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Let me say how pleased and honoured I feel to speak in your renowned Institute. And before starting my lecture, let me share a confidence with you. Bangalore's many historical and cultural features and the reputation of your Institute are such that, although I am here for the first time (but not the first time in India), you can't imagine how many things the simple name of your city and region did evoke in me. But there is one thing more recent that Bangalore and NIAS have meant for me. In the preparation of the UNESCO Conference on Science, which took place last June in Budapest, I was asked to re-write entirely the draft "Agenda for Action" whose first version was as bad as possible. I was then in the South of France and I received a fax containing a long paper whose title was the "Bangalore Declaration" – and instructions to take into account its main themes which were elaborated

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in your Institute.[1] Well, let me say that I had not much to add to what I had already written: the gender issue was already there, as well as the need to associate more closely the Western concept of science and the rationality, if not the wisdom, of traditional knowledge and practices. Even the notion and title of "a new social contract for science" was there, because I was writing at the same time a book, published last month in France, whose first chapter has precisely this title.[2]

I do not say this to appear as fighting for some priority nor even originality, since such a notion has been touched on by various authors in the last decade, but to introduce my lecture by underlining that neither the Bangalore Declaration nor the conclusions of the UNESCO Conference can be taken for granted. It will indeed require a long lapse of time and perhaps several generations before we will be able to witness scientists and concerned policy-makers fulfilling all the objectives and changes endorsed in Budapest. It is like the Test Ban Treaty: it would be better for mankind that all countries (especially the United States and Russia!) adhere to it, yet one is far from seeing such an all-out ban being implemented. You are as aware as I am of this gap between what we wish or want and the realities and constraints of the nation-states and world politics, since this is also the first day of the workshop your organise on the Draft Indian Nuclear Doctrine – to which you kindly invited me to participate.[3] Let me add that such a public discussion on such a subject is not simply another illustration of the democratic roots of your country, but a real exception in the world: where else has moving towards the "triad" of a nuclear weapons system ever been discussed publicly?

When I heard that I would have to speak about recent trends in science and technology policy, I decided to re-read one of the first books published on the subject, a book edited in 1965 by my friend (the late) Norman Kaplan, *Science and Society*.[4] What he wrote in his Introduction is still valid and relevant today: "It has been only in the last decades that it became so clear that studies on the relations of science and society could no longer be neglected. Even so, there is still no generally accepted label identifying studies of science and society. There is still no single identifiable academic discipline specializing in such studies. Sociologists, political scientists, economists, historians and perhaps not so strangely, the 'hard' scientists themselves have all shown some concern". And he added: "Who now needs to know something of the relations of science and society? The answer, especially in a democratic society, is that it is difficult to think of anyone who does not need to know".

This has not changed since: the field is still without an accepted label and there are more and more people in our societies who want to know more about this relationship. However, something is new: the knowledge and literature about the subject has increased to the point that it is difficult, indeed impossible, to keep up with the number of books, journals, articles and conferences that deal with it. In relation in particular to science policy, Norman Kaplan paid tribute to OECD for having organized the first meeting of ministers and others concerned with questions of national science policy. "This received", he wrote, "only a few inches of space, at most, in the newspapers, but it is quite likely that historians of the future may accord it considerably more importance. This was probably the first meeting of this kind and it is most likely not the last". Norman Kaplan was right: many other meetings of this kind did follow and I know, having been interviewed several times by historians about the very beginnings of this field within and outside OECD.

I don't mention that in order to point out my age, I mean to face the fact that I myself may be becoming a historical topic, but to stress that there is now almost half a century of institutionalised science policy. And since the 1960s there have already been so many important changes in the international economic and political context that many commentators have tried to divide them into "ages", "epochs", "periods", "stages" or – more commonly – "phases" of science policy. An author even spoke of a "paradigm of science policy" showing, in spite of national variations, a high degree of congruence in the core of views and instruments used.[5] This proves at least that, in spite of the fact that the domain has no generally accepted label, there is now around the world a science policy community within academia as well as within the national and international policy-making bodies, which functions like any other scientific community in the Kuhnian sense, spreading information, publications, memory and culture on views and instruments in the field. Science policy studies, social studies of science, science, technology and society, even science of science as it was called in the former communist countries – whatever the label, there can be no doubt that the field exists today and has both an intellectual and policy-oriented legacy. The research and publications of your own Institute illustrate this legacy perfectly.

