Challenges to the Indicators on Science, Technology and Innovation Development

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Challenges to the Indicators on Science, Technology and Innovation Development

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Abstract

The paper attempts to define the challenges to the indicators on science, technology and innovation development which result from the contemporary dynamics of the global knowledge based economy progress and the pursued challenges of identification of the specific national priority dimensions for public funding research and innovation projects on the case of Bulgaria.
It is argued that recent the most widespread methodologies of positioning science, technology and innovation indicators do not propose enough precise instruments to define the national context of the research and innovation policy which allows meeting the challenge of dynamics of global economy.
The paper suggests the solution of the problem of identification of specific national priorities in science, technology and innovation development is connected with a separate measurement of solvent demand and supply of knowledge. Further some results of application of this methodological approach are presented, based on Bulgarian case, and the tendencies of demand and supply of knowledge are summarised in a figure.

1. Knowledge Based Economy Development Challenges

Today we are witnessing an accelerated creation and introduction of new technologies, an accelerating globalization and regional economic integration. These processes provoke new economic facts, which cannot be explained with the existing theoretical models. Moreover, the necessity for introduction of new technologies and the global competitiveness significantly complicate the solution of the problem of acceleration of the economic development and creation of more and better work places. Seeking for solution is more and more connected

with the *new paradigm for knowledge based economy*. The integration to the European Economic Community forces the scientists and practitioners to face the challenge to adapt to the new paradigm.

The emerging of the new paradigm of knowledge based economy is determined by many factors. I will discuss here the influence of two of them: the accelerated development and introduction of new technologies, on one hand, and the realization by the society of the resulting economic problems, reflecting in the formulating of the tasks of the scientific studies, as well as the objectives and priorities of innovation strategies and policy at firm and national level.

The impact of the *first factor* – the accelerated development and use of new technologies – leads today to accelerating the process of turning the new knowledge into economic result. The innovation process ranges shorter and shorter time periods, which changes substantially its accompanying economic relations. As a result the organizations function in more and more intensive global competitiveness, accelerated life cycle of the products and technologies, higher and changing requirements of the clients. The criteria for success of their functioning also change. Not the size but the speed of the reaction of the new changes through renovation becomes decisive for the success of the firms.

The period, in which the use of new technological knowledge influences the macroeconomic characteristics of the economic development, decreases. This tendency is observed clearly in the construction of the so-called Schumpeter's waves of impact of the technological changes on the economy. Figure 1 presents a modernized to 1999 picture of the Schumpeter's waves[1] in the period since 1785, summarized by The Economist. The first wave of renovation in this period is provoked by the use of the water force, together with the development of the textile industry and the wide use of the iron. It lasted for 63 years. The second wave of renovation of the economy concerns the use of steam, the production and wide use of steal. It lasted for 55 years. The third innovation wave starts in 1900 with the wide use of the electricity, the internal-combustion engines and the development of the chemical industry. It lasted for about 50 years. The forth wave of renovation of the economy is determined by the production of chemical products from petrol, oil and gas, by the development of the electronics and the aviation. The duration of this wave is about 40 years. Since 1990 the fifth wave of renovation has started, which is supposed to last for about 30 years. It concerns the wide distribution and use of digital networks, software and the new media.

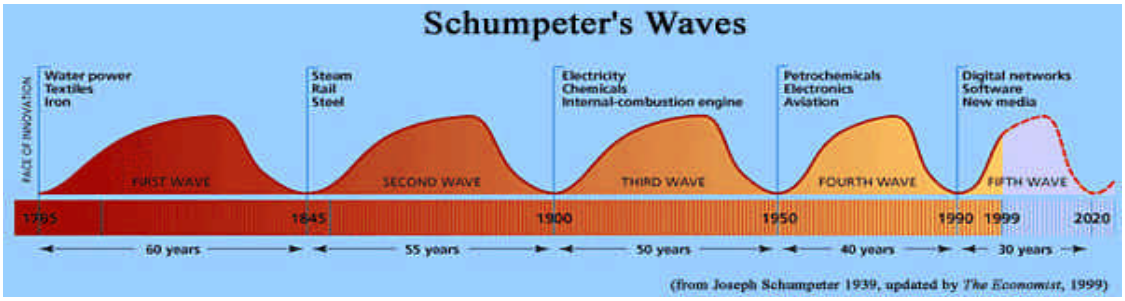


Figure 1. Schumpeter's Waves of Impact of the Technological Changes on the Economy

