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Perspectives on the Scientific Systems of the Post-Soviet States: A Pessimistic View

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ABSTRACT *This paper deals with the research and development/science and technology situation in the post-Soviet states. Since the collapse of the Soviet Union, these countries have chosen different ways to transform their S&T systems but all have so far failed to reach positive results in this process. Key features and problems of science in the main post-Soviet states, Russia and Ukraine, are the focus of this analysis. The conclusion is that further decline in S&T in these countries seems inevitable in the near future.*

Keywords: research and development, science and technology, post-Soviet states, transformation, perspectives of future developments.

Differences and Similarities between the Post-Soviet Countries

Following the collapse of the Soviet Union, all post-Soviet states inherited a substantial number of researchers and R&D institutions. Even Central Asian and Transcaucasian republics had relatively high shares of R&D staff per 1,000 members of the labour force.[1] At the same time, some authors stressed the relatively low productivity of the Soviet research system and its weak ties with the universities. In 1985, the Soviet Union had 35.6% of the world's researchers, while having only 0.2% of the world's patents. The number of students was 1.8 million, which was almost three times less than the number in the United States.[2] To a great extent, the R&D system was controlled by agents whose interests were in permanent expansion that led to over-expanded R&D, not expansion of production and service companies or individual consumers.

Now after 10 years of transition, S&T play different roles in the different post-Soviet states. The current states of Russian, Belorussian and Ukrainian R&D systems have some common features with the early stages of transformation in Poland,[3] Hungary,[4] and some other Eastern European countries, while the R&D systems of Central Asian and Transcaucasian states have completely distinctive trajectories.

Meske[5] has proposed a three-stage model for the transformation of R&D systems in Eastern and Central European countries. The last stage assumes 'new integration' to the world's R&D system. Meske suggests that the stages are common

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for all post-socialist states, but it is now evident that the 'integration' in FSU will definitely be on a much lower level than was initially expected.

During the last 15 years, the erosion of the S&T potential in the former Soviet Union has been the focus of many studies. As Etzkowitz noted, 'science lost ideological primacy to nationalism and institutional primacy to business in the former Soviet Union . . .'.[6] In fact, we have stressed the same idea by pointing out the changing functional roles of the post-Soviet S&T systems.[7]

At the same time, because the economic system of the Soviet Union, under which the R&D system evolved, has been discredited, the quality of the scientific base in many Slavic republics is greatly undervalued in the West. In fact, scientists were not only among the most highly privileged members of the Soviet society, they also enjoyed much greater intellectual freedom than their colleagues in the West.[8] Unfortunately, their involvement in the processes of the world's S&T development has been limited, as key indicators of scientific activity show.[9]

In contrast, the significance of S&T for the Soviet political and economic systems in the period after the Second World War was enormous. In conditions of relative isolation from the other developed countries, S&T were among the key factors that helped Soviet leaders to keep pace in competition with the Western world. It is difficult to agree with some authors that in the Soviet Union ties between enterprises and R&D institutions were weak.[10] This conclusion is only partially true. Enterprises and R&D institutes were integral parts of the organisations of higher level (ministries), which coordinated whole stages of innovation activities. This was especially evident in the military–industrial complex. Soviet leaders attempted to integrate their S&T policies with industrial and broader economic policies. The prime impetus for better coordination came from the efforts to direct S&T more effectively to military and economic needs.

Russian R&D institutes were at the core of the Soviet scientific system, although many scientific establishments were created in the national republics. Almost 67% of the Soviet R&D personnel and more than 72% of the total R&D expenditures in the USSR were placed in Russia. The Russian contribution in terms of R&D expenditures was almost five times greater than that of Ukraine, which ranked second among the Soviet republics.[11]

In the early 1990s some Russian and Western experts thought that Russia had better perspectives in the adjustment of its R&D system to the market economy and globalisation processes than some Eastern European countries.[12] According to different estimates, in 1990–91 Russian expenditures on R&D in real terms were comparable to those in France and the UK, while at the end of the 1990s the country is not only behind large European countries, but also Canada, India, South Korea and China.

