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EXPO 2000/OECD FORUM FOR THE FUTURE
21st CENTURY TECHNOLOGIES: BALANCING ECONOMIC, SOCIAL AND ENVIRONMENTAL GOALS

Main Issues and Summary of the Discussions of a Conference held on 7th and 8th December at Schloß Krickenbeck, Germany

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FOREWORD

As part of the preparations for EXPO 2000 -- the World Exposition in Hannover, Germany -- the OECD Forum for the Future is organising a series of four conferences to take place beforehand around the theme of “People, Nature and Technology: Sustainable Societies in the 21st Century”. The series will consider four key areas of human activity: technology, economy, society and government. The conferences will explore possible evolutions of key variables and analyse different development paths in order to expose some of the main policy implications and options. Each conference will provide analysis of underlying trends and policy directions. However, the overall aim of the series is to build a comprehensive foundation for assessing the critical choices likely to face citizens and decision-makers in the next century.

The entire series is benefiting from special sponsorship by EXPO 2000 and four German banks -- Bankgesellschaft Berlin, DG BANK Deutsche Genossenschaftsbank, NORD/LB Norddeutsche Landesbank, and Westdeutsche Landesbank Girozentrale (WestLB). Additional financial support is provided by numerous Asian, European and North American partners of the OECD Forum for the Future.

The first of these conferences, hosted by the Westdeutsche Landesbank (WestLB), was held at Schloss Krickenbeck near Düsseldorf, Germany on 7-8 December 1997. The theme was “21st Century Technologies: Balancing Economic, Social and Environmental Goals”.

Shaping the future in order to realise economic and social goals is one of the fundamental challenges of human society. Technology has proved key in meeting this challenge, and its role appears set to remain at least as important in the future. However, there are many uncertainties with regard to the transformation of technological potential into positive economic and social outcomes. Indeed, for many people displaced at work or bewildered by new, unfamiliar products, it seems as if technological progress is more of a curse than a blessing. This first conference examined both the positive and the negative sides, the opportunities and the risks, that may arise as technology develops over the next twenty-five years. In so doing, it explored the two-way relationship between technology on the one hand and economy and society on the other.

The conference was organised into three sessions. The first assessed general trends in pervasive technologies, particularly information and biological technologies, with the aim of identifying areas of technically feasible future applications. The second session explored how different economic, social and political frameworks might lead to differences in the extent to which technological opportunities are realised and risks reduced. In the concluding session, the focus was on the policy directions most likely to enhance the contribution of technology to the realisation of sustainable economic, social and environmental goals.

THE PROMISES AND PERILS OF 21ST CENTURY TECHNOLOGY: AN OVERVIEW OF THE ISSUES

BY

RIEL MILLER, WOLFGANG MICHALSKI AND BARRIE STEVENS
OECD SECRETARIAT, ADVISORY UNIT TO THE SECRETARY-GENERAL

Over the past century there have been many profound technological, economic and social transformations. In OECD countries the full development and diffusion of innovations such as electricity, telephones and automobiles have accompanied the emergence of mass production, mass consumption and mass government. There are many who, facing the next century, wonder if it will be possible and/or desirable to continue along the path of such prodigious change. Some worry about the capacity, both technological and social, to continue advancing and inventing new tools, new products and new ways of organising everyday work and home life. Others worry that the ongoing transition costs may be too high, or that the risks to cherished traditions or the threats to environmental sustainability will, singly or together, be too great to bear. Preservation versus dynamism, incrementalism versus radicalism -- these are the polar extremes that, unsurprisingly, haunt many end-of-the-century, future-of-the-millennium debates.

The OECD Forum for the Future Conference on 21st Century Technologies was no exception; all of these perspectives were analysed and discussed. However, perhaps the most striking thing about the conference was the widely held view that the prospects for prosperity -- economic, social and environmental -- over the next twenty-five years will probably hinge on actively encouraging changes equal to, if not greater than, those already experienced in the twentieth century. In particular, realising the full potential of tomorrow’s technologies to contribute to human well-being was seen as depending heavily on the capacity to embrace dynamic change. With only a few reservations, the analysis affirmed the benefits of pursuing socio-technical dynamism rather than preservationism. The analysis also underscored the urgency of pushing beyond incremental and ad hoc reactive approaches in order to develop and implement more transformative and integrated economic, social and technological courses of action.

This paper is divided into three sections. The first focuses on the prospects for twenty-first century technologies -- largely ignoring economic or social factors -- given the current state of play in today’s research and development labs. The second considers the crucial economic and social forces -- at micro, macro and global levels -- that are likely to play key roles in determining both the path of technological development and its diffusion. Lastly, the paper offers an assessment of policy initiatives that might foster the most beneficial patterns of technological development and distribution.

I. Envisioning technology's potential: opportunities and risks

Imagining possible applications of technology two or three decades from now calls for a better understanding of the ways in which performance trends interact with societies' readiness to embrace economic, social and technical change. In venturing a vision of technological possibilities rather than simply projecting linear or exponential changes in performance, it is crucial to think not only of how technical improvements lead to the substitution of a new generation of tools for existing ones, but also of how entirely new uses, and indeed new needs, might emerge.

Significant progress is likely across a broad spectrum of technologies: computing, genetics, brain technology, new materials (in particular miniaturisation and smart composites), energy, transportation and environmental tools and systems. The technical foundation (as distinct from the economic and social) for this continuing wave of innovation will emerge, in large part, from powerful developments in the fields of digital and genetic information. The exploration and manipulation of these two building blocks -- one of calculation, the other of nature -- are likely to unlock vast treasures for both tool-builders and -users. Indeed, there seems to be a strong virtuous circle between better information and higher performance tools, as each insight provided by digital computation or genetic mapping (still at an early stage) helps to drive forward new ideas about how to design and use technology.

This complementarity is particularly powerful in the digital realm. Improvements in the quantity and quality of the information transformed into strings of zeros and ones are allowing rapid advances to be made in many other domains of science and engineering.

Advances in the performance and use of digital information

Performance

One way of tracking technological change over time (and into the future) is to consider measurements of speed, size or cost. From this perspective, progress is easy to calibrate. Twenty-five years ago a megabyte of semiconductor memory cost around $550 000; today it costs around $4. Microprocessors in 1997 were 100 000 times faster than the 1950 originals. Should these trends continue -- and there are many experts who think they will -- by 2020 one desktop computer will be as powerful as all of the computers currently in Silicon Valley.

Faster, cheaper, smaller are more than slogans for the highly competitive information technology sector. In the development pipeline are a number of improvements that might even accelerate the already rapid pace of cost/performance improvement. For example, there is a good chance that mixed optical/silicon computers will come into widespread use. This will allow laser beams to transmit data within a computer chip, thereby overcoming some of the bottlenecks -- such as excessive heat -- that arise from miniaturisation of circuits on semiconductors. Developments in low-temperature superconducting and new refrigeration methods will also allow improvements in processing power. Quantum mechanical computing appears to be on the horizon, promising potentially large gains in computation speeds. All told, the prospects for the key component of computing technology -- the microprocessor -- look very promising.