Four factors of change

I would need much more than the time available for this talk to mention all the phases that science policy has witnessed since the first ministerial meeting on science held at OECD in 1963 – if one takes this event as the beginning of its irreversible institutionalisation. Rather than doing so I will discuss four major changes which have affected the relations between science, technology and society since World War II in order to illustrate not the past, but the current and even future landscape of science policy issues.

The first factor of change is indeed the end of the Cold War, the implosion of the communist system, the economic collapse of the former Soviet Union which no longer counts today among the great actors in the technological competition – except in space research in close co-operation with the West. For some of the most industrialised countries, those in particular which were involved in the challenges of the tensions between the East and the West, resources dedicated to defence research during this period represented two-thirds of the public research and development (R&D) expenditure – expenses worthy of the Pharaohs.

The relative decrease in investment in military R&D plus the economic difficulties, cuts in public spending and social pressures resulting from unemployment in most countries lead to efforts concentrated on competitiveness and innovation and to the restriction of the financial support allocated to fundamental research. This doesn't mean that military threats have disappeared, as we continue to see even in Europe. It just means that the strategic and ideological impetus that justified the state's unlimited support for scientific ventures has vanished. When discussing recent trends in contemporary science policy and science funding, the plural is really unnecessary. There is only one major overall trend: the increasing priority given to industrial research and innovation at the possible expense of curiosity-driven enquiry. This trend started earlier, but the end of the bipolar nuclear arms race inevitably meant that defence R&D investments would be cut and that market-oriented research would alter the direction of national science and technology policies.

The second factor is of course the scientific and technological revolution which we witness at the end of the century and whose effects will extend far beyond the next decade in all activities, whether civil or military. Revolutions in new information and communication technologies, biotechnology and the materials sciences have triggered momentous changes, analogous to those provoked by the printing revolution: an intellectual, economic and social metamorphosis of civilisation and culture. I would in fact call it a *single* revolution whose changes and applications indeed have the same characteristics: upstream, they are all related to knowledge – and capital-based industries, closely dependent upon multidisciplinary research, know-how and technologies that result from work undertaken both in universities and industry; downstream, they all contribute to the same phenomenon of "dematerialsation" which defines post-industrial societies in that they rely less and less on natural resources but are increasingly dependent on the intangible capital they are able to accumulate and diffuse.

In this flood of technical changes, it is from now on impossible to dissociate what belongs strictly to an intellectual venture from what answers to the interests of firms in their battles for competitiveness. There are at least three reasons for this. First, there is the increased association and even cross-fertilisation between science and technology: the frontiers between science and technology are becoming so blurred that it is more and more difficult to find a part of science that does not nurture or is not nurtured by technology; the reverse is just as true: technology depends more and more upon scientific research. The second reason is that few scientific activities as such can be dissociated from the support given by the state or by industry: the traditional autonomous status of science within the academic framework is more and more challenged by its growing dependence upon institutions that do not belong to academia. The third reason is that the great majority of researchers are now outside the university framework: to-day, most of them belong indeed to industrial or military laboratories.

The third factor of change, closely linked to the scientific and technical changes and to the industrialisation process which they stimulate around the world, is the globalisation of the economies and markets, which goes with the liberalisation of trade and privatisation of firms, the increasing role exerted by multinational firms and the declining functions exerted up to now by governments in regulating economic activities and their social repercussions. However, just as globalisation gives an illusion of convergence without global integration, the trend towards "innovation" leads to common challenges, without creating identical opportunities to respond. National economies are becoming more interdependent, and technical knowledge is becoming the common property of a worldwide technical community. But the dominant political concept still remains that of the nation state, which struggles to ensure that the production and exploitation of innovation remains largely circumscribed within its borders. And yet, there is at the same time a move towards greater cooperation (if not integration) of scientific and technological activities, as illustrated in particular by the European Union. I will come back later on this point.

Finally the fourth factor, which is as conditioned as the previous one by the current industrialisation process, is the multiplication of the environmental problems that affect the future of our planet. Beyond the phenomenon of increasing urbanisation, the nature and level of industrial and agricultural activity are bringing about changes in the biological, chemical and geophysical cycles that play havoc with nature's system. The results are extinction of species, pollution of air and water, new epidemics, ozone depletion, lack of rain in some areas, ecological disasters, and the worldwide spectres of water shortage and the greenhouse effect. Environment starts with settlement: 40% of the world's population are doomed to live in cities, out of a total of between 8 and 11 billion people. This gigantic process of accelerated urbanisation will have a two-fold result: on the one hand, megacities whose infrastructure will never match the needs of such a concentration of human beings, with problems of management, unemployment or underemployment, and violence that cannot be overcome; on the other, whole regions whose natural resources will lie fallow, so that the feeding of the megacities in most developing countries will be more and more closely dependent upon imports from industrialised countries, and thus their own growth will be jeopardised.