The main idea of transformation of the scientific systems in the post-Soviet states was 'creative destruction' and re-orientation of the scientific activities from military to civilian goals. In fact, most newly-independent states could not even preserve a 'critical mass' of scientific activities to be included in lists of producers of research results.[13] In many post-Soviet countries inputs from R&D systems have failed to generate wealth-creating outputs because of an apparent systemic inability to use resources, especially information effectively. In addition, many Russian-speaking specialists left these countries for political reasons. In many cases, in the Central Asian states Russian-speaking specialists formed the core of the republican R&D manpower, and their outflow created problems not just in R&D institutions, but even in the servicing of relatively complex equipment.[14]

Table 1. Expenses in R&D as a share of GDP (GERD) in the post-Soviet countries, 1991–99

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Azerbaijan	1.01	0.75	0.53	0.69	0.51	0.31	0.24	0.38	0.42	0.38
Armenia	2.54	1.09	0.83	0.30	0.22	0.08	0.27	0.23	0.28	0.30
Belarus	2.27	1.43	0.82	0.78	0.80	0.95	0.93	0.94	0.82	1.09
Georgia	1.20	1.10	0.48	0.04	0.09	0.11	0.20	0.33	0.25	0.28
Kazakhstan	0.74	0.56	0.26	0.43	0.33	0.27	0.35	0.22	0.21	0.19
Kyrgizia	0.73	0.33	0.31	0.20	0.27	0.26	0.22	0.21	0.21	0.14
Moldova	1.57	1.03	0.55	0.59	0.80	0.75	0.87	0.94	0.88	0.55
Russia	2.98	1.89	0.91	0.94	0.97	0.81	0.98	1.06	1.10	1.22
Tajikistan	0.73	0.44	0.46	0.26	0.29	0.11	0.06	0.04	0.04	0.06
Turkmenia	0.65	0.48	0.51	0.58		0.60	0.26	0.10	0.10	
Uzbekistan	1.22	1.16	0.86	0.78	0.70	0.39	0.41	0.33	0.37	0.36
Ukraine	2.33	1.81	1.40	1.09	1.11	1.05	0.81	0.8	0.71	0.61

Source: Database of NIS Statistical Committee, 2000 and author's calculations.

Data regarding the shares of R&D expenses in GDP in the post-Soviet states in the 1990s (Table 1) show a substantial decline in R&D efforts in all post-Soviet states.

It is evident that negative tendencies can be observed in all countries except Russia and Belarus, although some experts think that these data have to be corrected.[15] In any case, data on Asian and Caucasian states show that scientific activities are at a very low level in these countries. This conclusion could be confirmed by the data on the dynamics of scientific manpower (Table 2). It is also worth mentioning that in some post-Soviet countries foreign funding has started to play a significant role in aggregate R&D. This phenomenon has two main sources.

Table 2. Number of specialists involved in R&D in post-Soviet states in 1990s (in thousands)

Country	1990	1995	1998	1999
Azerbaijan	16.4	13.1	11.4	11.5
Armenia	17.2	6.7	6.6	4.9
Belarus	59.3	26.9	21.8	21.3
Georgia	24.9	18.9	13.7	12.8
Kazakhstan	27.6	18.0	12.5	10.8
Kyrgizia	5.7	3.6	2.6	2.5
Moldova	12.8	5.8	5.3	4.5
Russia	1079.0	620.0	492.0	493.0
Tajikistan	4.4	1.8	1.4	2.7
Turkmenistan	5.7	4.0	2.2	...
Uzbekistan	41.3	16.9	13.9	15.3
Ukraine	295.0	179.8	134.4	126.0

Source: Database of NIS Statistical Committee, 2000 and author's calculations.

First, a number of R&D institutions still have strong cooperative ties with their counterparts from the other post-Soviet states. The second reason lies in the fact that R&D budgets are very low in dollar terms and any order from a Western company or a couple of grants from foreign foundations constitutes a substantial fraction of the R&D expenses in some sectors in certain countries.[16]

[t]Insert Table 2 about here[/t]

It is important to mention that the decline in financing in R&D was more substantial than the decline in the number of researchers and engineers. This means that resources devoted to R&D are much smaller now than at the beginning of the 1990s. In contrast, in some Eastern European countries the decline in R&D manpower has been more important.[17] Instead of reducing the number of employees, R&D organisations reduced their material costs to a minimum but tried to save their 'human capital'. This step cannot be explained in terms of an apparent intention to preserve the best and the most experienced researchers. Scientific organisations in almost all post-Soviet countries must pay considerable social benefits to dismissed persons.[18] In fact, in many countries the systems of financing S&T organisations proportionally to the number of their employees is still in operation. So, if directors of research institutes were to have fewer employees, they would receive less money from the state budget. The problem is that some branch ministries have no money for support of subordinating organisations, and the budget injections are in a sharp decline. During the period of transformation, all FSU countries have seen significant reductions in their research and development systems, both in terms of expenditure and personnel.

