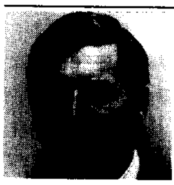
Science and technology in Central and Eastern Europe: after the revolution

Science and technology are increasingly important as drivers of change and foundations for economic growth and international trade. Government policies in the industrialised nations of the West and Asia that stress research and development, science education, and industrial research reflect this belief.

While this goes on in the industrialised countries, the nations of Central and Eastern Europe are preoccupied with the struggle to create market economies and political democracies from the ruins of the failed communist era. Simultaneously, the systems for science and technology inherited from the past are undergoing change and restructuring.

What is the outlook for this reform, and for science and technology in the region? What are the strengths and weaknesses as matters stand, and what is the potential for these countries to compete in technological areas? These issues, critical for the future of Central and Eastern Europe, are among those examined in this article.



John H. Moore, Director of the International Institute of George Mason University, Fairfax, Virginia

Introduction

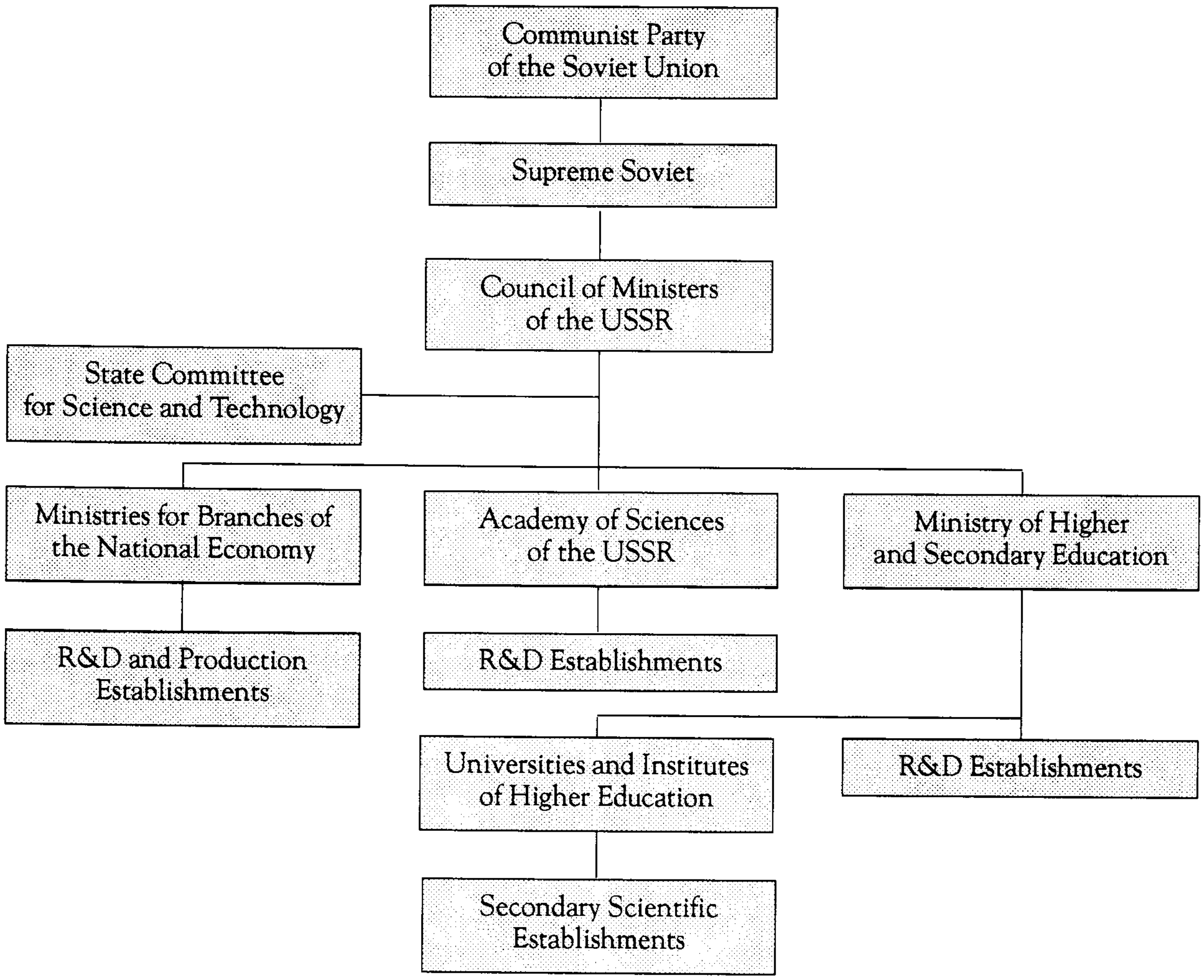
During the four years since the collapse of communism in Central and Eastern Europe,* attention has been focused primarily on political and economic reform. With less fanfare, the science and technology systems have also been undergoing scrutiny, criticism, and reform. Subjected to the same kind of centralisation and control as the economic systems under the old regimes, science and technology have heritages that are no easier to shed than those in politics and economics. Just as the political and economic reforms have proved to be difficult, so there are serious problems in reforming science and technology. And, just as the restructuring of the economic and political systems reflects the particular histories and circumstances of the individual nations, so reform of science and technology is taking place in circumstances that vary from one place to another. Finally, change in science and technology, like that in the broader sphere, is the result of a rich brew of rational planning, political struggle among competing interests, and spontaneous developments that depend on local circumstances.

The science and technology systems that emerge from this complex process will have a powerful impact on the futures of these countries. Economic growth will be affected by the effectiveness of research and its applications. But many other aspects of life, from health care and life expectancy to environmental improvement to national security will be affected as well. In some respects, the less prominent reforms in science and technology will have long range effects at least as great as the more publicised efforts in other spheres.