In this connection, something has happened that Norman Kaplan's book could not foresee, namely that the ethical facet of scientific advance is growing in importance. Nowadays the ethical implications of the use of scientific knowledge have become so profound and of so much concern to individuals and society at large, that any research or application of its results has to comply with ethical standards and principles. Scientists themselves have started to play an active role in defining and shouldering their responsibilities. Leaving aside all the circumstances of World War II which led to the decision to bomb Hiroshima and

Nagasaki, we can recall here how entering the atomic age meant, as Oppenheimer said, "the discovery of sin" or "the loss of innocence" for science. But this is not only related to the new links forged by the Second World War and its aftermath without peace between science, politics and the military establishment.

More importantly it is related to the disturbing consequences which science makes possible in other fields as well, for instance the risks of eugenics and abuses involved in the progress of the most advanced bio-medical research. Remember that already in 1975, when the biologists discussed at the Asilomar Conference the possible adverse consequences of genetic engineering, some were speaking in favour of a moratorium on research. In 1994, in his inaugural lecture at the Collége de France, Professor Pierre Chambon argued that a world moratorium for fifty years would seem to him an extremely wise decision. And more recently an international convention has been adopted within UNESCO which institutes a worldwide ban on human cloning. "How far is too far?" is the question confronting the scientific community in a political, intergovernmental framework which has little to do with the traditional arena of scientific debates. Actually, these are the issues that the book I published just a month ago in France is dealing with under a title which may appear provocative to the "traditional" scientists who believe that one can dissociate scientific research from its repercussions: *Can we survive science? – A certain idea of the future*. This title reproduces the title of the paper published by John von Neumann two years before his death: *Can we survive technology?* The fact is that what could so easily be said of technology earlier is now applicable to science itself.[6]

Nothing is more revealing of the change in the social image and function of science than this case, namely that the current pursuit of knowledge calls for barriers that are requested not only by people or institutions outside the scientific community, but within the scientific community itself. These were problems that Norman Kaplan had not foreseen because they couldn't be foreseen at the very beginning of the institutionalisation of science policy. And even less of course could their social consequences be foreseen. For instance, a salient feature of our times is the emergence of organised sectors of society demanding to take part in the debates and decision-making concerning scientific and technological issues. Alongside traditional actors such as trade unions and political parties, strong new lobby groups are coming to the fore, including industrialists, entrepreneurs, the media and a variety of non-governmental organizations as well as laymen or women. Many of these are concerned with the environmental and other issues that science and technology are addressing or are expected to address. All this is new, especially if one thinks of the predicament of the Charter of the Royal Society, which was given the objective of "perfecting the knowledge of natural things", while at the same time "not meddling with Metaphysicks, Moralls and Politics".

The demand for public participation and more transparency arises from two phenomena, both connected with the increasingly scientific nature of modern industrial societies: first, technical systems have become so complex that they have to be operated by experts, and secondly, people feel that they are being excluded from any democratic oversight of these activities.[7] The result is the paradox that although these societies have the means of acquiring, processing and sharing information which may give individuals far greater knowledge of the world they live in, this huge growth in the amount of information available is not matched by a similar degree of transparency of society vis-à-vis itself. On the country, the more the media provide instant coverage of world events as they happen and call on "experts" for comments, the more the information creates a vast blur, if not outright faking of "events", as we could all see for ourselves during the Gulf War or more recently during the Kososvo crisis.

The use of experts – turned into technocrats, strategists, prophets or gurus – is sometimes the best way of getting round conflicts and muddling the debate. While the public may be more eager to be informed, as levels of education rise and the middle class grows, public suspicion is far from being reduced when institutions with specialised knowledge – as we have seen in the case of nuclear power – make efforts to anticipate the public's questions. And thus while the public expectations of science may be high, there is also a widespread disenchantment and disregard for science, and fears as to the unforeseen or unknown consequences of technical change. The question one might raise today is the following: do these changes lead to the end of science policy? Let me now try to answer this question.

From one model to another

The paradox of the West, the cradle of modern science, of its accumulation of discoveries and industrial applications, is that there is now a questioning of the social cost of the achievements of science, the major risks involved, the mismatch between the strength that humanity now enjoys and the wisdom (or lack of it) brought to bear on its use. It is true that the experience of this century, whose barbarity owes so much to science, tends to raise doubts about the link between the progress of knowledge and the progress of morality postulated by the thinkers of the Enlightenment. The present "malaise of civilisation" is obvious; actually it is not new for those who read Husserl or Freud, but it has never before generated so much pessimistic debate.