[1] Schumpeter, J. A. (1939) Business Cycle, N.Y.: MacGraw-Hill.

Even though it is new, the picture of the Schumpeter's waves is already old. The accelerated development of new technologies today forms a new wave of innovations. This wave is characterized by the convergence of the nanotechnologies, biotechnologies, information technologies and cognitive science. This new wave overlaps the former one and is expected to provoke innovation "storm" in the development of the economy.
The process of turning the new technologies into economic result also changes. Besides the accelerating of the innovation process today we observe also change in the model of the process of turning the knowledge into economic result. The globalization, new technologies and mostly the information and communication technologies lead to increase of the potential of knowledge as a resource for business development. As a result the linear structure of the model of the innovation process, characteristic for the middle of the last century, turns into a complex network structure, in which the interactions aiming to exchange knowledge are especially significant. These interactions provoke new economic relations, the studying and directing of which becomes extremely important for the accelerated innovative economic development.
The *second factor*, which provokes change in the economic paradigm, is the realization of the economic significance of the resulting technological changes and of the necessity for an adequate reaction at macro- and microeconomic level. The impact of this factor is revealed in the formulation of scientific research problems and in the innovation strategy and policy of the different institutions.
In Bulgaria the degree of realization of the economic significance of the global technological changes and of the necessity for an adequate reaction to the different levels of decision-making is not especially high.
The increase of the innovativeness through creation, acquiring and use of new knowledge is connected with the increase of the public and business expenditures for R&D activity. But for large part of the economic staff in Bulgaria the existing level of 0.5% R&D expenditures as a share of GDP with average European level of 1.92 % for the moment is satisfactory. Satisfactory according to the dominating part of the public is 0.35% level from GDP of state financing of the R&D expenditures with average level of close to 1% for the EU countries. The fact that the business finances only 1/5 of the already insufficient according to the European standards R&D expenditures in the country does not provoke the necessary worries for the economic staff. As a result on the horizon till 2013 the national innovation strategy does not foresee changes in the level of the public and business investments for R&D activity. As it is well-known, the Lisbon strategy foresees 2/3 of all investments for scientific studies to be carried out by the business, and the total investments to reach 3% of GDP.
The accession of Bulgaria to the European Union and the new policy for economic development, based on the wide use of new knowledge in the practice, is determined as a stimulus for change in the paradigm of the economic thought and a challenge for many of the economists. In this direction the recommendation of the European Union for development and realization of national Lisbon programs for innovation development of the economy of knowledge with their national specific branch priorities will have an impact. The identification of such national priorities for renovation is next important challenge for the economic thought, more over, they need to be conformed and coordinated at European level aiming to become an element of the general European innovation strategy by 2010.
This state gives reason to assume that the incorporating to the European field of the scientific economic thought is a challenge to the Bulgarian economic thought, which can be met with

the introduction of the new economic paradigm. In this paradigm the creation and use of new knowledge becomes main source of increase of the public wealth and prosperity.
On the other hand, the issue how with limited knowledge resources, which change their content and value in time and space, to run economic processes aiming to satisfy the increasing and changing needs and interests of the society or certain parts of it in certain periods and on certain territories, becomes a central economic problem. The solution of this problem is connected with the formulation of contemporary decisions for the public impact (governance) on the acceleration of the creation, acquiring and use of new and newly acquired knowledge in the economic practice which needs respective methodology. Beside this the solution of the problem of identification of national priorities for science, technology and innovation is affected by the national innovation policy challenges.

