increasing PhD training capacities at universities outside of Zagreb or by developing measures that will foster the mobility of PhD holders after PhD training, or both.

RESEARCH CAREER SYSTEM DOES NOT SUPPORT ACCELERATED DEVELOPMENT OF THE KNOWLEDGE DIFFUSION CAPACITIES

In addition to the number of PhD holders, their balance distribution within fields of science and throughout Croatian regions, an important structural issue is the research career system and structure of PhD training programs. These two issues are intertwined.

The Croatian system of research careers is quite distinct from the rest of the Western Europe and not well aligned with EU practices (Fig. 5) *(23, 24)*. Although the career system has changed in the last 10 years, PhD students are still full time employees of research institu-

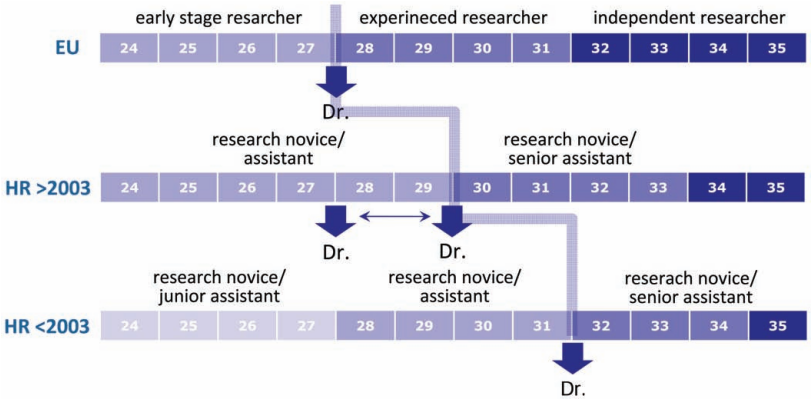

Figure 5. *Early phase of research career system in the EU and in Croatia before and after 2003. The scale represent the average age of young researchers when the career step can be achieved.*

tions and universities and, although they are formally enrolled to graduate programs, they do not have status of students and they do not feel like students. Rather, they feel as public servants with the right to be promoted. In addition, they have full time contract for ten years, with obligation to complete PhD thesis within six years and prolong the contract as postdoctoral assistant (not similar to PostDoc position in Western countries) for additional years up to altogether 10 years (Fig. 5). This system opens up a very limited number of state-paid PhD positions and, thereby, stimulates enrolment of a high number of part-time PhD students that do not spend full time at research institution and make different dimension of PhD training, when compared with full time PhD students. Additionally, many PhD students are employed at universities where they serve as research and teaching assistants, which makes additional burden and PhD training produces much less efficient.

After completion of PhDs, the research career system in public institutions is focused purely on the promotion based on minimal research achievements and the opportunities for development and diversification of the research careers are very limited – restricted to the positions available within institutions (often with constraints associated with state-governance over the research system) and confined with poor financial instruments, with exception of those that are able to get international grants.

Altogether, the Croatian system of PhD students' careers is very difficult to compare with the EU system. The early stage researcher *(24)*, which is supposed to complete PhD program within 3-4 years, is equivalent to Croatian research novice/assistant within the first 6 year of the contract, and the experienced researcher with the rest of his/her contract (Fig. 5). In addition to the 2 year deficit (Fig. 5), the post of the Croatian research novice/assistant is not structured in a way to ensure development into experienced researcher *(24)*, and very limited number of instruments, either institutional and/or financial, are in place for this development. Finally, the stage of independent researcher is very difficult to reach without institutional and financial instrument, which are not, again, well developed. Apparently, existing structure of positions at research institution and the lack of institutional and financial instruments do not support development of the European-compatible system of research careers. In addition, the majority of promotion and selection criteria do not recognize researcher's role in development of the knowledge diffusion social network.

WHAT RESEARCH CAREER SYSTEM SHOULD BE ESTABLISHED?

A key element of the science policy is selection of proper career system and its alignment with the national context and with the national strategy. Thus, decision about the career system is associated primarily with the political decision, because its establishment and development requires redistribution of resources and investments. There are many examples of good practices from advanced research systems in European countries that can be considered *(23, 25–29)*. In general, based on these experiences, major elements of the career system, at least in EU countries, are outlined in Fig. 6. The stage of PhD students should be used for acquisition of basic research competencies, enhancement of generic skills, acquisition of teaching competencies and to gain certain international experience. After this stage, entry into the postdoctoral stage (up to 4 years) should be based on achievements and transparent selection. At this stage, many PhD graduates should be redirected outside the public research sector and integrated into the knowledge diffusion network. Those who continue research career in the public sector should have access to instruments for further development of independent research career to the several stages. These instruments should be accessible by stringent selection, from independent researchers that work in services up to research leaders of collaborative research centres.

WHAT ARE THE INSTRUMENTS FOR ESTABLISHMENT OF THE RESEARCH CAREER SYSTEM?