Network technology as well will continue to move forward along a path that delivers both greater diversity and much higher bandwidth. Heavy-duty transmission systems will lean on ever-faster fibre optical systems, while mobile communications coverage will rain down from a variety of low- and high-orbit satellites. A larger part of the available frequency spectrum will be better used by digital broadcasts and compression methods that allow high-density data flows to reach a wide variety of locations and devices. Home installation of a personal network (PN) will become affordable. For users, communication services may not quite reach zero cost, but they will be close to it by the third decade of the next century.

Considerable progress will likely be made in improving the human-computer interface, largely because voice and gesture recognition will have been perfected. Instantaneous real-time translation may also be quite close to fully functional by 2025. All audio, video and text-based data sources will be in digital form and amenable to universal searches. Most current computer-related security, privacy and inter-operability questions will have been resolved, allowing for the same degree of confidence (sometimes more, via instant verification) that currently obtains when it comes to face-to-face transactions and communication. Semiconductor-based sensors, some at the molecular or atomic level and integrated with DNA, will be able inexpensively to collect vast quantities of highly precise environmental and biological information, and begin to open up new frontiers for direct human-machine interconnection.

One potential brake on performance improvements in the field of IT could be software. Many analysts see only modest advances in the area of “artificial intelligence” over the next two decades. The quest for software that is fully capable of undertaking autonomous thought and able to respond with inference and creativity to human conversation will probably continue well into the middle of the next century. However, intelligent agents capable of accumulating data about an individual’s tastes and behavioural patterns are likely to emerge over this period. Considerable progress is also expected in the development of VRML (Virtual Reality markup language), a three-dimensional version of the text-based HTML (hypertext markup language) that currently dominates Web pages on the Internet.

Uses

Twenty-five years from now, after more than five decades of development, the microprocessor, information technologies in general, and networks will probably have penetrated every aspect of human activity. Many parts of the world will be wired, responsive and interactive. Beyond simply accelerating the pace of change or reducing the cost of many current activities, the use of these high-performance digital tools opens up the possibility of profound transformations.

There is a good chance that the advanced power of computing will be used to help people stay in or create new kinds of communities, both virtual and real. In some parts of the world this could mean a return to villages and less urban settings. In other regions, perhaps where there is better infrastructure or other attractions, people will stick to their “silicon alley”. In either case, the use of computing power will allow us to make choices about where and how we live and work that were not possible before. The trade-offs imposed by distance will change in the networked world of 2025. Physical isolation no longer needs to impose as great an economic or social penalty.

The use of computing power will greatly enhance possibilities in production, transportation, energy, commerce, education and health. For instance, industrial robots will most likely become ubiquitous as the better software and hardware allow them to take on onerous, dangerous, high-precision or miniaturised tasks in many sectors of the economy. They will also be employed in deep sea and outer space operations. Computers will probably influence the environmental costs of transportation by both improving vehicle design/engineering (hybrid cars, hydrogen fuel-cell engines, etc.) and traffic management. In the field of energy production and conservation, whole new horizons will open up as computers and networks reduce the costs and risks of co-generation and allow the proliferation of local management of energy production and use. Powerful computers will make it easier to design products that are more environmentally sustainable because the production process is less wasteful and the end-product can be recycled, reused or remanufactured.

At a broader level, computer-enabled development of electronic commerce is likely to profoundly modify current ways of doing business. Anyone with a computer and Internet access will be in a position to become a merchant and reach out to customers across the globe, and any consumer will be able to shop the world for goods and services. As a result, new products and services and new markets should emerge, many a traditional role of intermediary could disappear, and more direct relations will probably be forged between businesses and consumers. Indeed, the process of inventing and selling products could be turned on its head, as consumers generate the custom specifications they desire and then seek out competent producers and even other buyers.

As for the inquiry and collaboration that are indispensable for learning and basic scientific research, the power of tomorrow’s Information Technologies will open up new vistas by radically improving the capacity to communicate and simulate. Virtual Reality’s capacity to mimic historical and physical situations might mean that learning by “doing”, joint experimental research and moving at one’s own pace are all within every “wired” person’s grasp. Once liberated from some of the cost, time and space constraints of traditional education, it might even be possible to get beyond the socialisation methods of industrial era schooling to create a system that encourages individual creativity.

In order to avoid drowning in an ocean of information, people will probably use “knowbots” (knowledge robots) to navigate effectively. Virtual robots with fairly narrowly defined tasks, a type of expert software, will have reached the point of being able to track and respond to many human needs, from the banal capacity of a networked toaster to identify users and recall their preferences to the more advanced functionality of e-mail screening, comparison shopping and assembling/tracking a person’s customised learning “adventures.” And in the field of healthcare, self-contained portable sensing and diagnostic equipment linked up to remote expert systems could bring about significant improvements in patient mobility and hospital resource efficiency.

Advances in the performance and use of genetic information

Performance

The identification of genetic information and applications of genetic engineering are already making their mark in many of areas of human activity. While they are unlikely to have quite the same pervasive impact as Information Technology on the organisational aspects of economy and society, they will nonetheless profoundly affect many facets of everyday life. Those that stand out most from today’s perspective are human health, food production (livestock, plants) and food processing, and activities at the crossroads between genetics and other technologies.

Work is already well under way on the human genome. By 2005, after fifteen years of intense activity, scientists should know the full DNA sequence of a typical man or woman. Although at present only a very small percentage of this information has been mapped, the pace of discovery is expected to accelerate dramatically. As the average cost of sequencing each of the millions of DNA base pairs rapidly diminishes -- from $5 in 1990 to less than fifty cents by the beginning of the next century -- the number of DNA base pairs sequenced each year is rising exponentially: from around 40 million in 1990 to over 400 million in 1997. In parallel, the next twenty-five years could see major breakthroughs in disentangling the complexity of the human body's biochemical pathways along which genetic information is transferred, and in understanding how certain genes interact with environmental influences to exert different effects on different people.

What the next twenty-five years are likely to witness is the identification and mapping of the genomes of thousands of prototypical creatures -- mammals, fish, insects, micro-organisms and plants. Large-scale initiatives are currently close to implementation. In the United States, for example, the National Science Foundation has launched a major $40 million Plant Genome Initiative, and the Department of Agriculture is working towards a $200 million National Food Genome Strategy. As the biochemical pathways of gene transfer are worked out for animal and plant life forms, vast possibilities could open up for the refined management, control and manipulation of their health, propagation or elimination. Routine genetic programmes could emerge for enhancing animals and plants, leading to faster breeding cycles, accelerated plant evolution, and the development of increasing numbers of patentable varieties. Twenty years from now, virtually every widely distributed seed could have been influenced in one way or another (i.e. through cross-fertilization or genetic manipulation) by genetic engineering.