After the Second World War, the rivalry between the superpowers and the arms race brought public and private interests closer together, to the point where systems of research and education were "socialised" even in the countries that considered themselves to be most liberal. Whatever was good for science was good for society – an article of faith first proclaimed in 1945 in the report by Vannevar Bush, then scientific adviser to the President of the United States, which was entitled *Science the Endless Frontier*, the next frontier after the conquest of the American West and industrialisation.[8] This report not only provided a justification for federal intervention in the private sector (in industry and the universities), but was also the source of accepted notions of the "linear" nature of innovation: it held that science *in itself* is the driving force of technical progress, and that science is therefore crucial to achieving national objectives in all areas of governmental competence.

This model, which was as simplistic as it was attractive in arguing the case in favour of science with governments, offered an idyllic vision of a process that led straight from basic research to production and the market. The more laboratories, staff and equipment allocated to those engaged in basic research, the better would the increasing number of discoveries guarantee an ever greater number of new products and processes for the economy. The mobilisation of brains and laboratories that had been so successful during the War was therefore set to carry on in peacetime, and all the major programmes involving defence, atomic energy, space and electronics could point to science as one of the top priorities pursued by the state.

In fact, the work of economists on R&D and innovation (C. Freeman, R. Nelson, P. David, N. Rosenberg, etc.) has gradually made people appreciate that the process is much more complex, since it involves many factors that have nothing to do with science or even research – such as market forces, the nature of the demand, social need, the contribution of design or marketing, and so on. At the same time their work has shown that it is important not to rely exclusively on the "market-pull" model, which is set up as the exact opposite of its rival "science or technology-push" in theological debates: neither demand nor supply alone explains everything.

The linear model prevailed for years and propagated the experience of the United States by convincing all the industrialised countries, and then what used to be called the Third World, that science was the royal road to economic growth, whereas in fact basic research provided an excuse – if not an alibi – for pursuing major programmes in the name of national defence and prestige. Here, the linear model did a great disservice to most developing countries because it encouraged them to mimic the wealthy countries and invest very heavily in higher education before they had adequate general secondary, or sometimes even primary education. As a result, they produced well-qualified scientists who tended to be cut off from the rest of their societies, all the more so because their countries lacked the institutional means to transform their knowledge into economically useful know-how. In doing so the poor countries forgot the lessons of the Industrial Revolution in Europe or, more recently, of the newly industrialising countries, since *all* of them began by aiming to expand general education rather than scientific research. The key people needed to achieve take-off are not so much researchers as engineers, middle managers and skilled manual workers who can master the knowledge and know-how required to establish the basis of industrialisation.[9]

The "market-pull" model, best illustrated by the Japanese example, became increasingly popular from the 1970s onward as it became clear that the competitive strength of firms and nations was closely linked to their capacity for innovation in the civil field. Whereas the United States had made national security the top priority of its science and technology policy, Japan had done the exact opposite – its science and technology policy had been its main means of ensuring national security. For years, the US (as well as France and Britain, which adopted similar priorities) boasted of the spin-offs for the civil economy that resulted from military research. Nevertheless, some observers kept insisting that the countries that invested most in defence-related research tended to have lower or little productivity growth.[10] Furthermore, military research led to the development of "esoteric", high-performance products which by definition are produced in small numbers at enormous cost, so that the spin-offs are less easily exploited in the civilian market.

The model favoured now is the Japanese MITI, which from the outset links technological advances with exports, rather than the American model emanating from the Bush Report, with its emphasis on the production of new knowledge. In short, it is no longer enough to have a solid infrastructure of basic research and to notch up Nobel Prizes in order to be the leaders in productivity and innovation. In spite of their current financial crisis, the example of Japan and the newly industrialising countries in South-East Asia show that a huge investment in basic research is neither a sufficient nor even a necessary condition for ensuring that innovations are successful in world markets. In other words, science is heading for hard times – with the exception of Japan, whose science policy, as Helga Nowotny argues, "has repeatedly been counter-cyclical". In the US, the idea of science as "an endless resource" is replacing that of science as "an endless frontier" in what Helga Nowotny called rightly the "rhetoric" of science policy – "a share of symbolic politics" which shows how strongly the orientation and management of the research system is dependent upon belief.[11]