2. National Innovation Policy Challenges

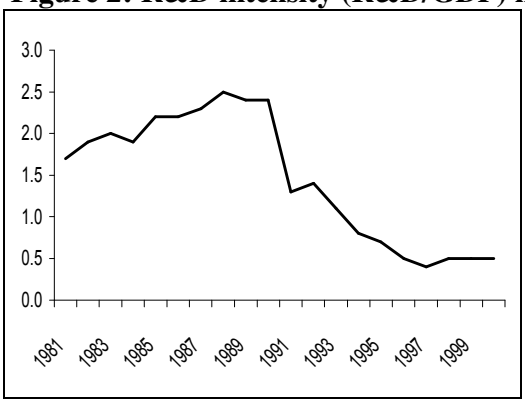
National strategy documents and mechanisms for innovation policy delivery have been elaborated, but nevertheless actual policy delivery and the provision of adequate resources remains relatively poor in Bulgaria. Hence, the measures proposed in strategy documents and draft laws are "either lacking the necessary resources or do is not supported by enough political will in the legislative process".
Based on the review of national studies on the Bulgarian science, technology and innovation development, ERAWATCH country reports and the trendchart reports, at present the 4 main challenges for the National Innovation system of Bulgaria with respect to R&D intensity are as follows:

1. To foster the overall R&D funding base
2. To initiate a recovery of R&D in the business enterprise sector.
3. To strengthen the human resource base of the Bulgarian economy.
4. To enhance the interactions between the actors of the STI system.

Challenge 1: To foster the R&D funding base

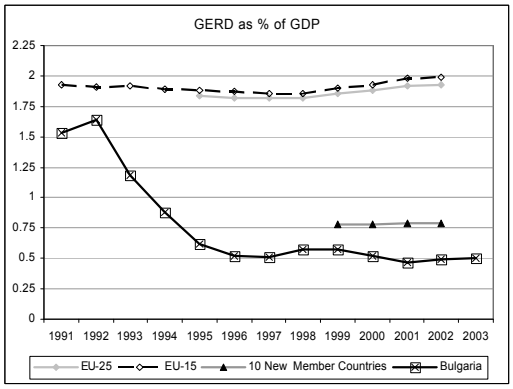
R&D intensity (R&D/GDP) declined heavily after the transformation from a command to free market economy (See Figure 2.). The highest R&D intensity appeared in 1988, when the highest volume of the foreign trade turnover also took place. Figure shows the development of R&D intensity in Bulgaria compared with the EU-15 and the New Member States for the period 1990 – 2002. Until 1996 the dynamics of the R&D intensity is negative, and after that it is more or less stable with variations at levels of 0.5%.

Figure 2: R&D intensity (R&D/GDP) in Bulgaria for the period 1981-2000, %



Source: NSI

Figure 3: Dynamics of GERD/GDP (1990- 2002)



Source: Eurostat, National Statistical Institute – Bulgaria

Table 1 presents a tendency of a slight decline of R&D intensity for the period 1996 till 2002, though an increase in the absolute sum of R&D expenditures appears, which points to the fact that the overall economic growth had a faster pace than R&D recovery.

Table 1: Total Gross Domestic Expenditures on R&D (GERD)

Year	GERD	PPP ($)	GERD as % of GDP	GERD per capita (in PPP$)
1996	9 148 000 (b)	236 850	0,52%	28,3
1997	88 591 000	221 769	0,51%	26,7
1998	127 598 000	258 547	0,57%	31,3
1999	134 449 (b,y)	264 158	0,57%	32,2
2000	131 098	249 386	0,49%	30,5
2001	129 721	235 951	0,44%	29,4
2002	158 327	278 313	0,49%	34,9

PPP: Purchasing power parity, * b – break in series, y - denomination change

Source: Eurostat

It could be concluded that the main instrument for fostering the R&D funding base is to increase foreign demand for domestically based technologies, products and services.