But perhaps the most dramatic breakthroughs in the not-too-distant future will be achieved through combinations of various scientific disciplines. For example, work cutting across biochemistry, physics, molecular biology, neurosciences, biotechnology, nanotechnology and microelectronics looks set to make significant advances in the field of bioelectronics (e.g. the development of biosensors) and neuroinformatics (linking microprocessing with the human nervous system). With the expected trend toward greater diversification of R&D spending on genetics into chemicals, materials, energy technologies, etc., major advances in other cross-disciplinary fields could take on significant proportions -- e.g. the creation of synthesised gene-derived enzyme catalysts, non-existent in nature, for use in chemical engineering; biological processes to fabricate molecular structures and more complex materials; bioengineered plants to produce pharmaceuticals and raw materials for plastics.

Uses

Biotechnology applications are likely to pervade most areas of activity in the next quarter-century. Already well entrenched and expanding in human health, animal husbandry, plant agriculture and food processing, they could find their way increasingly into environmental management, manufacturing processes, new materials and computers.

It is in human health that most people expect the greatest progress over the next decades. With the mapping of the human genome and the identification of biochemical transmission routes and of genetic predispositions, genetic testing could become routine. Therapies for single-gene and even some multiple-gene disorders could be widespread by 2025, as could gene replacement therapy. The prescription of gene-based pharmaceuticals might by then be commonplace -- for example, those using antisense DNA to block the body's process of transmitting genetic instructions to trigger a disease process. Concretely, disorders transmitted by a single gene, such as Huntington's Chorea and cystic fibrosis as well as certain types of Alzheimer's disease, arthritis and cancer, could by 2025 be both treatable and possibly reversible. Thanks to advances in interdisciplinary research, life expectancy and physical mobility could be further enhanced: with the increasingly standard application of biosensors in diagnosis; and, in surgery, the use of sensor implants, neuronal prostheses (e.g. for simulating hearing or restoring the functions of paralysed limbs) and even organ cloning.

The impact on the delivery of healthcare promises to be fundamental. It is not simply a matter of treatments becoming much more individualised. The quantum leap in genetic knowledge, information, diagnosis, prevention and therapy, combined with continuing progress in other technologies (notably IT) would mean -- at least in the more advanced societies -- more personal control over health and more possibilities for self-treatment, and thus more lifestyle choices. As a result, healthcare delivery could become much more decentralised. Indeed, the practice of medicine, increasingly encroached upon by research, self-diagnosis and self-treatment, may gradually be obliged to take a back seat.

With numerous prototypical animals, plants, insects and micro-organisms mapped and their gene delivery systems worked out, major avenues would open up for applications in food and agriculture. Genetically modified plants are increasingly common -- in 1997 American farmers planted some 10 million hectares with genetically engineered seeds, and across the world some two dozen varieties of genetically modified plants are in use. It is not difficult to conceive of routine production of transgenic customised livestock, fruit and vegetables, forming the basis for widespread consumption of “designer” food and new varieties and products. Transgenic sheep, pigs and cows may be kept as living factories to produce proteins and other much sought-after compounds, for example in their milk, or may be modified to resist particularly harsh climates. Aquaculture would have at its disposal genetic engineering techniques to refine the different tastes and textures of seafood. Crop plants and forest stocks across the world could be modified for inbuilt pest resistance, insecticidal or chemical properties, better storage, and greater adaptation to specific environmental conditions.

The outcome would be the prospect of significantly improved diets and greatly expanded food choices for consumers. For producers, it would mean nothing less than a radical transformation of farming practices and structures. Farmers will face a wide range of options as to new varieties, new products, and the degree of animal or crop specialisation they would need to pursue. New types of producer could enter the arena (e.g. pharmaceutical companies rearing transgenic animals for specific substances), and relations between producers, processors, retailers and consumers would likely be transformed by the emergence of highly specified, highly customised ordering systems.

Risks associated with advances in new technologies

Still, with all this scientific promise, there are myriad risks that could be provoked or exacerbated by tomorrow’s plausible technological innovations. As has been the case ever since technologies were employed not only for survival but also for conflict, these tools often have a double edge. Technological advances *per se* provide no foregone conclusions about how they will be used. Indeed, looked at purely from the perspective of technical feasibility -- without taking into account the economic and social safeguards that are likely to be prerequisites for the rapid emergence of tomorrow’s technological breakthroughs -- three broad dangers can be identified.

First, tomorrow’s technologies contain destructive potential that will be both powerful and difficult to control. They could pose threats to the natural and human environment. Either by accident or through malevolence, the advances and diffusion of genetic engineering could give rise to unintended, unanticipated diseases, ecological vulnerabilities, and weapons of mass destruction. Dependence on computers, networks and the software that runs them could leave critical parts of society's life-support systems, from nuclear power plants and medical systems to security and sewage treatment facilities, open to both inadvertent yet catastrophic crashes and intentionally debilitating attacks. Less deadly but still pernicious risks might emerge as the spread of information technology makes it easier to violate basic privacy or civil rights and to engage in criminal practices ranging from fraud and theft to illegal collusion.

A second set of purely technological risks involves the possibility of greater vulnerability to system-wide breakdowns in, for example, the air-traffic control infrastructure. Some people fear that as the world becomes more diversified, decentralised and dependent on technology, there will be a higher risk of unmanageable failures in either the physical or social systems that underpin survival. Lastly, the third danger relates to ethics, values and mindsets. Even the initial steps in the long-term development and diffusion of radically innovative technologies such as human cloning or computer-based intelligence (or even life-forms) could pose unusually strong challenges to existing ethical and cultural standards, and put greater burdens on people's tolerance of the unknown and foreign. The risk is that the shock induced by certain technological breakthroughs could end up generating serious social unrest.

Fortunately, the extent to which technology advances and actually poses such threats is fundamentally shaped by forces other than pure scientific feasibility. The emergence of these risks will depend not only on the extent of the actual and perceived dangers of new technologies but also, and crucially, on social and political choices. Such matters, however, lead to the broader debate on the enabling conditions for realising technology's potential.

II. Realising technology's potential: the enabling micro, macro and global conditions

If the risks can be managed, it is plausible that over the next twenty-five years a panoply of technological advances will vastly improve human welfare as well as help set the world's development on a sustainable course. However, as history demonstrates, the availability of a particular scientific discovery or innovative technology is no assurance that its potential will be extended into useful applications, nor that it will diffuse widely or to those who might use it most productively. Reaping the rewards and reducing the dangers generated by technological advances depend on a complex interaction with underlying economic, social and political conditions. Realising the fruits of socio-technical dynamism demands careful consideration of two dimensions: first, how various socio-economic environments lead to differences in the pace and direction of technological innovation and diffusion; and second, what the implications are of the uses and spread of new technologies for the economy and society.