Science "the endless resource" now inspires and justifies innovation policies in the same way that science "the endless frontier" inspired and justified science policy: utility and productivity have replaced science as a system of values and culture. This new catchphrase is very revealing of the present change of attitudes, reflected in the 1994 presidential report called *Science in the National Interest.*[12] This issue now is not so much to push back the boundaries of knowledge, in the hopes that society will derive some benefit at some time in the distant future, but instead as quickly as possible to use existing knowledge to solve the most urgent economic, industrial, commercial and social problems. The book recently edited by Lewis Branscomb, *Investing in Innovation*, proposes a variety of guidelines to create and foster "a research and innovation policy that works", which means that technological infrastructure, rather than science as such, appears as the foundation for the engine of economic growth in the current context of growing globalisation and competition.[13]

The linear model is by definition the credo of university researchers, whereas the market-driven model is the credo of industrial managers. The former assumes that the state will subsidise basic research without worrying about seeing results in the short or even medium term, nor about precisely how the money is allocated among the various projects. The latter requires priorities to be established for the short term based on demand and a concern to keep a close watch on returns on investment. In a period when budgets are tight, the temptation is great not only to impose on the universities the same systems of evaluation and management that apply to industrial laboratories, but to attach values to basic research other than those that pure scientists would claim for it.

This is where we are now, and the situation revives the debate that goes back to the end of the 1930s between Michael Polanyi, a great supporter of independence and self-governance for science, and J.D. Bernal, who advocated detailed planning of research activities to match social needs.[14] Paradoxically, however, in the present debate the roles seem to have been swapped. Polanyi was a free marketeer, Bernal a Marxist. The experience of the Second World War led to the adoption everywhere of Bernal's model, though the notion of the independence of university research *á la* Polanyi was preserved, at least in the West. Yet since the planned economies have collapsed, the freedom of university research has been under constant attack in the market economies.

As long as the Cold War ensured that funds flowed freely, Polanyi's model continued to be preserved, especially since the interests of the state and of science converged. I wrote long ago that "the scientific society is not just one in which science is one of the goals of the society, but in which scientists want their own goals to be those of society".[15] Scientists were mobilised under an "alliance" whereby the state agreed to support science for its own sake but had to refrain from interfering in the *modus operandi* of the scientists: how they were hired, their choice of research topics, their methods of evaluation, etc. But as soon as the strategic imperatives lost their urgency and economic considerations became paramount, the alliance was broken: the goals of society had priority over those of the scientific establishment.

At the same time, the relationship between the two extremes of science policy was reversed: the state withdrew from the scene, hoping that the private sector would take over its role, and simultaneously put pressure on the universities with the aim of forcing the researchers to leave their ivory towers and work to shorter deadlines. The criteria henceforth are to be "need-driven" not "opportunity-driven". Some, not without irony, have been tempted to see in this reversal the homage of vice to virtue: liberalism with a touch of Marxism. I am reminded rather of Saint-Simon's *Catechism for Industrialists*, in which savants were given a share of power provided they satisfied the demands of the industrial system. "Scientists", Saint-Simon said, "render important services to the industrial class, but they receive from it services that are even more important, they receive their very *existence*. . . . Thus it has the right to say to the scientists: we are ready to feed, house, clothe you and satisfy your physical tastes only on certain conditions".[16]

How far the "economic war" will lead private firms and laboratories to replace the state in taking on what now are public investments remains a question that is still open. These investments grew constantly during the Cold War as each of the superpowers tried desperately to keep ahead of the other in technology. As Galbraith realised early on, "Although spending of all kinds – whether on weapons, old age pensions or air pollution – boosts demand, they do not all have the same impact on technology".[17] The question to day is: will trade and international competition be as powerful a stimulant as the real or imagined threat of nuclear war? And since many major industrial firms are now suffering from cuts in the public subsidy that they once enjoyed, will they be more careful in their R&D expenditures?

The challenges still ahead

Unless there are new world crises on the same scale as those earlier this century, it is obvious that the research system will never again enjoy the same level of government support. This is clear in space research: the success of the Apollo mission gave hope of further manned flights to the moon and other planets. NASA even dreamed of space cruises in the 21st century. But now research efforts are being concentrated on perfecting unmanned flights, retrieving launchers and developing multipurpose satellites. In the year 2000 NASA is supposed to cut almost 4,000 jobs as well as 25,000 jobs connected with its contracts (31% of its labour force). Daniel Goldin, NASA's director, did not hesitate to announce very prematurely that his scientists had identified traces of fossilised life in a meteorite lying forgotten in a geological museum, because missions to Mars are less and less likely to be funded. Needs must: "smaller, faster, cheaper" has become the motto of the space industry, and is being applied to more and more of the entire national R&D effort.