Challenge 2: To initiate a recovery of R&D in the business enterprise sector

But not only R&D intensity declined dramatically, similar to other transition economies also in Bulgaria a shift in the sources of R&D funding along with a change of R&D performance by sectors occurred.

The most striking result in this respect is the collapse of R&D performance in the business enterprise sector. By 1999 its share had dropped by about a factor of three since the early 1990s. The long-term development of business R&D is shown in Figure 4, reinforcing the notion of an especially sharp decline in 1997. As compared with the common tendencies for Central and Eastern European (CEE) transition countries, perhaps the only surprising fact is that the share of business R&D remained at levels of 50% to 60% of GERD until 1996.

As the share of higher education has not changed much and the share of NGOs is negligible, the other side of this coin is the rising share of the state sector in carrying out R&D. A big shift in R&D performance occurred in 1997, when inflation and a redirection of macro policy hit the country and a sharp decline in total R&D expenditures occurred.

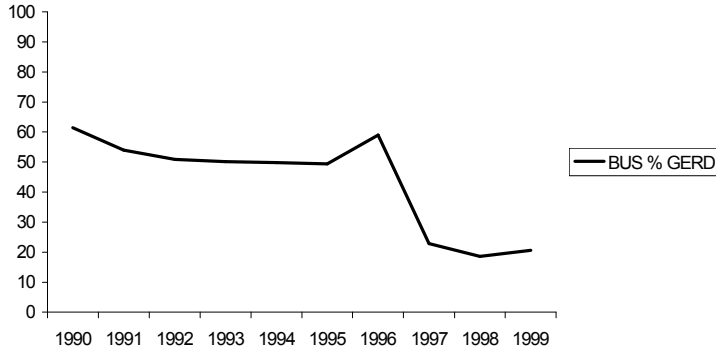
Since then, questions concerning the efficacy of relying increasingly on the state sector for pursuing R&D continue to arise, especially as privatisation and marketisation are key policy issues. It is expected, that the drastic decline in business R&D expenditures will have serious consequences for technological accumulation over the longer term.

Table 2: Sources of funds for R&D in Bulgaria

Years	Business Enterprise %		Government %		Higher education %		Private non-profit %		Funds from abroad %	
1996	60,4%	B	35,1%	b	3,8%	B	0,4%	b	0,3%	b
1997	23,3%		67,8%		2,4%		0,9%		5,7%	
1998	23,6%		69,7%		2,7%		0,2%		3,8%	
1999	22,8%	B	69,7%	b	3,2%	b	0,2%	b	4,1%	b
2000	24,4%		69,2%		0,9%		0,3%		5,3%	
2001	27,1%		66,2%		0,7%		0,3%		5,7%	
2002	24,8%		69,8%		0,2%		0,2%		5,0%	

Source: Eurostat, b – break in series

Figure 4: Share of business enterprises performing R&D, Bulgaria, 1990/1999



Source: Calculations by Chobanova, based on unpublished data supplied by the NSI

Challenge 3: To strengthen the human resource base in the economy

Since 1990 the total number of R&D personnel has declined by a factor of about 6. The data in the table 5 cover the period from 1996 until 2003. In this period the number of total R&D personnel declined by approximately 40%, the number of researchers by about 35%.

Table 3: Human resources in R&D

Year	Total R&D Personnel FTE	Female R&D	Researchers FTE	Female Researchers	Technicians and equivalent staff FTE	Female Technicians	Other supporting staff FTE
1996	26 158	13 788	14 751	6 114	8 169	5 462	3 238
1997	18 625	10 078	11 980	5 431	4 550	3 166	2 095
1998	19 116	10 148	11 972	5 321	4 862	3 295	2 282
1999	16 087	8 374	10 580	4 656	3 829	2 578	1 678
2000	15 259	8 106	9 479	4 354	3 833	2 441	1 947
2001	14 949	7 907	9 217	4 247	3 786	2 355	1 946
2002	15 029	8 106	9 223	4 353	3 713	2 374	2 093
2003	15 453	...	9 589	...	...	...	...