The framework conditions influencing the rate and distribution of technological advances can be broken down into three general categories: micro, macro and global. Socio-economic factors at the micro level involve, on the one hand, the specific institutional and organisational patterns of families, households, enterprises and government agencies, and on the other, the decisions made by individuals in their roles as members of a household, workers, managers, civil servants or politicians. Macro factors are the overall socio-economic circumstances within which households and enterprises must operate. Here, the general conditions and technological predisposition of product, labour and capital markets are shaped by national monetary, fiscal and regulatory policies that can alter the predictability of borrowing conditions (interest rates), price levels, competitors entering a market and changes in employment rates. Lastly, global framework conditions relate to the management of, for example, the international system of trade, investment and technology flows and planet-wide environmental interdependence. There can be little doubt that the rates at which ideas, technology and competitive pressures diffuse around the globe -- not to mention the extent of co-operation to reduce conflict and environmental pollution -- will play a major role in determining future socio-technological trajectories.

Micro, macro and global framework conditions can thus be seen as either favouring or impeding technological dynamism. Circumstances where the framework conditions are all favourable to technological dynamism are much more likely to open up the possibility of significant changes in socio-technical patterns. Alternatively, should the framework conditions be more adverse to such change, there is less chance that there will be a break from current economic and social structures. There is no one best formula for encouraging socio-technical dynamism. However, a useful distinction can be made between those framework conditions that are likely to be more supportive of major socio-technical transformations (with potentially strongly positive leaps in society's capacity to address challenges and reap rewards) and those that are more linear and remain entrenched in existing patterns.

A. Micro-level dynamism and resistance to socio-technical change

The micro level prospects for twenty-first century technologies are mixed. There are a number of changes taking place in the way that firms and households organise work and everyday life that seem conducive to technological innovation and diffusion. On the other hand, there could be an important clash between the radical possibilities opened up by technological change and time-honoured traditions, habits and relationships. Adopting new attitudes, accepting alternative approaches to risk management and equipping people for different decision-making structures is rarely straightforward. The conference examined these complex and sometimes cyclical processes by looking at the prospects for two important sectors that are at different stages of acceptance and diffusion. One is the mature automotive industry and the other is the booming Internet. A third example is included here to provide an even fuller picture: the transitional health sector.

Beyond Henry Ford

Future prospects for the automotive sector provide a good illustration of the forces that give rise to both dynamism and resistance at the micro level. What were, almost a century ago, the automotive sector's great contributions to technological dynamism -- the semi-automated assembly line and the vision of the automobile as a mass consumption item -- could well become some of the primary constraints on tomorrow's innovation. Like Frederick Taylor's approach to the time-motion division of labour in the steel industry, Henry Ford's techniques of mass production spread throughout the economy in ways that acted as a catalyst for developing both new production technologies and new products. The combination of more efficient organisation of production with advancing technology provided a massive stimulus to innovation, competition and productivity throughout the economy. Consumers, too, became caught up in this vision of mass production, mass consumption. The household integrated a large range of new products and ways of conducting daily life. This involved not only driving the car to work, to the shopping mall and on the family vacation, but also using washing machines, refrigerators and TVs. The search for solutions to social problems also succumbed to the production methods and product design approaches of the automotive era, with huge mass production, mass consumption public programmes even in health, education and welfare. For many years this was a transformative paradigm that propelled productivity forward and inspired major technological advances.

Within the confines of this automotive vision of production, consumption and mobility, there will continue to be considerable scope for iterative innovation. Competition is likely to continue to press firms to improve products, as will initiatives to address the important problems posed by automotive pollution, congestion, and safety. Major strides will probably occur in the technologies used to power vehicles, co-ordinate traffic and protect drivers. The sector will continue to advance through innovations such as "smart" highways, hybrid electric vehicles, extensions of "lean production" methods and, of course, the computerised car with GPS (satellite-based global positioning system) for navigation and a full range of telecommunications links including Internet-based data, voice and video. However, unless there is movement beyond the automotive paradigm, the opportunities for more radical organisational breakthroughs within the factory, the home and society at large could be missed. For instance, realising the potential to reconfigure where and how people work and live in order to greatly reduce overall environmental carrying costs such as those incurred by current transportation systems will, in all likelihood, require fairly decisive breaks with past socio-technical patterns such as commuting to the workplace and driving to the shopping centre.

Internet futures

In contrast, the Internet could pioneer a significantly different vision of work and society. That vision is rooted in, and hence naturally tends to propagate, a form of organisation embodying a more decentralised responsibility and power structure. One way of grasping how the Internet introduces new possibilities is by comparing it with a conceptually similar but technically different electronic network that is now vanishing: electronic data interchange. EDI took a proprietary approach to connecting enterprises, primarily supply networks in manufacturing and finance, in order to improve co-ordination. Pushed forward in the 1970s and 1980s, these exclusive systems were incompatible between vendors, and tended to be expensive and inflexible. Today, in an amazingly short time, the Internet has eclipsed most proprietary EDI systems.

Internet technology, initially developed through public sector initiative, provides free and open access to a valuable asset, a common standard. A powerful economic imperative is unleashed by the Internet's technology: the increasing returns to scale of both networks and a universal, open set of standards. Collaboration not isolation, extension not restriction -- those are the watchwords of the Internet. Indeed, one need only consider the rather sudden enthusiasm with which usually irreconcilable competitors work together to ensure that the Internet becomes a seamless, open space for commerce. National governments and international organisations from the OECD to the W3C (World Wide Web Consortium) are striving to make sure that the Internet becomes a widely shared and level playing field free from obstacles to electronic commerce, e-mail, and the open flow of information.

Compared with the hierarchical, largely centralised models of organisation dominant in most private and public sector places of work (and even in many households), the Internet is an anarchistic, overly decentralised and disorganised (virtual) place. It is an ocean of information connected according to the non-linear rules of hyper-links. It is highly efficient for sharing ideas and taking the initiative to make spontaneous connections oblivious to distance, time zones or preconceptions. It is in marked contrast with the more rigid industrial paradigm of mass production and mass consumption. The Internet thrives in a world where intangible assets are more important than yesterday's fixed assets and digital copying means almost zero-marginal cost reproduction. As a result, the Internet has the potential to transform completely many of the institutional and behavioural patterns that have characterised at the micro level both the supply and demand sides of OECD economies. On the supply side, new forms of work organisation, product development and distribution, market entry and collaboration are emerging. On the demand side, consumption is beginning to shift from passive to active modes. Entirely new business models are being invented in order to exploit these new conditions profitably. Individuals and firms are using the Net not only to actively seek existing products but also to initiate the production of items they conceived. The consumer is beginning to take on a key role formerly reserved for the producer. If this paradigm shift continues to diffuse, there is a chance that across a wide range of activities the value-added chain may be turned upside down.