And yet, even if the future isn't what it used to be, as Paul Valéry said, this does not mean there is no longer any future. A new generation is taking the place of the scientists (many physicists) and decision-makers who were responsible for science policy from the Second Word War to the Cold

War – a generation with other concerns than the arms race and an apocalyptic struggle between capitalism and communism. Nonetheless there is unlikely to be a return to the "laissez-faire" relationship between the state and the scientific establishment that prevailed in the pre-war period. That is impossible because the two have become dependent on each other in ways that cannot now be reversed.

For one thing, neither can now survive without the other: government needs the *advice, methods, proof, results* or simply *promises* of science in order to govern, while research cannot hope to make progress without support from government, since the private sector cannot be expected to take on all the costs and risks of basic research. From this standpoint, Saint-Simon was wrong: there is a feedback connection between what he called the industrial class and the scientists, by which the former owes as much its very existence to the latter. Science, having demonstrated in war its usefulness to industry and the state, will continue to demonstrate it in peace as part of the same business of the control, domination and innovation race of the "post-industrial" economic and social process.

For another thing, there are so many problems that scientific research can help to solve – including those that it has helped to create. Neither the number nor the significance of these problems was reduced as if by waving a magic wand when the Berlin War fell, and while the shambles of "real socialism" restrain any dreams of utopia in that direction, it is equally unthinkable to rely on capitalism as a panacea. On the contrary, there is daily evidence that market forces are not going to deliver full employment and assured prosperity nor reduce inequalities, and that the market could give rise to new disasters. The need for international regulation is more and more obvious, and the kind of negotiations that will soon take place in Seattle within the WTO are certainly not, as they have up to now been prepared, the answer to the most pressing world economic challenges.

In any case, the emphasis on competitiveness means that short-term economic interests alone determine the search for and spread of innovations while neglecting the risks that science itself constantly creates for the medium or longer term. These risks affect the future in the same way as natural disasters, with the difference that little can be done about the natural disasters, whereas we could act to reduce or prevent the man-made ones. Scientific research has a key role in solving these urgent problems, all the more so given that so many are the direct result of scientific "progress": destroying nuclear arsenals, processing nuclear waste, risks linked to genetic engineering, or eugenics or misuse of computers, etc. To this list of threats one can add all the problems that proliferate as a consequence of the type of industrialisation favoured in the 20th century and which carry risks for the whole planet. As I already said, the nature and scale of economic activities cause changes in systems of all kinds: biological, chemical, geological. It is no longer possible to deny that global warming exists as a result of gas emissions and the greenhouse effect; the Intergovernmental Panel on Climate Change produced a report, based on the work of 2,000 experts from around the world, which showed that global warming is not simply occurring, it is speeding up.[18] The commitments made at the Earth Summit in Rio and Kyoto – which not one country has respected up to now – are already outdated compared with a pace of development that is likely to be less and less "sustainable". Science could have a role here too, in identifying the precise nature of the problems, assessing the facts and highlighting the long-term costs of failure to act now.

Lastly, it is impossible not to mention the challenge of poverty and hunger in developing countries. Climate change can only exacerbate the imbalances that, together with the population explosion, already cause such suffering to their inhabitants. As scientists have been telling us for years, if only a tiny fraction of R&D spending were switched to concerted efforts to tackle the specific problems of these countries, the situation would improve. However, given that their population growth is likely to speed up in the next century, the poorer countries are the ones most at risk of suffering not just from the industrial fall-out of the rich countries, but from the increase in their own energy requirements. They will therefore need to acquire, with the help of the industrialised countries, a domestic capability in science and technology that will allow them to study, measure, give due warning of and, if possible, control the damage resulting from progress.[19]

It is far from certain that these problems will elicit the mobilisation of science and technology that they deserve. Other choices, other priorities would be possible for the policies whose subject is science. If this is a dream, we must confess that industrial societies leave little room for dreams. Men may well ask what scientific and technical progress will make of them, while they have forgotten what they could make of scientific and technical progress. On the other hand, it cannot be ruled out that the pressure of global problems will be such as to force the most advanced countries – not out of philanthropy but out of sheer self-interest – to devote a larger proportion of their R&D spending to these issues. Much of the malaise, of the worries about the future, would thereby be reduced since science "the endless resource", perceived by untrammelled capitalism as a good like any others, is a major element in the *fin-de-siècle* disillusion.