Research career system can be changed by gradual introduction of instruments, both national and institutio-

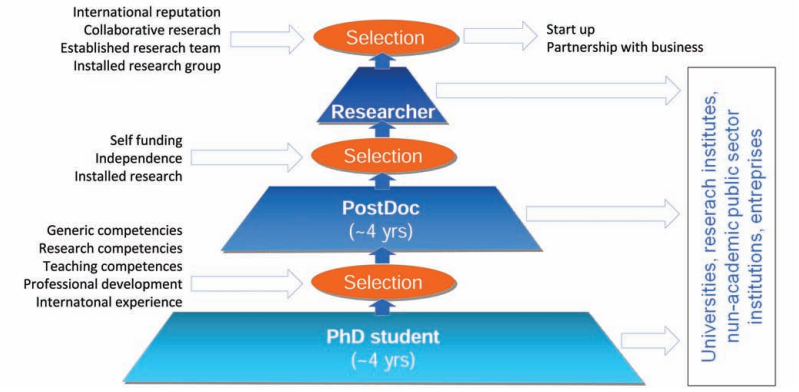

Figure 6. *Proposed research career system that should be established in the Croatian public research system.*

nal. These instruments include (i) adaptation of national and institutional legal framework, (ii) clearly defined long-lasting policies regarding promotion of researchers based on research outcomes and selection, (iii) flexible institutional posts, and (iv) financial instruments for development of individual research careers, establishment of research groups and centres of research excellence. Although within this framework issues regarding development of strategic priorities can also be discussed, from the author's perspective, selection and empowering research leaders with the capacity of formation of collaborative research team should be considered as the most important, especially for country as small as Croatia. Consequently, the following scheme of funding instruments is proposed for Croatia (Fig. 7). This proposal is based on analysis of funding instruments used by several research councils and/or foundations in Europe *(25–29)*.

In order to develop dynamic knowledge diffusion social network based on sufficient number of PhD students that will create the network, PhD training should be structured in a way that ensure their appropriate selection and progression in research career, including also selection of efficient supervisors. This selection can be based on competition, but also on their achievements and palette of proper funding instruments. Given that it is not likely that all PhD programs can be structured that way, it is essential to develop funding instruments for development of such programs – to ensure resources for PhD training (Fig. 7). The optimal approach would be integration of PhD programs into Graduate schools or research training programs. In addition to funding instrument for development of competitive PhD programs, it is essential to develop also funding instruments that would individually support PhD students: scholarships, fellowships or research training grants, especially in areas where there is a deficit of competence in Croatia (Fig. 7).

A critical phase for selection and profiling of young researchers is the postdoctoral phase. This phase should be supported by wider range of funding instruments, from fellowships and individual research grants towards early development of independent research through installation grants, grants for development of research groups, or excellence grants aimed for development of capacities for world class research (Fig. 7). Well supported progression through the postdoctoral phase is essential for construction of the innovator (creator) part of knowledge diffusion social network (see Fig. 1 and 2). Needless to say, through these instruments development of some specific or strategically important fields for Croatia can be promoted. Finally, through such large investments scheme it is possible to foster development of excellence centres and larger collaborative research groups (physical or virtual) or centres (Fig. 7).

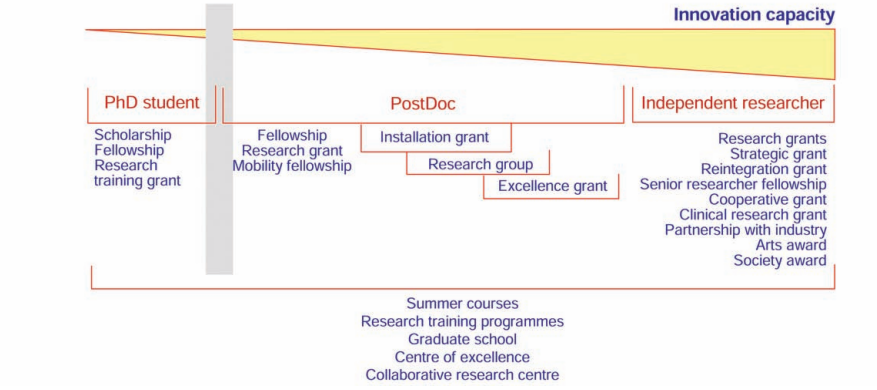

Figure 7. *Funding instruments for development of research career system and knowledge diffusion social network.*

Careers of independent researchers should be also supported by heterogeneous types of grants, aligned with the distinct typology of researchers. Of special interest is to develop grant schemes which support integration of foreign researchers, support reintegration of researchers of Croatian origin, enable circulation of researchers between research institutions or public research institutions and industry (Fig. 7). Additionally, grants and awards with specific focus on integration of science and society or artistic research are essential for the vitality of the knowledge diffusion social network.