Sustaining and extending such a radically different culture will take time, and could even fail. True decentralisation of decision-making and co-ordination that goes beyond telework just to save office space and reduce commuting will require individuals to take responsibility throughout the day, from the moment they choose (as producer/consumers) their personally unique breakfast cereal mix to the innovation they dream up (as worker/entrepreneur) in co-operation with a customer that afternoon. This is a daunting challenge. People are naturally resistant to giving up familiar strategies for achieving economic and social success, managing risk and assuring continuity. Although it may at times only be a question of perception, of how someone looks at change -- "is it a threat or an opportunity?" -- a new paradigm can be very disruptive. The demands of networked "dynamic reciprocity" go well beyond the roles people are trained to perform and the ways of learning that have been fostered by schools, offices and most homes. For all the potential of the Internet paradigm there are many constraints, not least of which is the powerful tendency to reimpose traditional methods by simply grafting the old patterns onto the new. These counter-currents can be seen in all areas, from the private firm or public agency that merely uses the Internet to de-layer operations without changing the organisational culture, to misconceived government policy initiatives that impose industrial era solutions on knowledge economy problems.

Healthcare prospects

Healthcare is already in transition. In most OECD countries the traditional approach to human health leaned heavily on the industrial mass production and mass consumption model, with the hospital as factory and the patient as passive consumer. The paradigm did lead to tremendous gains in reducing the mortality and morbidity associated with disease and accidents. Recently, however, serious limits have emerged in terms of both cost and effectiveness. Reform is under way, with considerable iterative technological and organisational progress already made and even more expected when it comes to controlling costs and improving delivery methods. What is less certain is the extent to which the combination of info- and bio-technologies will actually transform the current medical services sector into a decentralised, active source of preventative maintenance of more than physiological well-being. As indicated earlier, there is a possibility that the breakthroughs expected in understanding genetic and biological processes, along with the power of computing to monitor, store and assess huge quantities of biodata, could lead to major advances in the identification of hereditary and environmental factors likely to affect people's health. This potential for much greater individual control and prevention of health risks could bring with it a redistribution of power and transformation of the institutional and behavioural context. There are, however, many micro-level obstacles to such a transition.

Foremost, perhaps, is the fear and ignorance that still pervade most people's view of their health. The notion of taking personal charge of disease prevention, diagnosis and most treatment is not yet a widely shared vision in today's society. There are ethical and knowledge barriers, but there are also a wide range of institutional and entrenched interests that are likely to oppose a change in the sources of health-related information and decision-making. Here home-based real-time diagnostic and treatment technology, by making health outcomes much more transparent, could play a key role in reducing risks, opening up new markets and enabling institutional and behavioural change. In a world where health information is much more understandable and reliable, individuals can be expected to begin making their own choices. This, in turn, is likely to open up new markets and spur the development of new products that would allow people to benefit from the advances of info- and bio-tech. Technological advances, along with changes to the regulatory systems that protect and concentrate the present patterns of control of health-related information, could turn patients from passive consumers to active controllers. They could also turn medical monopolists into open competitors and doctors themselves into a new breed of practitioner.

Micro-level risks and resistance

Overall, these kinds of radical, technology-enabled changes in the micro-level organisation of work or in the familiar model of passive mass consumption could seriously disrupt or destroy a range of established mechanisms for managing or reducing the costs and risks of organised activity. Some of the most basic assumptions that underpin what people know and expect in the workplace and the home could be called into question. For instance, with the explosive development of technologies such as the Internet, there is likely to be an accelerating trend away from the reassurances, subtle information-sharing and planning assumptions that were once offered by stable career patterns, fixed responsibility pyramids, familiar local shops, and face-to-face encounters at work or in the schoolyard or doctor's office. Continued "dis-intermediation" -- a term that refers to the radical changes that occur in the mediating role of the retailer or university when bypassed by the establishment of direct links between the producer and consumer, student and teacher -- will in all probability compound the disruption of established micro-level organisational patterns.

Leaving behind the habits of the mass production, mass consumption era will not only overturn numerous comforting firm- and household-level traditions, but also demand the introduction of new mechanisms that are at least as capable of furnishing reliable and inexpensive information and expectations as yesterday's world of top-down orders and standardized choices. Without new methods for reducing risks, the perception of risk, and the costs of acquiring dependable information, socio-technical dynamism will likely slow down. Rapid technological development and diffusion are unlikely to take place without inventiveness, spontaneity and openness on the part of workers and consumers. Successfully addressing these challenges will, in large part, depend on the nature of the changes that take place in the surrounding macro and global framework conditions. These issues are discussed in the next section.

B. Macro- and global-level dynamism and resistance to socio-technical transformation

In general terms, the "conventional wisdom" is that a number of powerful macro and global trends will probably continue to create a fairly positive context for technological progress over the next few decades:

- first, the persistence of widespread adherence to economic policies aimed at non-inflationary growth, structural adjustment and reductions of public deficits and debt;

- second, the continuation of steady growth in productivity as competition drives forward innovation and the accumulation of intangible capital (technical, human and organisational), particularly in the service sectors of developed countries and the industrial sectors of the developing world;

- third, the continued reduction of restraints on market functioning at domestic level through deregulation and privatisation of such sectors as transportation and communication;

- fourth, the further liberalisation of international trade (including services), foreign direct investment and cross-border technology flows;

- and lastly, the ongoing integration of more and more countries, some of them with huge domestic markets, into the global economy.

Taking as given that these basically positive framework conditions will, for the most part, prevail does not resolve the question of the extent to which macro- and global-level conditions will encourage fundamental socio-technical continuity or dynamism. Proceeding along one or the other of these alternative paths will in large part hinge on responses to two further challenges. The first involves the capacity to sustain the positive impact of "knowledge spillovers". What is at stake here are those conditions that either encourage or discourage the high level of information-sharing necessary to spark breakthroughs in socio-technical organisation. The second challenge involves the establishment of an environment that encourages the emergence of new patterns of productive organisation, income, employment, consumption and public-private interaction. Creating these conditions, which not only allow but encourage a high degree of flexibility and innovation throughout society, will play a crucial part in determining the realisation and pace of socio-technical dynamism. Differences in how these two challenges are addressed will constitute a decisive factor in either accelerating or slowing down the emergence of the technological, organisational and structural changes that might, for instance, usher in a new post-automotive Internet era.

Macro

One way of clarifying how different macro-level responses give rise to distinct paths toward socio-technical dynamism is to consider two scenarios of what might happen to the national or regional economies of OECD countries over the next two decades. One scenario depicts a somewhat extreme vision of an almost exclusively market-driven society and the other an equally pushed version of a "new society" model. Neither scenario has a monopoly on socio-technical dynamism. Rather, what emerges is that different approaches to macro-level challenges can be expected to generate distinct sets of impediments and encouragements to socio-technical change.