The total number of researchers in former Soviet republics, except for Russia and Ukraine and, probably, Belarus, is less than desirable. Almost all these researchers are concentrated in the academies of sciences and the universities. Any impact of domestic S&T on industries is insignificant. It is possible to expect that in the near future the pattern of scientific activities in these countries will be similar to the countries of the same size in the Arab world or in Latin America. As Radosevic noted, 'Russia . . . has been characterised by sometimes explicit and sometimes implicit policy of gradualism in R&D restructuring; there has been a strategy of "saving science" since 1990. Russia's oversized and over-manned inherited R&D system . . . is very difficult to restructure in the face of the ambiguity of market reforms in these countries, have produced patterns of restructuring, that are distinctly different from the other Central and Eastern European Countries'.[19] The same words could be applied to Ukrainian and Belorussian R&D systems. In many cases, science policy has petrified the old profile. Thus, 'path dependency' in the science system, generated some time in the past, has not been properly modified. But the positions of 'Western' post-Soviet states are still high in educational and research areas. According to a recent international expert survey, Russia occupies 18th place in the level of higher education and 11th place as the country with strong research institutes.[20]

Decline of Russian and Ukrainian Research Institutes

Dynamics of R&D indicators in both countries are similar, although Russia has recently announced changes aimed at the restoration of its position in the world, including more energetic support for the R&D sector. In fact, the R&D sector is not a focal point of economic policy in either Russia or the Ukraine despite the support

that officials usually express for 'national science'. Different laws are not properly co-ordinated as they are prepared by different interest groups.

Key players in the Soviet research system were the branch institutes within the so-called scientific and industrial complexes (nauchno-proizvodstvennyh ob'edineniy). These institutes have suffered more than other types of R&D organisations. Dissolution of these scientific and industrial complexes has led to a separation of research institutes from production units. For the institutes, this means that relations with their traditional partners have became more tenuous. The financial situation in these institutes deteriorated rapidly as a result of losing state contracts and the worsening economic situation of the enterprises. The ministries try to support their 'own' institutes, but financial resources are scarce in comparison with the number of researchers.

Having largely lost their industrial partners, the branch institutes sought to survive by securing funds from other sources. But for a number of scientific institutions, especially in the Ukraine, ties with local industries are weak, which leads to the misuse of the existing S&T potential, while the majority of scientists could not find an adequate place in the transition process. The process of transition was also greatly influenced by attempts to preserve the existing number of employees and waiting for the resumption of large-scale direct state financing. This leads to substantial imbalances between the nominal and real activities of organisations.

Many institutes had to shift to non-R&D activities that now comprise more than half of their total activities. This was accompanied by a substantial decrease of publications in these institutes, as well as by a decline in patent applications. The latter is connected not only with the relatively low level of research efforts, but also with the high price of patenting, especially abroad. For instance, the price of patenting in the USA is roughly equal to the salary of a Russian or Ukrainian researcher for 25–35 years!

It is also important to mention that design bureaux have suffered more than other industrial R&D organisations. In fact, industrial research institutes declined by more than 70% in Ukraine and by 50–60% in Russia, while design bureaux declined by 70–90% in both countries.

Most of the employees who left their positions in the R&D sector in the 1990s did so voluntarily. In other words, their release was not the result of management decisions or the consequence of liquidation or restructuring of their organisations. This demonstrates, in particular, that the decline of R&D personnel in Russia and Ukraine in the 1990s was a spontaneous process that has not been regulated properly from the side of the state. Similar trends were observed in Eastern and Central Europe in the first half of the 1990s,[21] but the decline of the sector was not so dramatic.