What are the key problems in science and technology? What is their background in these

*Most of the attention here is directed at the members of the former COMECON – East Germany, Poland, Czechoslovakia, Hungary, Romania, and Bulgaria. Former Yugoslavia is a special case, as always, and the general comments made about conditions in Central and Eastern Europe usually do not apply to it.

FIGURE 1: ORGANISATION OF R&D AND HIGHER EDUCATION: THE SOVIET MODEL



Adapted from Zaleski et al (1969), p. 53, and Cocks, p. 19.

countries? What changes are being made, or are likely to be made? What are the opportunities and prospects for the future? These are among the questions that are explored below.

Commonalities

The nations of Central and Eastern Europe were forced into a general mould specified by the former Soviet Union, but the mould was stretched and bent by the fact that each country had its own unique history and culture. These differences were reflected in the particularities of the economic and political systems that developed under Soviet hegemony. They were also reflected in the science and technology systems. However, the systems overlaid by the Soviets on the individually distinctive countries created certain common features; these commonalities are now at the heart of the efforts to change the science and technology systems.

From command to market economy

The Soviet system of economic administration, here termed the command economy, was imposed throughout Central and Eastern Europe. This had important consequences for economic performance, of course, but also for science and technology. In the economic realm, the command system brought with it centralisation of authority, compartmentalisation of economic sectors, the substitution of hierarchical for horizontal relationships among industrial enterprises and other entities, and the use of a system of incentives generally linked to physical outputs rather than financial outcomes. (See Zaleski (1980) for a thorough analysis of the paradigmatic Stalinist command system.) In some respects the COMECON members were used by the Soviets as auxiliary entities whose production was intended to fill gaps in Soviet economic plans. Today's industrial structures in the former bloc countries reflect this; some of the industrial white elephants – the great steel mills, for example – that present the worst headaches for the reformers are the result of this practice.

Science and technology was similarly centralised in the Soviet system. Figure 1 presents a simplified view of the organisation of higher education and research and development in the former Soviet Union. This basic model was repeated, with local modifications, throughout the satellite countries. As seen in the chart, research and education were under central administration. Nearly all research was conducted either in institutes belonging to the Academy of Sciences of the USSR (where most basic research was done) or in institutes attached to the various branches of industry (mostly applied research), themselves under the purview of the centralised command system. The universities were controlled by the Ministry of Education. In all of this, the ultimate authority resided in the Communist Party of the Soviet Union (CPSU), which was particularly concerned with the control of ideological issues – precisely the stuff of research and, especially, education.

The influence of the central plan pervaded science and education as well as economic performance. In the Soviet system, the State Committee for Science and Technology was the key agency in which plans for research and education were developed and coordinated with the overall economic plans produced in other agencies. Research was, to varying degrees, keyed to plan objectives and subject to priorities laid down by the CPSU and central government. For example, defence-related research generally had priority over purely civilian research. Institutes conducting defence-related research received not only more resources than other institutes, but also better quality resources. Fields of science that were perceived as having potential for defence applications were relatively well-treated and left more at liberty to follow undirected paths; this is one reason for the excellence of Russian physics, for example. Not all research was centrally directed, nor was excellence only to be found in defence-related fields, but the general pattern was clear.

The system of higher education was also subjected to central planning. It does not exaggerate significantly to say that its main function was to supply graduates to the economy in numbers thought necessary to meet broad plan objectives. Universities essentially lost their research functions or had relatively unimportant research programmes. This is not to say that the system produced poorly-trained scientists and engineers. Although the education provided in the social sciences or humanities was often ideologically loaded and of dubious value, that in the natural sciences and engineering was generally of high quality. As with research, high priority was given to some fields because of their special importance to the regime.

This system was imposed on the former bloc countries, which, along with the former Soviet Union itself, are seeking to transform their systems from the old centralised command system to decentralised market economies. The difficulties of doing so have been made only too evident by the events of the last four years. Again, the transformation of the economic system has important implications for science and technology. There must be some systemic correspondence between the two systems if the science and technology system is to operate effectively in a new decentralised market setting. In particular, a hierarchical system in science and technology, with an incentive structure that would inevitably run vertically within the system, would not be effective in transferring technology to the firms in a decentralised market system*. Perhaps more importantly, a research organisation in a market system must be responsive to market forces; in particular, it must respond to price signals that are generated in the market.

*Experience in the US with its vast system of national laboratories funded by the Federal government has shown how difficult it is to mate a centrally funded research system, even one that is much more decentralised than the old Soviet system, with a decentralised universe of individual market-driven firms. The exceptions to the rule of difficulty are the National Institutes of Health, where there is a combination of in-house research and external, sponsored research in universities (and thus a link to a highly decentralised system), and the aerospace industry, where the number of private sector firms is relatively small and there has historically been much defence-related work and therefore an element of hierarchy intruding in the private sector side. It has been especially difficult to develop any effective method for transferring research results from the national laboratories to small- and medium-sized firms.

From politically constrained to free systems

The impact of politics on science and technology in the old systems is hard to overstate. It went far beyond the central planning of research programmes or higher education. Certain fields of science were subjected to ideological control; the infamous Lysenko episode in the Soviet Union is only one example of this. Some fields, mostly in the social sciences, were so ideologically fettered as to be virtually worthless from a scientific point of view. Funding of research depended heavily on the political influence of a laboratory director or individual scientist. Appointments to research institute staffs were frequently made on the basis of political connections rather than ability, creating an overhead of intellectual deadwood that is a major problem today. Political reliability was the primary qualification for university faculty members, and less reliable but nevertheless capable professors were moved to Academy research institutes. While not quite in the same vein, anti-Semitism played a role in limiting research in some parts of the former Soviet empire; mathematics in the former Soviet Union is the prime example.