Source: EUROSTAT

The full time employed R&D personnel is 15 453 in 2003. Women represent approximately half of the total R&D personnel, taking a higher share in technicians and equivalent and supporting staff than in researchers. The decline of the human resources in S&T in Bulgaria is confirmed by table 3 also.

There is a very strong process of brain drain from the R&D sector in Bulgaria. A lack of a clear strategy for transformation of the Bulgarian S&T sector and its European and international integration has especially affected adversely higher educated and skilled personnel. Since 1992-1993 the share of Bulgarian higher educated (HE) emigration has started to increase. The major factor motivating this emigration is a higher living standard and possibilities for better professional and personal realization abroad. Better social relations are another important factor affecting this tendency.

A first survey on emigration (1991)[2], covering the beginning of the transformation period, shows that the main direction of Bulgarian HE emigration is Europe – mainly Germany, but the second one, covering the period of 1995/1996 shows that the USA have become the main direction for HE emigration. Furthermore an increasing share of young people emigrating characterises Bulgarian emigration.

According to a feasibility study on the immigration of higher educated people, immigrant flows are to be neglected comparatively to the emigration phenomenon and mainly connected with personal reasons. The country lost one small town of 55-60 000 of its higher educated and skilled population each year during the last decade. However, a lack of data availability is burdening the detailed analysis of this process. In this respect it is extremely important to launch a survey on this topic in order to collect much more facts on flows.

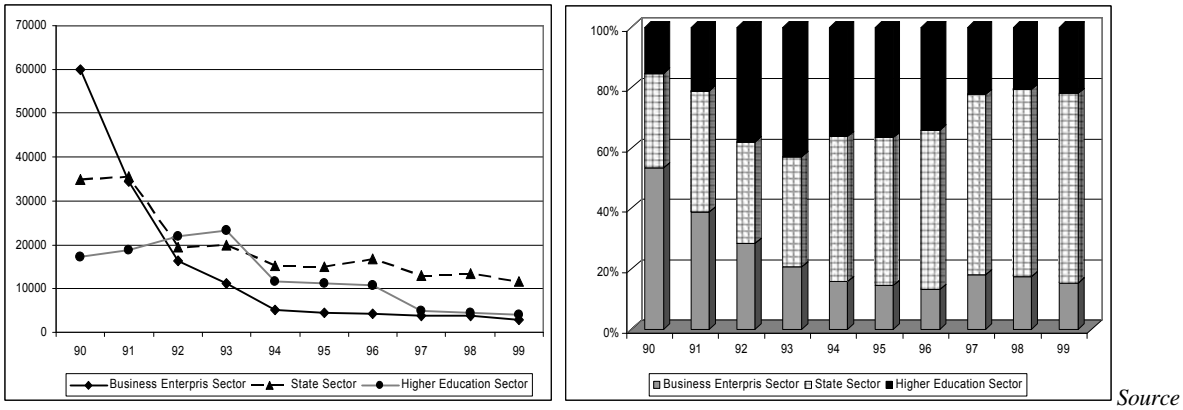
[2] COST project (1997), Brain drain from Central and Eastern Europe; ? ?????, ? . (2001) ? ??? ???? ? ??????? ?? ??????????? ? ????????, ? ???? ? ??? ? ? .

Table 4: Human resources in R&D - indicators

Years	*Researchers (FTE) per million inhabitants*	*Technicians (FTE) per million inhabitants*	*Total R&D Personnel (FTE) % Female*	*Researchers (FTE) % Female*
1996	1 765	978	52,7%	41,4%
1997	1 441	547	54,1%	45,3%
1998	1 450	589	53,1%	44,4%
1999	1 289	466	52,1%	44,0%
2000	1 160	469	53,1%	45,9%
2001	1 149	472	52,9%	46,1%
2002	1 158	466	53,9%	47,2%

Source: Eurostat

Figure 5: R&D personnel by performance sectors (levels and shares of total)



Source: Calculations by Chobanova, based on unpublished data supplied by the National Statistical Institute.