Governments of Russia and Ukraine created special state research centres (56 in Russia and three in Ukraine), but financial support of these centres is at a very low level, while very limited interest is shown in industry for the results obtained by domestic R&D institutes.[22] The efficiency of the fiscal and financial means employed by the Ukrainian and Russian authorities to boost demand for R&D results among companies is far from satisfactory. There are insufficient incentives for economic agents to develop and patent new solutions. The existing system of tax relief, exemptions and subsidies is imperfect and is a source of much controversy. There is a lack of strong financial and organisational ties between units operating in the sphere of S&T, on the one hand, and industry on the other, as well

as between these units themselves. A limited number of industrial enterprises and R&D units are trying to change the situation. In some cases the collapse of the old branch structure of the Soviet-type economy led to the development of new linkages between research institutes and industrial companies, and especially of direct links with foreign companies. At the same time, the changing boundaries between private and public sectors should lead to new, nationally specific structures of innovations.

In recent years, several types of restructuring have been proposed for implementation by R&D institutes. The most common one is the creation of relatively prosperous 'islands' within the institutes in the form of so-called small enterprises (SEs). These units can usually use research equipment and office space free of charge. SEs are focused mainly on providing specific technical services to financially stable companies (adjustment of Western office equipment in the banking sphere, upgrading computers and communication systems, preparation of design documentation and so on).[23]

It may be hoped that many applied research institutes and design bureaux will be transformed into relatively small research or production companies. But their future depends heavily on the speed of economic transformation in key industries. At the same time, it is also possible to note that some sectors, especially in Ukraine, have no prospect for economic recovery. Unfortunately, these sectors, such as electronics, determine the dynamics of modern economies. Without sufficient financial support from the industry, the institutes are unable to retain their best staff or update their technical base.

Serious efforts have been made to support small business in the R&D sphere while other types of innovation activities have no such support in Russia.[24] In Ukraine the situation is similar. There are numerous programmes in support of SMEs that receive financial help from Western agencies. For instance, the EU Tacis programme has provided 1.8 million Euro to build a network of business incubators in Uzhgorod, Ternopil and Rivne regions. Tacis also initiated a special competition 'Small business in small Ukrainian'. The Eurasia Foundation has provided $US190,000 to create five special business centres for SE in the Sumy region. The Foundation also participates in a special programme along with the Ukrainian Foundation for business promotion. They are working in nine Ukrainian regions offering consulting services and micro-loans to SME. The total amount of money involved in the project has reached $US1.2 million. But the number of SMEs in the R&D sphere has remained stable for several years—about 4000. The majority of employees working in these enterprises are on a part-time basis, and many of these enterprises are involved in activities that are not connected with R&D. In conditions of a general simplification of production in the Ukrainian economy and utilisation of the relatively simple technologies, SMEs in the R&D sphere cannot absorb all the specialists that left research institutes and design bureaux.

Differentiation in Scientific Communities

Differentiation among scientists is another important feature of the post-Soviet states. Plusnin studied the situation in academic institutes in the famous Russian Novosibirsk scientific centre.[25] He found that about 30–40% of scientists from academic institutes felt that they had no positive prospects in their institutes, and only about 25% were successful due to a combination of scientific and commercial

activities. Plusnin also considered the attitude of these scientists to the processes in the scientific communities and he comes to the conclusion that a substantial share of these people have serious psychological barriers to effective work as a result of chronic stress and negative emotions they have experienced in recent years. Deep dissatisfaction with the present situation is widespread among scientists in Novosibirsk.

Similar conclusions were made by Kugel[26] on the basis of his research in St. Petersburg. In accordance with his sociological surveys, made in academic institutes of the city, many scientists are dissatisfied with their present status. So, there are no 'rich' people among scientists, only 26.7% of respondents consider themselves persons with an 'average' level of income, 46.7% think they belong to the group defined as 'slightly better than poor', 20% to the 'poor', 6.7% 'beggars'. More than 25% of scientists are not buying books on their scientific specialisation because they have no funds for this purpose.

On the other hand, the situation in St. Petersburg is slightly better than in remote Novosibirsk. Up to 50% of those doctors of sciences who are working in natural sciences and mathematics receive grants from the West, while the share of representatives of humanitarian sciences with Western grants is much lower—only 18%.