All of this was greatly resented while it was being carried out and is not forgotten today. The impact on the quality and quantity of research is obvious. There is virtually universal recognition of this and a corresponding widespread determination to de-politicise science and education. But, like everything else in this post-revolutionary period, the matter is not as simple as it might seem.

First, in the scientific community as well as elsewhere, many people who were politically favoured under the old regime now profess to be reformers. Many of those whose positions were gained in the old system are fighting to retain them. This often takes the form of defending the former system, and is particularly evident in the defence of the old Academies of Science, which are understandably reluctant to see their power and budgets reduced.

Both the desire to de-politicise the systems and the need to match the structure of the new science and technology systems to the emerging market economies carry implications for the universities. Despite the fact that universities had a major role in research in the pre-war period, this was gradually removed as the Academy structure was developed. This was due to two factors. First, Academy institutes could be more easily bent to the task of carrying out research to meet plan objectives, so funding and the most capable researchers were shifted from the universities to the institutes. Ideological control of the universities also contributed to the shifting of faculty to the institutes. By the time of the 1989 revolutions, the function of the universities had been reduced to almost complete focus on instruction.

Western experience, especially in the United States, suggests that the combination of research and education (particularly graduate education in the natural sciences and engineering) is highly effective for both the development of new knowledge and its transfer to applications. The combination contributes to the vitality of teaching, since professors who are actively engaged in research are stimulated to remain abreast of developments in their subjects and can communicate the state of the art to their students. Graduate students are themselves highly stimulating to research, bringing fresh approaches and an experimental spirit to their work, and thereby complementing the ideas and work of the faculty. Graduate students are also highly effective conveyors of new knowledge when they complete their studies and enter the workforce.

All of this seems to be recognised in Central and Eastern Europe (see, for example, Drobnik (1992), p. 89), and there is a general movement to restore research to the universities. However, this too is not a simple matter. Restoring university research means a reallocation of resources, which means taking money from the institutes. Especially now, when all of the countries are experiencing deep budget crises, this is extremely difficult politically and must be one of the reasons that the Academies are fighting so hard to retain their positions.

From isolated to open systems

Science is known as the universal language and is traditionally international in scope. But science, and especially scientists, in the former Soviet Union and its satellites became isolated from the West and, to some extent, from the rest of the world. Uniquely in these societies, there was also a kind of internal isolation. This isolation is one of the most remarkable legacies of the communist period. It continues today, but the cause now is financial rather than political.

Isolation resulted from a number of causes. Travel was tightly restricted under the old regime.

Only scientists who were considered to be politically reliable could travel to Western countries, and then generally accompanied by members of the state security apparatus. Agreements to exchange scientists were cautiously negotiated and carefully supervised; for years, the agreement between the US National Academy of Scientists and the Academy of Sciences of the USSR provided for a very small number of visits by Soviet scientists and required, at Soviet insistence, that the Soviet scientists be selected by them rather than by their would-be American counterparts.

Even contacts between scientists from different bloc countries were limited by the nature of the COMECON system. Since the science and technology systems of the member states were seen as resources to be used by the Soviets, and because of the universal suspicion that pervaded the system, there was little provision for intra-bloc exchange, travel, or contact. In addition to these restrictions on foreign contacts, access to foreign literature, even technical literature, was controlled. Finally, the nature of the totalitarian state, with its networks of informants and continual surveillance, had a chilling effect on communication among scientists.

The impact of these restrictions on science is well understood in the countries of Central and Eastern Europe; it is hardly necessary to mention that all of these controls were bitterly resented or that their removal was among the most immediate objectives of the reformers. In fact, the only real impediment to close contact with foreign scientists now is economic. The financial situation in all of these counties is so poor that funds for foreign journal subscriptions are nearly unavailable, let alone money to support travel abroad for conferences or research visits. Research institutes lack the funds for routine maintenance or supplies for experiments, and salaries are so low that many scientists are simply abandoning their research careers. For the best researchers, overseas opportunities exist, and many have left for positions in Western Europe and North America. These fortunate individuals represent a significant break with the isolation of the past, but their absence imposes a cost on their home countries. (One Russian institute director has said that he would prefer having his top people working abroad rather than being idle at home, since they at least stay abreast of developments in their fields that way. He is confident that they will return in due time; of course, he may be wrong.)

From education for the plan to education for the future

Along with industrial production, research, and much else in East European life under Soviet domination, education was bent to accord with the objectives of the political leadership. In higher education, this frequently meant dramatic shifts in the structure of specialties, away from studies in pure sciences or the arts and humanities and toward more technical or vocational fields. In Romania, for example, between 1970 and 1989 higher education enrolments in the arts, sciences, and humanities fell from 40% in 1970–71 to less than 10% in 1989–90. During the same period, enrolments in engineering rose from 30% to 65% (World Bank, 1992, p. 191). Places in higher education 'are allotted by specialisation, and the number of places per specialisation was determined by the projected manpower needs from the central plan' (World Bank, 1992, p. 84).

Thus higher education was seen primarily as an instrument of central economic administration. Education under communist rule may be seen better as the production of another input to the economic machinery, akin to capital investment, rather than providing individuals with the opportunity to develop their talents and interests in the tradition of Western liberal education. That is why higher education in these countries produced thousands of natural scientists and, especially, engineers. Non-technical fields of higher education were neglected or deeply distorted by ideology, again for political reasons. In these senses, the purpose of education – and especially higher education – was to benefit the state.