In any case, two things are certain. First, the context of innovation policies will increasingly affect university research, forcing it into ever closer links with private industry. A new balance must be worked out between the opportunity-driven criteria based on what scientists want and the needs-driven criteria of society. University research is condemned to operate against a background of the need for innovation, for a range of programmes that transcend traditional boundaries between disciplines, a "market for knowledge" shaped by social demand, closer ties between "hard" and social sciences in dealing with problems that the essentially social ones (from the environment to megacities and poor neighbourhoods) that all societies, industrialised and developing, will have to face in the 21st century.

It will take more than a generation of researchers for these changes to achieve their full impact on the institutions, funding and methods of university research. At the same time as the traditional role of the universities is being drastically altered by having to cope with mass education, and they are urged increasingly to offer short, vocational courses, other pressures are forcing changes in the conception, practice, hiring and direction of university research. The book edited by Michael Gibbons, *The New Production of Knowledge: The Dynamic of Science and Research in Contemporary Societies*, shows how these changes are already affecting research institutions.[20] The domination of technology requires multidisciplinary research and a new kind of cooperation with industry that lead to a new scientific environment where engineering becomes much more important than the advancement of knowledge. There is no more striking illustration of this trend than the way Berkeley is now bringing together fields ranging from physics to molecular biology in new research buildings involving 100 million dollars, or how Harvard, Stanford and Princeton are attempting to break age-old departmental and disciplinary barriers to take advantage of the new opportunities in genomics, biophysics and nanotechnology. The pressure of industrial competition is such that new university "entrepreneurial" postures are required. For instance the new Berkeley "effort formally known as the Health Sciences Initiative will cut a wide swathe through the campus, involving some 400 scientists from at least 8 departments".[21]

Secondly, although technological competition between nations, with state support for their industries, is likely to become increasingly intense, it will not prevent an expansion of multinational co-operation in research. The prime reason will be financial: today even the United States, once little interested in joining international research projects, is following closely the OECD Magascience Forum discussions; soon the US will be participating more and more in international programmes to build and develop major facilities. They have already joined CERN in Geneva and their space station programme depends upon the co-operation of Europe as much as that of Russia. Another revealing example is that of the European Union where, even if its R&D spending as such seems tiny (5 to 6%) compared with the total expenditures of the individual member states, links are being forged between scientists and laboratories through common projects as national programmes become more dependent on the European research system. Progress towards union is perhaps greater in science and technology, through the network of programmes linking universities and industry, than on the political level. As a student of mine has recently demonstrated in a brillant doctoral thesis, since national R&D budgets have been slashed, support from the EU is no longer just a little encouragement, it is a major contribution to national efforts without which national research institutions would suffer.[22]

All the issues I referred to, far from challenging the need for a science policy, imply that governments must increasingly make basic decisions regarding the size, organization and orientation of the national research effort. The task ahead is difficult, since priorities will be much more diffuse, complex and harder to define and implement than in the past. The scale of the scientific effort will be in question – but so will other public investments – during this time of economic crisis, unemployment, public debt and international competition. These changes will require both demonstrated excellence and relevance, which means rethinking the distribution of resources and research programmes relative to the overall social context.

Let me now conclude: all these changes lead us to conceive of a new social contract of science which is precisely the major theme that was discussed during the UNESCO Science Conference held last June in Budapest. The next century will tell us how far this new social contract will be more or less beneficial to the progress of our knowledge and understanding of nature and ourselves than the former "alliance" between science and politics conditioned by World War II and the Cold War's intense strategic, ideological and economic competition. How far also it may be more beneficial to mankind is another question that the future will answer. Let us simply hope that it will.