Results for Moscow and some other Russian regions[27] show that more than 52% are satisfied with neither the conditions nor the results of their work and only 4.5% are satisfied completely. Negative assessments prevailed when such factors as financing of research and utilisation of instruments, equipment and machinery were considered. In addition, many researchers mentioned the fact that they have lost some opportunities for scientific contacts and publishing both within and outside Russia. Besides, the level of research supervision is decreasing and opportunities for defending dissertations are declining. Zubova's project was mainly devoted to the study of values, and it is worth mentioning that the bulk of respondents proclaimed their loyalty to the traditional values of scientific communities; however the answers to some questions showed that reality differs significantly from the ideal system.

Russia has a system of so-called naukograds or science cities. Many of them are based on older technologies (such as some nuclear energy technologies) and it is difficult to expect fresh results from their declining industries. Sixty Russian naukograds are difficult to transform into modern R&D centres. There are 10–12 institutions that could be considered technoparks with Western standards. There are plans to double that number by 2001.[28]

In Ukraine, the situation is similar, but the number of research grants is fewer and standards of living are lower. But it is worth mentioning that in both countries falling living standards, and the emergence of new opportunities outside the sector, has driven the process of decline in the domestic R&D workforce. At the same time, contrary to widespread opinion, manpower losses have involved the best as well as the worst specialists, but overall losses are very high, anyway.

To recapitulate with some degree of simplification, it is possible to discern several groups that emerged from the scientific community in recent years in the key post-Soviet states. We can use the actual involvement of scientists in different types of activities as the primary characteristics of each group.

- First, scientists–entrepreneurs who have their small enterprises that operate in domestic and foreign markets.

- The second group consists of old Soviet directors and top managers who usually have shares in these newly established private organisations, as the institutes permit the commercial use of scientific equipment and office space. In the Soviet Union there was a direct correspondence between bureaucratic and administrative positions. This led to the system of values typical in bureaucratic organisations. So, for directors of the institutes, it was usually possible to be an Academician or a corresponding member of the academy. Communist Party officials tried to obtain scientific degrees. Even members of the Central CSPSU Committee could receive the status of Academician. This old nomenklatura still controls the lion's shares of financial resources in the post-Soviet states, especially in Ukraine and Belarus, where democratic traditions in science were especially weak. A new phenomenon of scientific organisation in these countries is connected with the emergence of different 'branch' academies under the control of directors of branch institutes. This was a response of 'marginal' elites from branch sectors to try to preserve control over financial resources distribution and influence even after the collapse of branch structures in industries. As mentioned above, these 'marginal' elites actively participate in the redistribution of property in the modern Russia and Ukraine by selling or leasing office space and equipment.
- Third are those who have Western grants and who can continue scientific activities.
- Fourth are those who are still formally associated with the research institutes, but are working outside the scientific sphere.
- Fifth, those who receive miserable salaries in the research institutes and have no other means for survival, except, probably, small agricultural plots to grow fruits and vegetables for private purposes.

The problem lies in the fact that the number of researchers from the fourth and fifth groups is growing much faster than the number of researchers in other groups. Very few professional organisations of researchers are really active in lobbying on behalf of scientists. In Russia, the Scientific Union of St. Petersburg is the only remaining fragment of the All-Union Scientific Union created in 1990.

The Problem of Emigration

Losses from emigration are already significant in the Ukraine and Russia. This is especially true in the case of intellectual potential. The estimates are based on the assumption that 9–11% of all emigrants are former employees of the R&D sector. About 1% of all emigrants are specialists with scientific degrees. Officially, about 5,000–6,000 scientists have emigrated from Russia and Ukraine in recent years. These figures do not appear to be very high, but in some sectors they are particularly significant. As sociological surveys show, shares of specialists in mathematics, physics and biology among emigrants from the research institutes are extremely high.[29] That means that for some specific areas losses were critical. In many cases official statistics do not reflect the real processes that take place. So, in accordance with the results of Belorussian Institute of Sociology survey, up to 30% of all emigrants from the country had higher education. An intention to emigrate or to work abroad on contract was expressed by 15% of scientists. Among the younger group of scientists and post-graduate students this share was much higher—34.2%.[30]