The systems left a complex legacy. On the one hand, the emphasis on science and engineering produced vast numbers of trained individuals, many of them highly talented, a reservoir of human capital in these fields that is a valuable asset. It is also likely, however, that rather large numbers of persons who were trained in these fields did not in fact have comparative advantage in them. It is well known that there has been overstaffing in many research institutes and that productivity is relatively low. Dealing with this aspect of the heritage, which may involve large layoffs and redundancies, is already proving to be a difficult task.

On the other hand, there is a dearth of educated persons in other fields, and a poor educational infrastructure to correct that situation. For example, the entire field of business administration for the market economy simply did not exist under the old regimes. Managers who received training were trained in management methods appropriate for the central planning system. They are notoriously ignorant of market accounting methods, banking, personnel management, and most of the rest of the tools of management in market economies.

But the problem goes deeper than that. Apart from the best natural scientists (whose talents were great enough that independent thought was natural, and who were afforded opportunities for independence denied to persons of lesser ability), people did not emerge from the educational systems with the habits or even the abilities of independent thought. Technical training was just that: it trained people for the technical tasks they were expected to take up in the workplace. In the social sciences and humanities, education consisted mostly of the inculcation of dogma. Questioning authority was not only discouraged but even dangerous, since controlling dissent and indoctrinating the population are crucial to the political survival of totalitarian regimes. But the consequences of success in this regard are grave. Surely the habits of mind thus developed – or destroyed – were critical factors in the ultimate economic failures of the communist system.

Now, reform and restructuring in the economic and political spheres must be accompanied by fundamental change in education. Higher education for the state must be replaced with higher education for the individual if the kind of individual initiative that is required for the success of a market economy is to be developed. Even if educational reform is successful, there will for many years be large numbers of people whose habits of mind were formed under the old regimes. The opposition to restructuring that has been visible already is due in part to the understandable inability of many such people to adjust their ways of thinking to a way of life that is foreign to their education and experience. Of course, this problem varies from place to place, depending on the particular histories involved. But the backlog of people whose mental equipment was developed and hardened around communist era thinking will continue to be a reactionary element in Central and Eastern Europe. A survey taken in Russia in early 1992 (Boeva and Shironin, 1992) that compares attitudes toward aspects of the reforms reveals striking differences by age group. Generally, younger persons display more positive attitudes towards privatisation, the entry of foreign capital, private farming, individual initiative, and the change in government than the older generation.

Problems

A wide range of serious problems afflicts science and technology in the region. Some have already been noted, but there are many others.

The financial crisis

The most obvious problem, and one of the most serious, is due to the economic collapse that accompanied the fall of communism. In every country, output fell dramatically in the first years after the 1989 revolutions (Table 1), and there is little indication that the situation will improve in the immediate future.

As Table 1 indicates, only in Poland is there any real indication that the corner has been turned. According to official data, industrial output in 1992 was slightly higher than in 1991, although still 30% below the level reached in 1989. GDP held steady in 1992 after large declines in 1990 and 1991. Agricultural output also rose between 1991 and 1992, although still 15% below the 1989 level (Bossak, 1993, p. 43).

These drops in production have caused huge budget deficits; since research and education were financed primarily from the central budgets, funds to support them have fallen precipitously. For example, R&D spending in Poland fell from about 1.6% of GNP in 1988 to about 0.6% of a much smaller national product in 1992 (Izdebska, 1993).

Individual institutes were told that they must find funds on the market to replace those cut from the central budget. In addition to placing a new burden on institute directors, this will lead to shifting research toward applied work that can

TABLE 1: *National income trends in Central and Eastern Europe, 1990–92 (%, year on year)*

Country	1990	1991	1992*
Bulgaria	–11.8	–22.9	–15.0
Czechoslovakia	–0.4	–15.9	–8.0
Hungary	–4.0	–10.2	–5.0
Poland	–11.6	–7.0	0.5–2.0
Romania	–8.4	–13.0	–7.0

*GDP.
Data from Bossak (1993).

attract commercial sponsors. Salaries of research staff have been cut throughout Central and Eastern Europe, a problem made worse by high rates of inflation. As a result, some scientists have found opportunities in the West and have emigrated – the notorious brain drain. This has stripped the East of some of its most talented people. But there is also an internal brain drain, as scientists (especially, apparently, younger ones) who are discouraged by prospects in research leave it altogether to enter private business.

Both brain drains have been widely noted and disparaged by external commentators. However, these developments may not be entirely negative. Research establishments are notoriously overstaffed, and therefore reduction is desirable (some indication of the extent of overstaffing can be deduced from experience in East Germany after reunification, where the restructuring of research institutes led to a reduction in employment of two-thirds (Sabel, 1993, p. 1756); for comments on the situation in Poland, see Lepkowski 1992, p. 9.). In a functioning market system, individuals make decisions based on alternative opportunities open to them. The changes in Central and Eastern Europe are creating new opportunities for many people who have been engaged in research. To the extent that individuals in research are responding to these opportunities, the brain drains represent an expected adjustment.

But this is an overly sanguine view from the standpoint of long range scientific capabilities. Positions in the existing research system have become much less attractive primarily because of the budget problems. The brain drains are cause for concern if the eventual political outcome results in substantially higher budgets for science, in which case the current, short-run adjustment would be reversed at some cost, or if the process by which people are moving out of science has adverse selection characteristics. About eventual budgets for scientific research, essentially nothing can be said; the political and economic future is so unclear and the sense of priorities so uncertain that years will elapse before funding for scientific research will be stable and predictable.