Thus, the role of proposed funding instruments is not only development of an individual researcher but also construction of a dynamic knowledge diffusion social network. These instruments, when developed, should also include elements for close integration of innovators and imitators (see Fig. 1 and 2), development of PhD supervision capacities, and dissemination mechanisms within the social network. Additionally, these instruments should be carefully aligned with policies and instruments for development of knowledge-generation centres and technology transfer centres.

SELECTION PRESSURE IS IMPORTANT FOR DIVERSIFICATION OF RESEARCH CAREER SYSTEM BUT SHOULD NOT FOCUS ONLY ON SELECTION OF RESEARCH LEADERS

Long-term research policies, grant schemes and funding instruments in highly competitive research systems are designed with the aim to facilitate selection and promotion of best achievers. They are implemented at the system level and usually supplemented with a wide range of institutional policies and instruments. These concepts, very often partial, have been implemented into a small research system, such as Croatian, unsuccessfully. The major reason for failure is, among other issues, the Croatian governance model of research system, the state governance model which does not recognize institutional policies. In fact, due to the existing funding system and the governance model, the institutional research strategies and policies, including financial instruments, hardly exist. Thence, goals and objectives at the national and institutional level are at least not clear, if existing at all. Therefore, development of institutional policies is equally important for development of knowledge diffusion social network.

Both, national and institutional policies should avoid implementing research policies and funding instruments that are designed for selection of research leaders. The development of instruments should be more sophisticated and more carefully structured, keeping in mind that there are different profiles and types of researchers *(30)*, not only leaders and innovators. The effective policies should focus on generation of the knowledge diffusion network and incorporate all existing profiles in the system. Nevertheless, leadership is important, although it is sophisticated and complex social role that requires qualities which are based on talent but also many qualities that are developed through experience, education and training, and conscious self-development. Thus, leaders are more made than born *(31)* and mostly found within the cohort of early adopters. Therefore, efficient science policy should include also early selection strategies and integration the leadership in education and training at the earliest opportunity. In terms of research leaders in innovation this means selection of students and development of leadership skills throughout the research career ladder. Effective leadership in research is essential for establishing an effective innovative social network within the research system in order to enhance innovation capacity of the Croatian research community.

CONCLUSION

After almost five years of hesitation, Croatia is on the crossroad regarding development of the long-term development strategy, including also development of education and science policy. Although it is difficult to rise above the noise of enormous demands for restructuring in many other fields, it is becoming clear that diffusion of knowledge and an increase of innovation capacity is essential for development of the entire society, not only for economic activities. Thus, development of science policy cannot be focused solely on maintenance and improvement of the existing public research sector and technology transfer. Significant transformation into the high added-value economic activities requires significant improvement of the knowledge diffusion social network, in volume and quality of knowledge flow. To scale up this network it is essential to treat it as long-term strategic investment which should be carefully planned, with clear mid-term and long-term goals and objectives, including financial instruments. To be able to further develop this network, especially keeping in mind that we live in the second decade of the 21st century, its planning should be based on scientific analysis of the existing knowledge, thorough research of the current Croatian knowledge diffusion capabilities and modelling (mathematical and computer modelling), instead of superficial *á la carte* copying of good practices from other systems. Unfortunately, the diffusion of knowledge is not a topic of significant research today and a coherent program of research into the diffusion of scientific knowledge and its relation to scientific progress does not seem to exist at this time *(32)*.

In addition to the projections of the future Croatian knowledge diffusion social network, it is also important to envisage how knowledge diffusion will behave in the fortcoming decade. Namely, most of knowledge diffusions occurred so far through scientific publications and communication within rather small scientific communities, very often requiring too long to reach distant communities *(32)*, i.e. diffusion of generated knowledge from community in superconductor engineering towards the community of learning research. However, beneficial diffusion of knowledge today requires efficient diffusion in a wide array of scientific communities due to the increasingly interdisciplinary nature of research today.

Rapid development of Internet and World Wide Web technology, especially Web 2.0, opens up new perspectives in diffusion of knowledge, scientific publishing, communication between scientist and organization of scientific communities, i.e. "invisible colleges" *(33)*. Thus, in addition to smart development of approaches to use current development of the semantic Web for acceleration of knowledge diffusion, many other traditional practices within scientific community should be also changed and adapted to the opportunities that are arising with exponential development of communication technologies. Good example of how invisible colleges have migrated to an online environment is the Faculty of 1000 (F1000), which can be considered as Peer Review 2.0 and will challenge the traditional peer review system *(34)*.

In this contribution I focused mainly on research career system and development of the volume of the knowledge diffusion social network as essential element of science policy. However, reshaping and modernization of public research institutions, higher education institutions and governance over the system, as well as technology transfer are also equally important pillars of the science policy. From my point of view, science policy should also consider these elements through the prism of knowledge diffusion social network and innovation capacities of the society.

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