Very often many emigrants from the former Soviet Union could not find work in accordance with their qualifications in recipient countries just after emigration. This was especially true in the case of Israel in the early 1990s. This comparatively small country simply could not properly absorb a flow of highly qualified emigrants in 1989–91, although Israel has a long-standing and successful record of human capital utilisation. With the passage of time, the knowledge and skills of R&D specialists from Ukraine and Russia have been used with increasing efficiency.[31] According to calculations of Russian specialists (Tsapenko & Yurevich, 1995) Russia loses about 300,000 USD with the emigration of each scientist. Among emigrants from Russia, mathematicians and specialists in software dominate (52%), biologists possess the second place with 27%. Some experts suggest that the number of science administrators and the number of 'real scientists' among those who emigrated from the country are about equal. The more radical estimates also assume that those scientists who have not left Ukraine and Russia are 'simply more patriotic persons and have plans to work in their own country despite all hardships than those who emigrated'.[32] This position is close to the position of many top officials.

It would not be right to mention 'pure' emigration only. There are other forms of migration of highly qualified specialists from key scientific institutions. So, according to official information, approximately 700 specialists left the Ukrainian Academy of Sciences only in 1989–92 for long-term business visits and training. More than a third of them have not returned, although they are still considered as members of the Ukrainian research institutes. A growing number of scientists use 'unofficial' (that are not under the control of administrators of the research institutes) channels to go to the West. They participate in training programmes, receive stipends from foundations, etc., without even consulting with the heads of their institutions. Such behaviour could not have been imagined in the former Soviet Union.

Let's consider an example connected with the National Academy of Sciences of Ukraine. Recent data show that in 1997, 530 scientists (among them 100 doctors of sciences and 320 candidates of sciences) from the National Academy of Sciences of Ukraine left the country to work abroad in accordance with long-term contracts, while only eight doctors and 25 candidates of sciences emigrated.[33] As to emigration from the National Academy of Sciences in 1999, only 35 persons (seven doctors of sciences and 23 candidates of sciences) left the academy to stay permanently in foreign countries, but it is more important that 377 persons (95 doctors of sciences and 255 candidates of sciences among them) from the academy have received long-term contracts for the work abroad. Many do not cut their ties with the home country and they even preserve Ukrainian passports, but they do not return to Ukraine, rather they continue to work abroad on a permanent basis. This can be explained by a number of reasons, namely tax regulations, visa rules and so on. In any case, these data show that emigration has changed from its traditional forms and this has yet to be studied.

Some cases are well known and may be representative of a positive impact of emigration on R&D in the post-Soviet states. For instance, the most prominent Ukrainian biologist and one of the youngest members of the Ukrainian Academy, Yuri Gleba, is dividing his time between Ukraine and the USA. He spends more time in America than in Ukraine, but he uses his Institute of Cell Biology and Genom Engineering of the Ukrainian Academy of Sciences as a partner in joint projects. Scientists of the institute receive orders from American companies and this enables them to work with modern equipment,[34] but such examples are not numerous.

Speaking in general, in the second half of the 1990s three new tendencies appeared in the pattern of emigration. First, emigration became 'professional' rather than 'ethnic'. There was a strong evidence of outflow of specialists irrespective of nationality from Ukraine and Russia during 1995–99. For the first time Russians and Ukrainians began to receive permission to emigrate to developed countries under the classification of specialists, rather than as refugees or family members. Second, the will to emigrate grew stronger among young scientists. Many young people are trying to pass exams to enter Western universities or to receive long-term working contracts in the West. Third, there has been a change of direction in emigration, especially in Ukraine. From the second half of the 1990s a remarkable number of specialists left Ukraine for Russia—mainly from the military–industrial complex and the nuclear energy industry. To a great extent, this is because the difference in salary between specialists in Russia, particularly in the nuclear energy sector or in some military-oriented companies, and their Ukrainian counterparts, is very substantial. The process of emigration to Russia is not primarily a result of ethnic problems. The introduction of the Ukrainian language, as the one and only state official language in Ukraine met a negative reaction from the research community.[35] Traditionally the bulk of scientific literature was published in Russian and dissertations and papers were also written in Russian.

But it is important to stress that the problem of internal relocation of educated persons is more serious than the problem of emigration. Low wages and lack of orders for intellectual products have led to an outflow of millions of educated people to other sectors of the national economy, and primarily to private businesses.[36] This process could not be considered as purely negative, because the effectiveness of the whole economy could rise as a result. The pressure on state budget is eased and preconditions for old colleagues from R&D institutions are usually maintained. The diffusion of former researchers from R&D into other sectors could bring positive results at the present stage of economic recovery. Unfortunately, the absolute majority of former scientists have undertaken relatively simple work that does not require their scientific qualifications.