More can be said about adverse selection. The external brain drain probably is populated mostly by the better researchers, and the internal brain drain may preferentially siphon off the more ambitious, energetic, and imaginative younger scientists. Furthermore, there is little reason to think that the deadwood in the systems will be removed by the brain drain. The end result of the process may be a scientific establishment from which the best and most promising people have been drawn away, leaving much-depleted cadres of less talented researchers.

The brain drain is not the only consequence of the budget crunch. Where efforts to continue research have been maintained, they are hobbled by lack of the supplies and equipment needed for the work. Maintenance of instruments, computers, and other equipment is neglected. Budget cuts have been absorbed in part by layoffs of technical support staff, further contributing to the problems of maintaining effective research. Building maintenance has been neglected for years, a problem exacerbated by the recent budgetary shortfalls. The isolation of researchers from the external scientific community that was put in place for political reasons is continuing because of the lack of funds. The telecommunications infrastructure, never up to Western standards, remains neglected, doing damage not only to contacts with foreign colleagues but even among researchers within the countries themselves. Research teams, developed over years of cooperation, are being broken up as key individuals leave for other pursuits. Collections of unique scientific specimens and data are neglected for want of funds, with permanent loss a real possibility. (See Press et al (1993) for a summary of problems in the Russian science and engineering system. These problems are common throughout Central and Eastern Europe.) In short, the financial crises in Central and Eastern Europe have very severe consequences for research in those countries. That damage is being done is beyond question; the only question is its reparability.

Education for science and engineering

Certain problems in higher education have already been discussed. However, additional difficulties should be noted.

These problems are the result of the treatment of universities under the old regime. As noted, political considerations strongly coloured the selection of faculty. Furthermore, the conversion of the universities to teaching institutions, as noted above, led to the evolution of a faculty whose members often did not hold the level of qualifications required in Western colleges and universities. For example, in Czechoslovakia, it appears that as many as one-third of full professors and 90% of associate professors did not hold the equivalent of a Western doctoral degree. No doubt there are excellent teachers in the universities, and no doubt that this problem, like so many others, varies from one country to another. On average, though, the faculty reflects this selection mechanism. In addition, government officials whose usefulness had declined were often put out to pasture in the universities. This is one reason for the extremely high faculty to student ratios in universities (in Romania, for example, the ratio of undergraduate day students to faculty was 6.6 in 1991 (World Bank, 1992, p. 199)). These factors produced an instructional faculty of uneven and probably less than Western quality.

Coupled to this problem is the fact that participation rates in higher education are very low. In Czechoslovakia, only 16% of the 20–24 year old age group enrol in institutions of higher education. This is well below average OECD levels, but not as low as Romania, where the participation rate of this age group is about 10%. (The OECD average is over 30%; World Bank (1992), p. 84.) These rates of participation may be artefacts of the old system of central planning, which attempted to calculate the numbers of persons required for plan fulfilment while simultaneously seeking to avoid the risks associated with large university enrolments. Of course, nobody can say what the optimal participation rate is, but these are sufficiently below average to conclude that some increase would be beneficial. Between the need to revitalise faculties and to increase participation rates – both in addition to the needs for more openness in course selection and to re-insert research into the universities, not to mention the general financial situation – higher education is obviously in a crisis of its own. This can only represent a problem for the future of scientific and technological research in these countries.

Weak linkages

The Soviet-style system of research and technology, with its separation of research from education and the division of research between Academy and industrial branch institutes, failed to produce strong linkages between researchers and users of research results. Building better linkages is one of the major challenges for policy-makers in Central and Eastern Europe.

The problem begins with the universities. With the removal of research to the Academy institutes, higher education lost the ability to include graduate students in advanced university-based research. Students, having worked at the cutting edge of research in their graduate studies, become the most effective agents of transfer of that knowledge to other uses when they complete their studies and move on to employment in industry or academe. They cross-fertilise ideas within academic institutions and transfer knowledge from academia to industry. This has been a powerful force in the West, but was almost entirely lacking in Soviet-style research and education systems.

The old systems also suffered from poor linkages between basic and applied research because of the separation of Academy institutes from industrial users, on the one hand, and the separation of the industrial branch institutes from the enterprises within their own branches. These organisational separations, coupled with poor incentives for innovation in the system of central planning (Moore, 1980), are key factors in explaining the low rates of technological change in the civilian sectors of all Eastern bloc economies. (Defence sector technology advanced more rapidly because of the high priority placed upon it by the authorities and better integration of research efforts with application and production.)

Improving technology transfer in these systems is only partly a matter of organisational change. In fact, many organisational changes intended to improve the use of technology in industry were attempted, with very little success, during the communist years. The structure of incentives is undoubtedly the more important factor. In this, improvements in the science and technology infrastructure are intimately linked to the broader efforts at economic reform and restructuring. The legalisation of private property rights and the development of institutions for their adjudication and enforcement are essential steps in this direction. The institutions of the new systems must lead entrepreneurs and owners to be confident that they will reap the benefits of successful innovations (and, of course, bear the costs of errors) if they are to risk investing in new technologies. (The same is true, of course, for would-be foreign investors.) Under the appropriate set of property rights, they will have the incentive to reach out to the researchers in universities and the remaining institutes to acquire such technologies.