“Market” scenario

The primary attribute of the Market scenario is a radical reduction of public activities to those of the “night watchman” state which attends only to military, judicial, administrative and regulatory issues. All of the social services, including education, health, social security and welfare, as well as other services such as transportation and communications, are left up to private sector market delivery. The introduction of market discipline to the social services sector is expected to accelerate the pace of innovation, leading to more rapid economic growth. This is in turn likely to lead to a virtuous circle where fully privatised social services can respond to demand with greater output and relative price declines, which then spurs further demand. With booming health, education and insurance sectors in private hands, the fiscal requirements of the public sector should fall, leading to lower interest rates and hence lower capital costs for private investment. The combination of competition-driven technological change and lower capital costs could cause a significant displacement of labour, particularly in the more labour-intensive service sectors such as banking. However, labour market conditions for employment are not expected to deteriorate, since in this scenario wages are sufficiently flexible to achieve full employment. On the downside, there is a good chance that income inequality will widen rapidly, along with the associated problems of exclusion and social costs. A similar accumulation of negative social externalities, items kept outside the purview of minimalist state intervention, could also develop to the point where environmental conditions and general quality of life indicators, e.g. infant mortality among the very poor, deteriorate.

The technological dynamism of the Market scenario arises primarily from the powerful competitive forces that are given complete freedom to transform what and how goods and services are produced. A drastic reduction in the constraints that might inhibit technological change leads to significant innovation across all sectors of the economy. At the same time, however, important counter-forces are likely to develop as the degree of uncertainty and insecurity rises. One of the main brakes on the rate and distribution of technological development and diffusion could turn out to be fear of the harsh penalties for failure. In a world of privatised social services, few regulatory requirements and high degrees of income inequality, many people may adopt strategies at work and at home that minimise risk by sticking to what is familiar and more predictable. Macro-level turbulence could induce greater micro-level risk-aversion, thereby slowing down considerably some of the key behavioural changes that are usually essential to the full development and utilisation of technological potential. Another significant constraint on overall dynamism in this scenario would arise if there is a reduction of knowledge spillovers from both the private and public sectors. On the private side, information hoarding and excessive secrecy could combine with highly restrictive treatment of intellectual property to shut down or severely limit the sharing of ideas that is essential for learning and creativity. On the public side, the reduction in government support for both R&D and the delivery of social services could end up eliminating or significantly reducing the free flow of information, a necessary condition for most technological advances. Such an overall increase in the exclusivity of intellectual property might end up crippling both the development and the diffusion of new technologies, and generate seriously negative consequences at the macro level.

“New Society” scenario

The New Society scenario depends, in large measure, on leadership from the public sector in reaping many of the gains from technological development and diffusion. Using public procurement across the full range of government services in conjunction with active support for R&D spurs innovation and the wide diffusion of technologies that serve collectively determined goals. Improving the quality of life and taking steps towards the establishment of an ecologically sustainable society are at the forefront of the technological agenda. Fairly rapid growth of productivity is expected to continue in those sectors exposed to competition, but without market-based imperatives driving technological advances in the social services -- and faced with higher financial requirements in the public sector -- this scenario shows lower overall economic growth rates. With slower growth and somewhat less flexibility in labour and capital markets there is likely to be a much weaker market-based solution to excess unemployment. Instead, efforts would need to be made to find regulatory and institutional measures to share work hours more equitably among the active labour force, and even to go so far as to redefine and perhaps delink the relationship between income and paid work (e.g. minimum guaranteed income). Complications arise in this scenario from efforts to redesign incentive systems, including taxes, without generating excessive dependency, “moral hazards”, protectionism and risk-avoidance. Public sector inefficiencies and sub-optimal resource allocation could also weigh heavily on macro performance in this scenario.

Technological dynamism, however, gains considerable support from the more mission-oriented and open nature of knowledge development and sharing. With clearly articulated public priorities for the health, education, energy, transportation and communication sectors, considerable reorganisation and technical innovation occur. Info- and bio-technology are more explicitly harnessed to a policy agenda and the private sector also faces greater market certainty with regard to innovative efforts in many areas such as learning, medicine, electric power generation, public transit, etc. The pursuit of accessibility targets to ensure broader equality of opportunity seem likely to provide modest incentives for technical innovations aimed at cost reduction and usability improvements. Nevertheless, such incentives would probably fall short of the creative/destructive intensity of wide-open market forces. As a result, technological opportunities are likely to be lost while institutional continuity in the fields of education, social security and labour market regulation leads to inflexibility and complacency. Although for some firms and individuals the micro-level risks that arise when pursuing technological innovation are reduced, for many there is the temptation to continue with business as usual, which could inhibit both the development and adoption of new techniques and ways of organising daily life. These rigidities increase the cost of realising important public policy goals, such as environmental sustainability, that might require considerable restructuring of basic approaches to today’s resource-intensive production and consumption approaches. From a macro perspective the New Society model offers both the merits and demerits of an overly stable, preconceived and centralised framework for technology development and diffusion.

Macro-level risks and resistance

Reality will no doubt be less pure than either of these two scenarios. At the macro level of national approaches, two stylised possibilities might be more realistic. One is that in the future the domestic framework moves towards some middle-of-the-road model that is half-hearted in both its efforts to encourage the extension of private markets and its attempt to provide public sector leadership. This grey option could end up with the worst of both worlds, with innovation restrained in both the private and public sectors. A second national-level option moves in the opposite direction by expanding the scope of competitive markets wherever possible while at the same time championing public sector initiatives where they facilitate adaptability, socio-technical dynamism and well-being. This approach would have the virtue of encouraging change at a national level, but might end up generating significant friction at the international level if different countries adopt divergent and inherently incompatible policies.

Either way, socio-technical dynamism could be seriously delayed or misdirected by macro-level hurdles arising from the inadequacy of the basic frameworks needed for the smooth functioning of everything from labour and capital markets to intellectual property rights and fundamental scientific research systems. Examples already abound where the spread of the flexible, creative economy has out-stripped the capacity of established employment rules, competition laws, securities regulations, knowledge-sharing incentive schemes (e.g. university funding formulas), and even copyright and patent administrations. Undoubtedly, the nature and extent of these problems will vary across countries in accordance with differences in macro-level framework conditions and the underlying capacity to pursue socio-technical dynamism. In some nations or regions the most acute problems are being posed by anti-competitive practices and the danger that collusion and/or tacit acceptance of technology standards will end up locking in inferior solutions. In other places the main challenges involve adapting labour and capital market regulations and customs to the diverse and often unexpected changes in direction of an innovation-driven economy.