The main threat to the intellectual potential of both countries comes from hidden emigration. This type of emigration is based on a combination of formal maintenance of the workplace in a scientific institute or design bureau while pursuing other work that is not connected with R&D. This is a widespread practice in modern Ukraine and Russia. Many specialists formally associated with R&D institutions or production enterprises spend the bulk of their time on outside activities and mainly in the retail trade.

The main reason for this situation is the above-mentioned lack of demand from this side of industry, but actually the state supports this kind of activity indirectly by compelling people to take long unpaid leaves or by delays in salary payments.

Deterioration of the Age Structure

The aging of the scientific community became the leading factor of potential erosion of R&D. A number of models are proposed to simulate processes of R&D manpower dynamics. So, Varshavsky[37] proposes to use a variant of a manpower relocation model that is based on wage differences between sectors. In accordance

with his calculations, if the situation in Russian science does not change, the number of researchers will fall by more than half by 2015. Were R&D salary levels merely 10% higher than the average level of salaries in the country the existing number of researchers could be preserved.

Another approach has been used to estimate the level of possible decline of scientific manpower in Ukraine.[38] While information about doctors and candidates of sciences was available, unfortunately, no data about the age structure of other researchers was available. These groups form the core of the research community, and we think that their dynamics may reflect the main characteristics of the whole process of change. A Forrester model of system dynamics has been used for the simulation of the R&D personnel aging processes. Six main age groups were studied in this model. Estimations of the inflow and outflow of specialists to and from each group were made on the basis of expert opinions and existing statistics. For instance, these data show that the outflow from the most productive groups of scientists (aged 30–50 years) is four times more intensive than inflow into such groups, while differences inside some other groups are less significant. At the same time, overall numbers of persons with scientific degrees and those that are involved in R&D activities is in permanent decline. In 1995 up to 40% of all candidates and doctors of sciences were involved in scientific activities, while in 1999 only 31% were. Many have changed their place of work to take positions in business or state administration. Usually they do not return to the R&D sector. The simulation model enabled several different combinations of parametric variants. Calculations show that the age structure of the scientific community in Ukraine will deteriorate significantly when groups of researchers older than 51 years constitute up to two-thirds of all researchers in 2015. The most energetic people will leave R&D and the gap between generations will continue to widen. This raises significant questions about the functions and possibilities for sustainability of the Ukrainian research community in the next 15 years.

The age distribution of researchers in Belarus is very similar to that of the Ukraine. The only difference is a slightly higher share of those in the 40–49 years group. But the gap in junior categories is evident. It could be argued that inertial processes in Belarus are stronger due to fewer market-oriented changes in the national economy.[39] Data about the age structure of Russian science also show that processes of aging are advancing. So, in the Russian Academy of Sciences, the share of researchers who are under 40 years old fell from 42.3% in 1992 to 28.1% in 1998, while the number of researchers of pension age jumped from 8.4% to 19.8% during the same period. More than half of all doctors of sciences are pensioners and the average age of academics is over 70.[40]

The long gestation period during which very few young scientists are brought into the research system will be seriously detrimental to scientific progress. Science has long been characterised by the influx of the young researchers and dynamism they bring to research: the present situation is unique in the recent history of science in the post-Soviet states and its ramifications for the future are not favourable.

Conclusions

While financial support is of considerable concern, the aging of the research community and the obsolescence of their research equipment poses the greatest threat to the future of R&D systems in the former Soviet Union. The great bulk

of researchers in the main post-Soviet countries are in their maturity, and opportunities for recruiting young scientists are very limited. It applies analogously to the aging of research equipment. The obsolescence of the tools of research is particularly evident in natural and life sciences and in some engineering areas. The problem developed over many years and has now reached such proportions that neither quick nor inexpensive solutions are feasible. Maintenance and repair resources, usually less than 2% of the research budget, tend to be used on more expensive equipment, so researchers often repair their own equipment. Because equipment is expensive to replace, institutions seek ways to extend the 'life' of their equipment, keeping what they have for longer. Much of the older equipment is frequently in need of repair. Most of the research tools cannot compete with modern Western equipment. Thus, scientists from the post-Soviet states have very limited possibilities to obtain results that will be comparable with the results of their foreign colleagues. The outlook on research instrumentation in main post-Soviet countries is not promising in the near term. It is clear that government action is required to arrest and reverse the changes in the research system, but it seems that resources are so limited that further decline is inevitable. At the same time it is clear that without remedial action, the productivity of the system will continue to fall, with negative consequences for the economy as a whole.