One important component in the system of private property rights must be intellectual property rights. The development of solid systems of intellectual property rights is critical so that researchers will have the incentive to develop new technolo-

TABLE 2: Intellectual property rights regime – adherence in Central and Eastern Europe (as of 1992)

	World Intellectual Property Organisation (WIPO)	Berne Convention	Paris Convention	Universal Copyright Convention (UCC)
Poland	Yes	Yes	Yes	Yes
Romania	Yes	No	No	No
Czechoslovakia	No	Yes	Yes	Yes
Hungary	No	Yes	Yes	No
Bulgaria	No	No	No	No

Source: US Senate (1992).

gies. These systems protect inventors from piracy of their creations not only by fellow citizens but also by foreigners who would seek to appropriate the property. Perhaps more importantly, they also provide protection to potential foreign investors who may be reluctant to bring processes or products to countries where their property may be taken from them without compensation. A joint venture in Hungary that involved the Digital Equipment Corporation, a state supervised computer systems designer (Szamaik), and the Research Institute for Solid State Physics of the Hungarian Academy of Sciences apparently had as its main objective the prevention of unlicensed cloning of DEC equipment by the very organisations that became its partners in the deal (*Wall Street Journal*, 1990). That is why it is important for these nations to have intellectual property systems that conform to international standards and to enforce those standards within their borders.

Formally, there has been recognition of intellectual property in Central and Eastern Europe for some time, and there is evidence of growing acceptance of the importance of intellectual property rights as countries move to adopt new legislation. Table 2 presents a summary of adherence to several major conventions by these countries as of 1992. However, adherence to these conventions, where it exists, does not necessarily mean effective protection of rights. Enforcement of copyrights and patents is generally poor. The Hungarian system provides for only process protection, which has been particularly harmful to outside pharmaceutical interests. Piracy remains a serious problem. Losses are very difficult to measure, of course. The International Intellectual Property Alliance (1993) estimates, for example, that 1992 trade losses due to piracy were in the order of $100 million in Poland and $20 million in Bulgaria. It will require steady effort and considerable political courage to solve this difficult problem in the former bloc countries.

In this light, measures such as those taken in Hungary to strengthen institute–industry relations attack only half of the problem. In Hungary, as already noted, the budget crisis has led the government to insist that institutes seek industrial research contracts for financial support. As long as potential industrial partners are confident that the research results obtained under contract will result in appropriable benefits to themselves, this approach makes sense. But if the firms do not see this result, if they believe that resulting profits will be taxed away or otherwise taken from them, they will have no incentive to enter such arrangements.

Thus, as far as the commercial side of technology transfer is concerned, improved performance in the research sector is inextricably bound up with success in the broader economic reforms. Since research and development in the end depend heavily on public support, it is clearly in the interest of researchers and science policy-makers to support the development of strong market systems.

Scale

Poland, with its population of 38 million, is the largest of these countries by a substantial margin (reunification puts East Germany in a special category). Small size has a number of consequences for science and technology.

First, it means that resources for R&D will always be relatively small in absolute size. Even if these nations devoted proportions of national income to R&D that were high by global standards, the amounts would still be small. But research and development are increasingly costly, especially in certain leading edge fields such as microelectronics. Even basic research in a number of subjects is increasingly costly; it is clear that the wealthiest countries in the world no longer can go it alone in research in some areas (high energy physics, astronomy, oceanography). It is also clear that no nation will be able to lead in all categories of research; a recent study under the auspices of the US National Academy of Sciences reached this conclusion for the United States (Committee on Science, Engineering, and Public Policy, 1993). (It should be noted that the report's conclusion is not universally accepted.) For smaller countries, the point is only too obvious.

Some means must be found to choose among fields of specialisation for R&D. There is a conundrum here, since this suggests a form of central planning – just what these countries have been trying to get rid of. However, policy-makers everywhere realise that some mechanism must be developed to set priorities for public funding of R&D precisely because of the factors just mentioned. It must be admitted that efforts to do so have been less than highly successful. In the United States, there are a few cases of successful priority setting within scientific disciplines, but no real success in setting priorities across disciplines. Astronomy is the leading example of success in setting priorities in a single discipline. Astronomers have produced so-called decade reports that list major projects for the decade in priority order. Even though these priority lists have met with the approval of the American astronomy community, it is not necessarily true that federal funding has followed these priorities. In at least one instance, a major radio telescope that did not appear on the list was funded through the influence of Congress. The most recent effort to develop a scheme for setting priorities across fields of science is represented in Committee on Science, Engineering, and Public Policy (1993).

Perhaps the most successful effort at developing a policy that addresses these problems to date is that of the smallest country in the region, Slovenia. Its Science and Technology Council recently developed a policy statement (Science and Technology Council, 1992) that clearly recognises the limitations of size for the nation's science and technology effort. Realising that specialisation is unavoidable, the policy calls for relating research efforts to national economic capabilities, building on identifiable economic advantages and international trade opportunities. It also recognises that there must be a viable intellectual base for whatever research programme is envisioned, and so calls for strengthening the universities and maintaining a basic research capability in fields related to those where technology is being developed. Of course, it remains to be seen whether the policy can be put into practice, but its development is a significant first step.

A second necessary step toward the effective use of public resources for R&D is the development of funding mechanisms that provide support in accordance with priorities and excellence of the work performed. As both the theory of public finance (more specifically, the theory of public choice; see Mueller (1991) for a comprehensive treatment.) and experience in Western democracies show, this is not an easy assignment to fulfil. The mere availability of public funds for research produces efforts by would-be recipients to use the political process to obtain support, rather than being satisfied with reliance on merit-based selection procedures. In the United States, where competitive merit review is perhaps most widely used and respected, political pork-barrelling currently is responsible for research awards in the vicinity of $ 1.7 billion. Difficult as this problem may be in democratic countries, the old systems of finance in Central and Eastern Europe were still more highly politicised. Essentially all funding for R&D was centrally controlled, so the government agencies that held the funds were in a position to reward whomever they saw fit. Political influence on the part of institute directors and researchers was often as important as the merit of the research or the abilities of the researchers (Karczewski, 1991; Sabel, 1993; World Bank, 1992).