The absolute numbers show a very sharp drop in personnel in business-enterprise R&D until 1994, then a slower decline. Personnel in government R&D also dropped but less sharply, mostly in 1992. Personnel in the higher-education sector rose somewhat until 1993, but then fell very sharply until about 1997. The right panel of the Figure shows proportions in each of these performing sectors. It is clear the solvent demand for tacit knowledge is lower then the existing supply.

Challenge 4: To enhance the interactions between the different actors of the STI system

The Bulgarian STI system has a well-developed STI institutional system but with not enough mature interactions between the state/higher education R&D system and the business sector in Bulgaria. This hampers speeding the innovation processes in the country.

As stated in the Trendchart report, the innovation governance system is currently better developed in terms of structure, better established in terms of legislation and better coordinated than it was just a few years ago. Nevertheless, there are still weak horizontal and coordinational mechanisms between the main NIS institutions on central level.

Challenges both for policy and economic actors in the present situation and in the future could be summarised as follow:

- Increasing internal demand for domestic R&D activities and outcomes, mainly the business demand
- Increasing foreign demand for domestic R&D activities and outcomes
- Increasing the quality of R&D potential and quantity of R&D personnel
- Fostering domestic and international innovation networks alignment
- Increasing R&D in industry.

In this respect the definition of the priority dimensions for public support for research and innovation projects based on precise definition of the state of the art and tendencies of demand and supply of knowledge in a country is a problem of increasing significance.

3. Separate Measurement of Demand and Supply of Knowledge – Challenge to the Indicators for Science, Technology and Innovation Development

Government legislation and policy can have a wide range of impacts on research and innovation on the move towards European research area. Amongst other factors, the ability to precisely identify the sectoral and institutional priority dimensions of the policy determine the scale and scope of these impacts. The contemporary methodologies, applied for science, technology and innovation policymaking have limited capacity to identify science areas, economic branches and institutions to be supported by public funds. They do not offer measurement of supply and demand of knowledge as a practical tool for better identification of sectoral and institutional tendencies and priority dimensions for public support on national level of policy making.

Methodology –state of the art

The recent methodologies applied in the area of science, technology and innovation policy formation are based on 'positioning indicators' as indicators for input, output, and outcome of innovation. The most influential methodologies are built in the framework of the World Bank and of the European Commission as a practical tool for policy makers and scheme managers in the area of knowledge based economy development and innovation.

The research team of the World Bank has developed *Knowledge Assessment Methodology (KAM)* as an interactive benchmarking tool created for the Knowledge for development (K4D) program to help countries to identify the challenges and opportunities they face when making the transition to the knowledge based economy. The unique strength of the KAM methodology is its cross-sectoral approach, which allows the user to take a holistic view of the wide range of relevant factors, rather than focus on one area. The KAM – 2006 consists of 80 structural and qualitative variables to measure the 128 countries' performance on the four key pillars:

- Economic incentive and institutional regime for efficient use of existing and new knowledge, and the flourishing of entrepreneurship;
- Educated and skilled population to create, share and use knowledge well;
- Efficient innovation system of firms, research centres, universities, consultants and other organisations to tap into the growing stock of global knowledge, assimilate and adapt it to local needs, and create new technology;
- Information and communication technologies to facilitate the effective creation, dissemination, and progressing of information.