The role of the R&D sector in the post-Soviet states declined radically in the 1990s. Despite numerous declarations from the national leaders in support of S&T, the real priority of the sector is extremely low. Under-financing and the outflow of scientists to the other sectors of the national economies were the main reasons for weakening of S&T in these countries.

It is evident now that arguments for lessening state control over the process of transition is not working in many cases, especially in transforming the R&D system. Weakness and uncertainty of S&T policy has conspired with the economic crisis to inflict loses on manpower and technical assets in all post-Soviet states, and indeed to produce unfavourable structural changes. The crisis in former Soviet Union countries can be solved only by co-ordinated efforts of the state and scientific communities. The challenge to government policy in the area of S&T is how to mould the remaining national research capabilities into a pattern which will contribute better to processes of economic recovery. For the time being, however, R&D 'assets' are considered largely as a liability. This is partly a result of structural and organisational mismatches, partly because of the low immediate relevance to new market realities. Competition from the side of foreign companies is growing and simplification of production reduces the demand for R&D results from the local industries.

All post-Soviet countries urgently need not only serious transformation within the S&T system, but also important changes in its institutional environment. So, the introduction of adequate legal protection for intellectual property rights is of critical importance for S&T institutes and science-oriented SMEs. This is also very important for foreign companies seeking to engage in direct investment or some other form of business alliance, and for domestic companies that co-operate with them. Development of facilities for provision of venture capital is also underestimated in the post-Soviet states, but this development is of equal potential importance for S&T organisations, and companies involved in international business co-operation. For the large post-Soviet states the introduction of local-content stipulations in relation to S&T development would be very useful. Existing

schemes are not very effective. At the same time, leaders of the post-Soviet states have to realise that it would be prohibitively expensive to develop and maintain the potential research capabilities of all of a nation's research institutes at a uniformly high standard.

To summarise it would be possible to conclude that post-Soviet states have neither institutions nor the proper instruments (developed market-based economy, independent scientific communities) necessary for effective transformation. Unfortunately, every year the possibilities for the implementation of an effective transformation policy are shrinking. In the economic sphere a key precondition for successful change is the switching to an intensive growth policy, which has to be based on innovations. Several years ago Torok[41] predicted that the technological gap would widen between developed and some post-communist countries. It seems that this prediction has come true in the case of post-Soviet states.

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14. In Tajikistan, hydroelectric stations and enterprises are on the brink of closure thanks to emigration of Russian-speaking specialists—*Zerkalo Nedely*, 10 June 2000.
15. See, for example, Adaptatsiya nauchno-innovatsionnoi sfery Rosii k rynochnym usloviyam y puti povysheniya ee effektivnosti, *Report of the Bureau of Economic Analysis of the Government of the Russian Federation*, Moscow, 1999.
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18. For example, in Russia and Ukraine, research institutes usually have to pay the equivalent of a salary for 6 months to any dismissed person.
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23. Managers and directors of the institutes usually have shares in these enterprises and they can receive substantial dividends, while the bulk of employees are suffering from permanent delays with miserable salaries. The Ukrainian, Gazproekt Institute is the typical example of this type of asset stripping. The director and several top managers concluded contracts with Libyan and Algerian companies on pipeline designs on behalf of the institute in the early 1990s. But the money was channelled through the director's private company registered as a SE. As a result, the lion's share of the money is, allegedly, in the personal accounts of the director and his assistants in Germany, while the majority of researchers and designers received nothing from the contract. In this case the institute has been used as a formal legal body and the source of labour to facilitate the contract. The institutes are used not only by their management, but also by ministry apparatchiks to solve their personal problems. Ministry officials provide institutes with useless 'research' contracts and receive money as consultants and scientific workers. There are a number of cases in Ukraine when, it is claimed, ministry officials received up to 80% of money from such contracts.
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