It is widely recognised that this system must be radically changed. However, under the old Soviet-style system, the Academies of Science were among the dominant agencies in allocating funds for R&D. This presents reformers with a difficult problem. In the first place, the Academies often remain politically powerful; despite all of the criticisms directed at them, their members and leaders are influential because of their connections and reputations, and they are politically experienced and knowledgeable. They naturally and capably defend their positions in the R&D structure. Moreover, Academy institutes are the strongest research entities in many fields. They include research teams that have been developed over periods of many years and which few want to see broken up.

The problem is to develop a new system for funding that will reduce the role of the Academies while not breaking up the research capabilities that they include. The problem is further complicated by the desire to shift funds for research and the scientists to use them back to the universities, a move that the Academies often resist.

Poland has taken perhaps the boldest step in this regard, having formed the new State Committee for Scientific Research in 1991 (Karczewski, 1991, p. 16). This committee is dominated by scientists elected by the scientific community. Decisions on research support for all scientific institutions are made by Commissions of the Committee, also dominated by scientists. In effect, this removes budget authority from the Academy of Sciences. The move could result in more autonomy for research institutions, since they will no longer be dependent on the Academy, and it should contribute to rebuilding research in the universities. However, the substitution of one monopolistic governmental organ for a monopolistic quasi-governmental organ is no guarantee that resource allocation will be done on the basis of competition and merit in the long run.

Small size has another aspect that has international implications for science. It is generally believed that competitive review of research proposals by anonymous experts (so-called merit review) is the best basis for allocating public funds for research. Science policy-makers in Central and Eastern Europe are aware of this method and most support its application for their countries. But small size means that it is difficult to maintain anonymity in the procedure and to avoid conflicts of interest. Again, Poland is in the best position in this regard, with size sufficient to maintain a list of 14,000 possible reviewers at the State Committee for Scientific Research. In comparison, the US National Science Foundation has a list of some 150,000 potential reviewers. The obvious way around this problem is to use panels of reviewers drawn not only from the home country but also from abroad. In addition to the organisational problems involved, this approach presents problems with languages, but it is worth consideration.

Opportunities

The litany of problems in the research and education establishments of Central and Eastern Europe presented here is extensive but not exhaustive. Yet there are opportunities for cooperation and investment that have potential for the West.

It is not merely idealistic to say that the development of sound research and education organisations in the former bloc countries is in the interests of the West. From a political point of view, the educational system is essential for the creation of democratic societies. The communist states attempted to use the educational systems to indoctrinate young people in socialism and Marxist thought. This was partly successful, as the residual attitudes of some citizens reveals, but the ideas of freedom and democracy could not be completely suppressed, as the 1989 uprisings (and the earlier rebellions in 1956 and 1968) so clearly showed. Education that is based on the Western traditions of free inquiry and freedom of speech finds fertile intellectual ground in the people of Central and Eastern Europe.

In this, science education can play an important role, since science is based on free inquiry and openness of communication. Indeed, throughout the Cold War, despite all efforts to control contacts with the West, channels of communication were kept open between the best scientists on both sides. This connection was one factor that helped to keep the ideas of political freedom alive behind the Iron Curtain.

Economically, the case may be less obvious. But political stability in Central and Eastern Europe will not be achieved if these countries remain in the poor economic condition they suffer today. Science and technology are not the only source of economic growth, of course. The creation of the institutions required for the market economy, increased capital investment that is responsive to market signals, improved labour quality (through education and retraining), and, importantly, a shift in mental habits from those of the command system to the attitudes needed for the market economy – these are more significant than science and technology. But technological change cannot be overlooked. Studies of the American economy indicate that technological change is responsible for about one-quarter of growth in potential national income (Denison, 1985, pp. 30–31).

Improved technological capabilities in the former bloc countries will mean stronger competition for Western firms, of course, and may therefore be seen as detrimental to their interests. But there are two responses to this. First, to the extent that improved economic performance contributes to the development and maintenance of stable democratic regimes, it is in the interest of the West to encourage it. Second, science and technology in Central and Eastern Europe have much to offer to the West, despite the many problems that have been discussed here. Just as there are potential gains from commercial trade, there are opportunities for mutual benefit in cooperative ventures involving science and technology. These opportunities will be improved with improved capabilities in the former bloc countries.

Joint venture activity in former bloc countries has often had a strong technological flavour, illustrating the potential for mutually profitable cooperation as scientific and technological capabilities develop. The chemical industry presents many examples. Dow Chemical, through its European subsidiary, has made substantial investments in Czechoslovakia. A Japanese–American consortium is planning to enter a joint venture with Poland's largest petrochemical company (Tattum and Alperowicz, 1992, pp. 28–29). Austrian, Dutch, Finnish, French, Swiss, and Italian firms are among those developing cooperative ventures in the Czech and Slovak chemical industries (Alperowicz, 1992, p. 38). Polish chemical firms have developed processes that have been licensed to Western and other firms. Lepkowski (1992, pp. 11–12) mentions a process for partial oxidation, used in burning flue gas emissions from manufacturing plants, licensed to Volvo, and a process for synthesising cyclohexane, developed by the Research Institute of Industrial Chemistry, licensed in Taiwan, India, South Korea, Thailand, and Spain. Part of the reason for the high level of activity is the 'legacy of elite engineers and scientists' left by the communist regimes, according to an officer of one of the firms involved (Tattum and Alperowicz, 1992, p. 28). In telecommunications, Contel has developed joint ventures with new Hungarian companies, deals made possible in part by the quality of Hungary's technological capabilities, needed to meet Contel's servicing and production requirements (Weiss, 1990, p. 26).