Innovation is a priority of all member states and of the European Commission. Throughout Europe, hundreds of policy measures and support schemes aimed at innovation have been implemented or are under preparation. The diversity of these measures and schemes reflects the diversity of framework conditions, cultural preferences, and policy priorities in the member states. The "First Action Plan for Innovation in Europe," launched by the Commission in 1996, provided for the first time a common analytical and political framework for innovation policy in Europe. Building upon the Action Plan, the *Trend Chart on Innovation in Europe* is a practical tool for innovation policy makers and scheme managers in Europe, which serves the benchmarking and the "open policy coordination approach," laid down by the Lisbon Council in March 2000. Run by the European Commission (Innovation Directorate of DG Enterprise and Industry), the Trend Chart on Innovation in Europe pursues collection, regular updating, and analysis of information on innovation policies at national and Community level. This methodology in its 2005 edition focuses on:

- Innovation drivers – to measure the structural conditions, required for innovation potential;
- Knowledge creation – to measure the investment on human factors and R&D activities, considered the key element for a successful knowledge based economy;
- Innovation and entrepreneurship – to measure the efforts towards innovation at the microeconomic level;
- Application – to measure the performance, expressed in terms of labour and business activities, and their value added in innovative sectors;
- Intellectual property – to measure the achieved results in terms of successful know how, especially referring to high-tech sectors.

In 2005 the 26 indicators, used for measuring the above five areas, for the first time were summarised as input and output indicators. The summary indicator for innovation input includes 16 indicators for innovation drivers, knowledge creation, innovation and entrepreneurship. The summary indicator for innovation output includes 10 indicators for application (to measure performance, expressed in terms of labour and business activities, and their value added in innovative sectors) and intellectual property.

On their basis a summary innovation index for each country is defined. This approach allows making attempts to measure the effectiveness of the national innovation systems, i.e. their ability to transform their innovation inputs into innovation outputs. The capacity of this methodology also allows identifying and benchmarking the recent state of the art of innovation process performance on macro and micro level, also some trends, strengths, weaknesses, opportunities and threats in fostering this process.

The results obtained by these methodologies, KAM and Trend Chart, outline the level of development of the knowledge based economy in different countries. However, they do not allow the policy makers to define precisely the priorities for public funding for economic sectors, science areas, and institutions.

A new approach

Here I argue that the separate measurement of solvent demand and supply of knowledge is a necessary step towards solving this problem in a market economy. The basic arguments have two origins. The first one is the globalization of market economy, which also leads to a speeding globalization of demand and supply of knowledge. The second origin is based on the specificity of the national context of the economic development in the global economy. For countries like Bulgaria this specificity is defined by the process of transformation of the economy during the last 16 years, and more concretely of the R&D sector.

As mentioned above, the existing methodologies do not allow the identification of the areas of science and industrial sectors, which should be a priority for public funding. In order to determine these priorities, a new typology of S&T&I indicators was developed. It groups them as indicators for supply and indicators for demand. Each of these groups is further separated into micro, macro, and international levels for both explicit and tacit knowledge. Each level includes the basic institutional sectors: public sector, business sector, university and research institutes' sector, and NGO sector. In order to allow the practical implementation of the suggested methodology and take responsibility for losing some answers to possible comments, the data used for the indicators and analysis is limited to the internationally comparable one (those, guided by OECD/Eurostat Frascati family manuals). The usage of this typology allows the priority (mainly sectoral, but also institutional) dimensions for public funding research and innovation projects to be identified. It also discloses the micro (mainly firms) foundations of the macroeconomic innovation performances. The benchmarking based on EU-average level supposes some conclusions to be made on the level of the country performance for each indicator. It also allows the general tendencies of demand and supply of knowledge in any country to be summarized.

Results

The methodological approach was tested on the example of Bulgaria, and it could be applied for identification of the national dimensions for public funding as well as for the purposes of EU policy. The data used was those of official sources, used by the above mentioned methodologies KAM and Trend Chart. For covering the gap of innovation data, a database of an innovation survey of 371 firms in the country was created. The empirical results identify sectoral dimensions for public funding research and innovation projects classified by seven criteria.

The assumption of the results shows that the globalization and the transformation lead to the lowering of the demand and supply of knowledge in Bulgaria (Fig.6). This suggests that an increase of the public funding of research and innovation projects is urgent:

First of all, the analysis shows that both the supply and the demand for knowledge need public support in order to reverse the process of losing the potential for knowledge creation (including also the brain drain phenomena).