Notes

1. International Symposium: *Science in Society- A New Social Contract: A report*. NIAS *Special Publication 2 – 99*, 27-29 January 1999
2. *Survivre á la science — Une certaine idée du futur,* Albin Michel, Paris, 1999
3. Workshop on Draft Indian Nuclear Doctrine, organised by NIAS and the Regional Centre for Strategic Studies, Bangalore, 26-27 November 1999
4. N. Kaplan, *Science and Society*. Rand McNally Company, Chicago, 1965
5. B. Rivo, "Phases or Paradigms of Science Policy?" *Science and Public Policy*, Vol. 21, No.3, June 1994
6. John von Neumann, Can we Survive Technology?. *Fortune Magazine*, 1955
7. J.-J. Salomon, *Le Destin Technologique*. Balland, Paris, 1992, reprinted Gallimard/Folio, 1993
8. V. Bush, *Science the Endless Frontier: A Report to the President on a Program for Postwar Scientific Research* (1945). Reprinted by the National Science Foundation, Washington, 1960
9. J.-J. Salomon and A. Lebeau, *Mirages of Development: Science and Technology for the Third Worlds*. Lynne Rienner, Boulder-London, 1993. Also J.-J. Salomon et alii, *The Uncertain Quest: Science Technology, Development*. United Nations University, Tokyo, 1994
10. R. A. Solow was the first to call attention on the lack of links between the amount of defense R&D investments and the acceleration of economic growth: "Gearing Military R&D to Economic Growth", *Harvard Business Review*, November-December 1962. On the same theme, see in particular N. Rosenberg, "Civilian `Spillovers' from Military R&D Spending: The US Experience since World War II", in *Strategy, Defense and the Western Alliance*, (S. Lakoff and R. Willoughby, eds), Lexington Books, Lexington, Mass., 1987. For the case of France, see J.-J. Salomon, *Le Gaulois, le Cow Boy et le Samourai: La politique française de la technologie*, Economica, Paris, 1986, and Elie Cohen, *Le Colbertisme High Tech.*, Paris, Hachette, 1992.
11. H. Nowotny, "Phases or Paradigms of Science Policy? A Response", *Science and Public Policy*, vol.21, no.6, Decmber 1994. Actually, Nowotny dealt with the content of certain research developments terminated or altered in the western world which Japan has taken up. I would like to stress the fact that in Japan the whole academic and basic research is now receiving a big boost, whereas the same area is getting fewer resources in the western world: a counter-cyclical choice of investment already obvious at the end of the 80s (see Y. Okubo, *Regard sur la science et la technologie japonaises*, Paris, 1997, and D. Normile, "Basic Science Spending to Jump in 1997", *Science*, vol. 275, 3 January 1997.)
12. W. J. Clinton and A. Gore Jr., *Science in the National Interest*, Executive Office of the President, OSTP, Washington, 1994, p p. 1-2
13. L. Branscomb and J. H. Keller (eds), *Investing in Innovation – Creating a Research and Innovation Policy that Works*, MIT Press, 1998. See also, less recent, R. J. Samuel, *Rich Nation, Strong Army: National Security and the Technical Transformation of Japan*, Cornell University Press, 1994; and

D. C. Mowery, *Science and Technology Policy in Interdependant Economies*, Francis Pinter, London, 1993

14. A good summary of this debate is provided by C. Freeman, *The Economics of Hope: Essays on Technical Change, Economic Growth and the Environment* (chap.1), Francis Pinter, London, 1993
15. J.-J. Salomon, *Science and Politics,* MacMillan and M.I.T Press, London, Cambridge, 1973, p.64
16. H. de Saint-Simon, *Catéchisme des industriels, Oeuvres*, vol.V, Anthropos, Paris, 1967, p. 25 (author's italics)
17. J. Galbraith, *The New Industrial State*, Houghton Mifflin, Boston, 1967, p.339, note 9
18. Reports published in 1997 by Cambridge University Press, summarised in French in *Les Cahiers de Global Change*, no.7, July 1996, available at the IPCC Secretariat, WMO, Geneva, Switzerland
19. E. B. Sokolnikoff, *The Elusive Transformation: Science and Technology and the Evolution of International Politics*, Princeton University Press, 1993, and "New International Trends Affecting Science and Technology", *Science and Public Policy*, vol. 20, no. 1, April 1993
20. M. Gibbons et al, *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*, Sage, London, 1994
21. See R.F. Service, "Berkeley Puts All its Eggs in Two Baskets", *Science*, vol. 286, 8 October 1999; pp. 226-227
22. Regina Pinto de Gusmao, *L'engagement français dans l'Europe de la recherche*, Economica, Paris, 1997. From 1988 to 1993, the European Union financed almost 3000 European research consortia which mobilised more than 5200 French participations (teams involved in a project) and with which were associated more than a thousand French research institutions, private and public. The average annual amount of the EEC spending is estimated to be 2.5 billion francs, that must be compared with the 2 billion francs of the "crédits incitatifs" spent from the French State budget during the same period.

As Head of the Science Policy Division at OECD, Paris during 1963 to 1983, Prof. J.-J. Salomon was one of the main architects of the restructuring of science and technology policies in Europe. As Head of the International Council for Science Policy Studies for UNESCO, he promoted many programmes in developing countries. He initiated the first post-graduate programme in Science, Technology and Society at the Conservatoire National des Arts et Metiers at Paris. He is the author of several books, including Mirages of Development – Science and Technology for the Third Worlds. *His new book,* Survivre a la science – un certaine idee du futur, *is currently under publication.*

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