Finally, in either scenario there is the risk that in a more technologically complex and interdependent world the continuation of today's unequal access to and distribution of knowledge would exacerbate the already serious cleavages within society and between regions. Polarisation of technology insiders and outsiders, be it within a city, a region like Europe or across oceans, could end up imposing a range of constraints on socio-technical dynamism. Protectionism, social strife, intolerance and even hatred or open conflict might be inflamed by growing and seemingly unbridgeable gaps between the knowledge haves and have-nots within and between countries. Should such fragmentation, isolation and exclusion proliferate, the pace of socio-technical dynamism would likely be slowed considerably. This in turn might provoke the kind of vicious as opposed to virtuous spiral that ends up further exacerbating problems such as inequality, environmental degradation and global tension.

Global

At the global level there is the possibility of a heterogeneous world where some countries or regions pursue the pure Market model and others the New Society approach. In this context there might be an optimal mix where the advantages of one model are used to fill the gaps of the other. Or, equally plausible, system frictions could arise as the different models have difficulty coexisting. However, before venturing further towards the consideration of the policy issues, it is important to examine the more general question of the relationship of global-level frameworks to socio-technical dynamism and resistance. Here, once again, the focus is on the challenge of establishing the conditions in which "knowledge spillovers" and organisational change are likely to encourage socio-technical transformation. Setting up an effective global framework will probably play a decisive role in the development and diffusion of many technological breakthroughs over the next twenty-five years.

Opportunities and risks

Global framework conditions are likely to be critically important for four reasons. First, continued progress towards a seamless global economic system, with harmonized approaches toward, e.g., intellectual property rights, will probably be indispensable for the effective allocation of investments that underpin both technological advances and the infrastructure needed for socio-economic change. Second, it will be difficult for scientific and technical innovators to capitalise on the leverage made possible by advances in information and communications technologies without strong systems for ensuring knowledge openness and sharing on a global basis. Third, in the commercial realm, both the pressures to compete and the capacity to innovate will be deeply influenced by the extent of global information transparency regarding everything from prices and quality standards to market place collusion and differences in tax regimes. And lastly, the ability to devote resources to the general advancement of technology and the human condition will likely depend on the success or failure of efforts to achieve global co-operation regarding planet-wide issues such as environmental pollution, disease, hunger and poverty. In sum, both advancing towards as well as reaping the benefits of tomorrow's ever-“smaller” planet will depend on the establishment of open, transparent and co-operative framework conditions at the global level.

Without addressing the geopolitical aspects of such global frameworks, there are a number of complicating factors that are likely to be pushed forward by the attributes of emerging technological possibilities. Four divisive forces in particular may reduce the chances of establishing conducive global framework conditions. The first involves the values or cultural assumptions that are either premises for or built into particular technologies such as the Internet or genetic engineering. Here, the risk is that the socio-technical pioneers will ignore the clash of cultures and insist on market access as if it were value-neutral. This could lead to confusing legitimate, democratically expressed social preferences for protectionism, thereby invoking possibly harmful international tensions. The second difficult issue for global frameworks involves the new burdens presented by the destructive potential of some socio-technical possibilities -- including easier access to the knowledge needed to attain lethal military or terrorist capacity and greater vulnerability of key infrastructures to attack over the Internet. More than ever, it will be crucial to assess and monitor at a global level the dangers, even if inadvertent, that might arise in an environment that is conducive to socio-technical dynamism. Third, there is the particular risk that today's global frameworks may be more vulnerable to fragmentation as socio-technical advances allow effective decision-making to descend towards the local and ascend towards the global simultaneously. In this context, differences might be exacerbated and the crucially important global agreements could either disintegrate or fail to emerge. Lastly, the power of technology and new forms of organisation could work to undermine the effectiveness and legitimacy of important collective institutions, from the centralised firm and national government to the family and religious organisations. The current base of the pyramid upon which global frameworks rest could begin to crumble as socio-technical dynamism disrupts existing patterns of assuring societal cohesion.

All of these tensions are amply illustrated by the challenge of achieving environmental sustainability in the next century.

The example of environmental sustainability

Environmental sustainability offers one of the best examples of the divergent implications of realising (or not) global frameworks conducive to socio-technical transformation. The first reason is that socio-technical progress is probably an indispensable part of improving ecological outcomes without facing unacceptable trade-offs in terms of wealth or individual liberty. Secondly, environmental sustainability is the foremost example of two sets of externalities: the cross-jurisdictional nature of pollution, and the probability that the overall social rates of return on investments in socio-technical change aimed at improving the environment are greater at a global level than at the country level.

Unlike certain previous technological challenges -- such as the Manhattan Project, which resolutely pursued the major scientific and engineering breakthroughs needed to build an atomic bomb in the utmost secrecy and isolation -- the success of efforts to achieve environmental sustainability will depend largely on the capacity to openly share and jointly develop socio-economic and technological changes. Similarly, it will be important, as noted above, to seek global framework conditions that are sensitive to the cultural, educational and income differences that may inhibit the worldwide development and diffusion of the socio-technical change. This is not just a challenge for developing countries. For example, making the leap to less wasteful and more local energy production and consumption will probably require fairly radical breaks from existing patterns of working and living, and from the passive and highly resource-intensive approaches, that now largely predominate in most OECD countries.

As for the externalities associated with the global environment, they clearly indicate the need to push global co-operation to new levels. A case in point is the shift to much greater use of local renewable energy sources: progress in this field is likely to require a wide range of often disruptive, expensive and mutually contingent initiatives. For instance, decentralisation of power generation and management to the household and firm level, reversing a century-long tradition of centralisation, would probably involve major reorientations in energy research and product development, significant regulatory changes, major educational efforts, new energy pricing/cost structures, complex equity considerations, and probably lifestyle adaptation. Waiting for one jurisdiction to take on all of the learning costs associated with such a paradigm transition would probably lead to sub-optimal delays from the perspective of the global social returns to be gained from wide diffusion. Competitive forces such as those being unleashed in California that lead private utilities to push ahead with the offer of solar power options to customers will play an important and positive role. But given the technical and equity challenges associated with the conversion to sustainable energy patterns, it will probably be necessary to share costs and benefits at a global level. Without such sharing there is a good chance that the social and technological changes needed to achieve sustainability will either fail to occur or emerge very slowly.

Towards a global approach to encouraging socio-technical dynamism

Ultimately, in light of increasing international interdependence, global as opposed to national-level approaches look set to become the most effective way of addressing macro-level problems such as ensuring that stocks and bonds can be traded seamlessly worldwide, or that producers of intellectual property are compensated fairly and efficiently when someone uses their output. Indeed, one of the main macro-level obstacles to socio-technical dynamism is the fact that available institutions are national or inter-nation(al) while many emerging challenges appear to require more holistic, global thinking. As many analysts have pointed out, particularly with respect to future environmental sustainability, the shift towards more integrated, planet-wide initiatives will probably accelerate as people come to recognise the enhanced benefits -- both private and social -- of action at a global level.