Second, the solvent demand for knowledge is on a lower level than the knowledge supply and needs more support. It is suggested that a substantial foreign demand is required for the creation of knowledge in a small and open economy like the Bulgarian one.

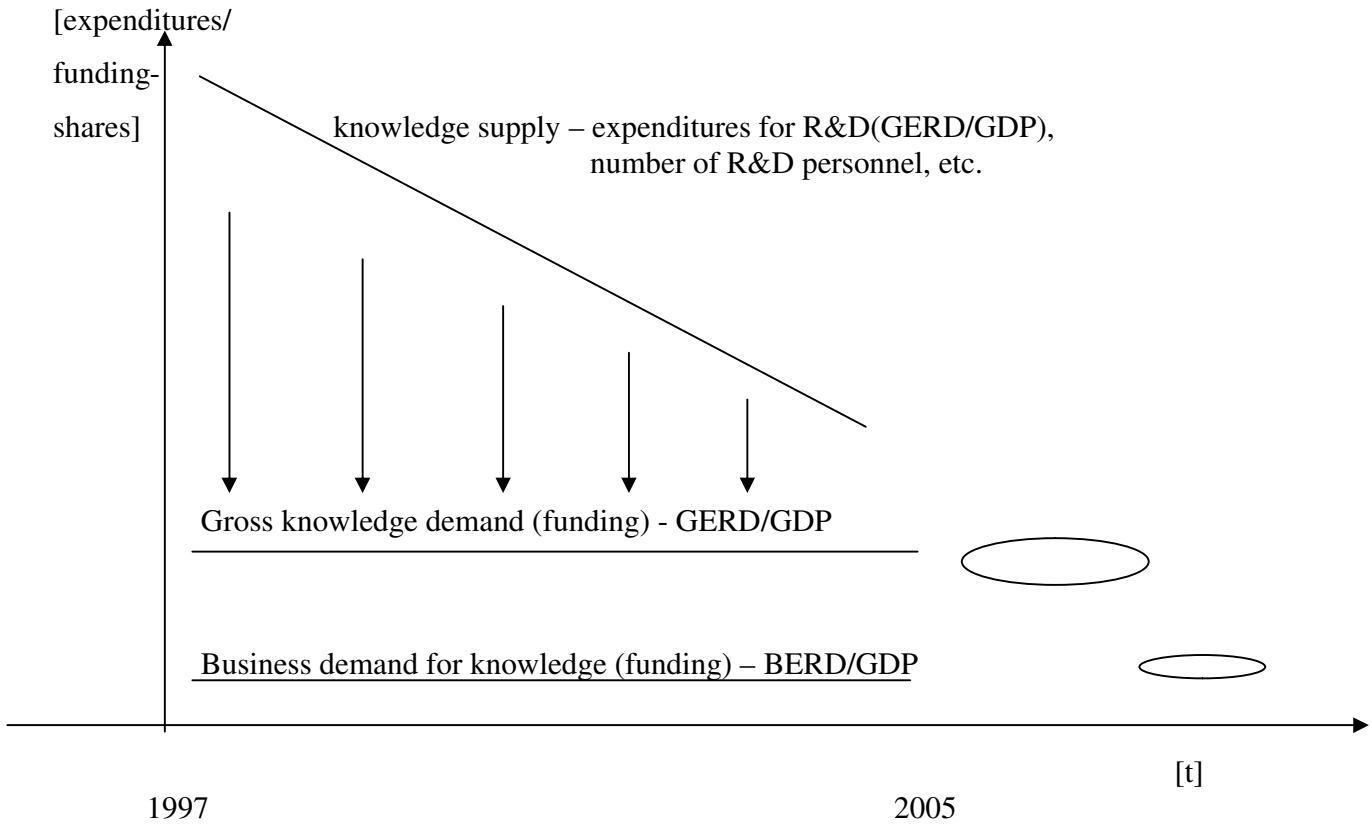


Figure 6: General tendencies in demand and supply of knowledge in Bulgaria (1997-2005)

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