And there are well-known cases in Russia that illustrate the possibilities. One of the best known was the arrangement by which Sun Computers contracted with a group of leading Russian computer scientists to work on development of scalable processor architecture (Johnson, 1992, p. 113).

These opportunities demonstrate that the old systems generated valuable capital, especially human capital, despite their many shortcomings. The systems trained large numbers of people in technical subjects, creating the human 'legacy' noted above. Scientific research continued, although not under the best of circumstances, and despite the fact that funds were not always allocated on objective grounds. The former bloc countries have given the world some of its most eminent scientists (one need only think of the Hungarians) and there is no reason to think that they will not continue to do so. Research facilities have been neglected and are now in jeopardy because of the budget crises that are affecting all of life in the region. Reforms and restructuring are needed and proceeding at varying speeds and with differing likelihoods of success. Nevertheless, there is reason to be optimistic about the future for research and education in Central and Eastern Europe. This optimism, in turn, gives reason to think that cooperation in science and technology projects with researchers and their organisations in the region, whether academic, government, or business, has considerable promise. It is in the interests of Western governments to promote that cooperation and to aid the reconstruction of the research and education systems, since strengthening the institutions that support free markets and democracy can only promote stability and peace. Additionally, however, there are potential private gains for Western business and industry from cooperation with and support of the scientific and technological establishments of Central and Eastern Europe.

Editor's note: *Scientific projects in the ex-USSR.* Some 1214 scientific research laboratories across the newly independent states of the former USSR will participate in around 509 joint initiatives with labs in western Europe under an EC-sponsored initiative. The projects, to cover all fields of science from astrophysics to aeronautics, were announced at a meeting of the International Association for the Promotion of Scientific Cooperation in the Newly-Independent States (INTAS) which comprises scientists from the EC, Austria, Finland, Switzerland and twelve former USSR republics. Research Commissioner Antonio Ruberti said that the INTAS initiative was a major stimulus and a key to encouraging cooperation between the republics of the former Soviet Union.

References

Alperowicz, N. (1992), 'Czechoslovakia's privatisation program gathers pace. *Chemical Week*, 15 July, pp. 38–39.

Boeva, I. and Shironin, V. (1992) *Russians Between State and Market: The Generations Compared.* Glasgow: Centre for the Study of Public Policy.

Bossak, J. (ed.) *Poland: International Economic Report. 1992/93.* Warsaw: Warsaw School of Economics.

Cocks, P.M. *Science Policy: USA/USSR*, v. II, *Science Policy in the Soviet Union.* Washington DC: National Science Foundation, no date.

Committee on Science, Engineering, and Public Policy (1993) *Science. Technology and the Federal Government*. Washington DC: National Academy Press.

Denison, E. (1985) *Trends in American Economic Growth. 1929–1982*. Washington DC: The Brookings Institution.

Drobnik, J. (1992) Science and research at Czech Universities. In Kuklinski, A. *Society Science Government*, pp. 89–92. Warsaw: State Committee for Scientific Research.

International Council of Scientific Unions (1992) *An Evaluation of Science in Hungary*. Paris: ICSU (ms.), December.

International Intellectual Property Alliance (1993) personal correspondence.

Izdebska, B. (1993) Fights for resources spells trouble for Polish institutes. *Nature*, vol. 364, 26 August, p. 748.

Johnson, M. (1992) SPARC seeds sown in Russian soil. *Computer Industry*, vol.26, 7 September, p. 113.

Karczewski, W. (1991) Some remarks on science and technology in Poland. In Kuklinski, A. *Transformation of Science in Poland*, pp. 15-18. Warsaw: State Committee for Scientific Research.

Lepkowski, W. (1992) Poland struggles to forge new policy for science. *Chemical and Engineering News*, 8 June, pp. 7–15.

Moore, J.H. (1981) Agency costs, technological change, and Soviet central planning. *Journal of Law and Economics*, October, pp. 189–214.

Mueller, D.C. (1991) *Public Choice II*. Cambridge: Cambridge University Press.

Press, F., Getzinger, R., Moore, J. and Soros, G. (1993) *Sustaining Excellence in Science and Engineering in the Former Soviet Union*. Report of a Conference. Washington DC: National Academy Press.

Sabel, B.A. (1993) Science reunification in Germany: a crash program. *Science*, vol. 260, 18 June, pp. 1753–1758.

Science and Technology Council (1992) *Foundations and Directives for the National Research Program*. Republic of Slovenia.

Tattum, L. and Alperowicz, N. (1992) The view from Warsaw. *Chemical Week*, 24 June, pp. 28–29.

United States Senate (1992) *Country Reports on Economic Policy and Trade Practices*. Report to Committee on Foreign Relations and Committee on Finance of the US Senate and the Committee on Foreign Affairs and Committee on Ways and Means of the US House of Representatives, March 1992. Washington DC: US Government Printing Office.

Wall Street Journal (1990) 12 February, p. A5A.

Weiss, J.M. (1990) Ringing up sales in Eastern Europe. *Europe*, September, pp. 23–25.

World Bank (1992) *Romania: Human Resources and the Transition to a Market Economy*. Washington DC: The World Bank.

Zaleski, E. (1980) *Stalinist Planning for Economic Growth. 1933–1952*, translated and edited by Marie-Christine MacAndrew and John H. Moore. London: The Macmillan Press.

Zaleski, E., Kozlowski, J.P., Wienert, H., Davies, R.W., Berry, M.J. and Amann, R. (1969) *Science Policy in the USSR*. Paris: OECD.