Finally, converging economic, social and technological forces seem poised to create a leap in both the importance and feasibility of global management. From this vantage point, overcoming the obstacles to socio-technical dynamism serves simultaneously as a catalyst to address the challenges likely to be posed by greater interdependence and as a way of developing the tools needed to tackle such global issues. These linkages flow naturally to consideration of the most promising directions for policies aimed at stimulating socio-technical dynamism while minimising the risks and overcoming the varied and often complex barriers.

III. Making the most of 21st century technologies: strategies for encouraging socio-technical dynamism

Many people welcome the prospect of technological innovation offering such bountiful possibilities for the twenty-first century. However, along with this optimism there is also a profound recognition that both the desirability and feasibility of technological developments will depend primarily on the introduction and diffusion of numerous economic, social and governmental enabling conditions. Reciprocally, the direction, pace and diffusion of scientific innovation is seen as fundamentally influencing the underlying structures of knowledge, economic incentives and social constraints. Thus, the realisation of technology’s potential will, it is widely accepted, depend in large part on encouraging a complex interaction of mutually reinforcing societal and technological advances -- an interplay that can be called socio-technical dynamism.

Four particularly potent and pervasive forces can be identified as prime factors likely to spur the advance of socio-technical dynamism over the next few decades. First, the diffusion and intensification of competition in existing and emerging markets locally, regionally and globally seem set to provide an important stimulus to all forms of technological and organisational innovation. Second, the transition to a knowledge economy promises to both rupture entrenched relationships of the industrial era and open up new horizons for intangible, non-firm-based value-added activity. In tomorrow’s networked knowledge economy, imagination -- even artistry -- may become as important as the increasingly vital competitive edge gained by being first to market with a new product. Third, growing economic, social and environmental interdependence, particularly at the global level, will probably compel significant changes in the way knowledge, resources and sovereignty are managed. And fourth, undiminished individual and collective aspirations -- people’s hopes for a better life -- are also likely to play a major role in both altering public policy parameters and leading individuals to take the risk of adopting new patterns for structuring the where, when and how of many basic human activities.

Each of these strong currents could be expected to generate significant economic and social changes; combined, they are likely to furnish a powerful wave upon which socio-technical dynamism will move into the twenty-first century. Just as the transition from agriculture to industry opened up a vast range of new choices for firms, individuals and governments, so too could socio-technical dynamism and the transition to a knowledge-based economy and society. Barring catastrophic political breakdown or natural disasters that could freeze the status quo, it is broadly expected that a dynamic socio-technical path will generate changes in the basic conditions of life for most people. For businesses and households in OECD countries, taking a dynamic socio-technical path will probably mean breaking with a wide range of ingrained habits and customs in order to move towards unprecedented levels of proactive innovation and customisation in all aspects of commerce and life. In much of the rest of the world, the changes could be equally dramatic as new forms of industrial organisation and technology diffuse more fully. Over the course of the next few decades it is not far-fetched to expect major transformations in the long-established patterns of where people work, what they produce, when they engage in learning activity, how they structure different phases of their life and day, what they consume, who supplies them, and how they interact.

Fostering such socio-technical dynamism over the next few decades will demand an emphasis on two broad goals. First, decision-makers in both the public and private sectors will need to devote considerable effort to encouraging individual and organisational creativity -- the capacity and liberty to introduce innovations and changes into the ways in which we work and live. Second, in the public and private domain there will need to be substantial stress on ways of improving collective decision-making at the local, national and (perhaps most importantly) global level in order both to advance socio-technical dynamism and to reap and share its benefits. Much of the analysis stresses the strong interdependence between co-operative efforts to ensure the accessibility and reliability of information in the knowledge economy, and the individual capacity to compete, assess risk and learn. Equally interdependent are the co-operative pursuits of openness, tolerance, and people's ability to find creative inspiration in the free sharing of ideas and contrasting perspectives.

Highlighting these two goals for future policy does not in any way imply an abandonment of more familiar policy thrusts, such as ensuring a stable macroeconomic framework; encouraging structural adjustment through flexible product, labour and capital markets; improving people's learning capacity; and preventing social exclusion. On the contrary, rather than diminishing in importance, these well-known policy priorities are seen by most analysts as crucial for achieving the creativity and co-operation underpinning an innovative, adaptable economic and social context. A stable macroeconomic framework -- consisting of policies that aim for low inflation and solid public sector finances -- plays a key role in reducing some of the volatility that can discourage risk-taking and innovation. More flexible labour markets, transparent and open capital markets, and competitive goods and services markets are all essential to the fluid resource reallocation and experimentation that are likely to be typical of robust socio-technical dynamism. Another continuing policy priority will involve adapting the learning infrastructure -- including but not limited to the industrial era's preoccupation with the educational supply side and massive R&D projects -- to the requirements of an innovative knowledge economy. Ongoing efforts will also be needed to make sure that social support, pension and healthcare systems are adapted in ways that correspond to the needs of tomorrow's highly diverse, possibly less predictable society. Taken as a whole, the reforms currently under way in these conventional policy areas are likely to be necessary although not sufficient for fostering socio-technical dynamism in the twenty-first century.

Meeting the challenge of nurturing an innovation-driven economy and society will likely require equally inventive policy initiatives. For many commentators there will probably need to be a major overhaul of competition and intellectual property laws and administration to take into account the greater importance of intangible assets and global markets. The Internet's extra-national characteristics will also demand novel policy responses. New ground will have to be broken in order to provide the policy frameworks that enable existing technologies to provide every person with the verifiable cyberspace identity needed for voting or sharing medical data. Breakthroughs will also probably be needed in managing global issues like climate change and in pursuing the development and diffusion of technologies that ease some of the negative trade-offs between economic growth and environmental sustainability while at the same time capitalising on the possible synergies. As micro-level decentralisation alters the mass production/mass consumption paradigm, new forms of risk-sharing, information verification and spontaneous co-operation will need to emerge. Rules -- in some cases, creative regulatory initiatives -- regarding electronic commerce will probably be essential for encouraging both the global functioning of existing markets such as insurance or equities, and the development of entirely new transactions such as the sale to business database services of private personal information (e.g. individual preferences, income, purchasing intentions, evaluations of products or brands).

Less typical issues will also need to be integrated into the policy mix. In many cases, sparking transformations in values and culture will be an essential part of facilitating the necessary tolerance of new ideas and diverse lifestyles, as well as entrepreneurialism and experimentation. Pursuing these goals will require a wide range of inventive policies with particular sensitivity to local, national and regional differences. Finding the appropriate combinations of public and private, local and global, innovative and traditional approaches will be not only an ongoing challenge but also a moving target. For if creativity is to be the well-spring of progress, then the conditions that assure such socio-technical dynamism are likely to be continuously evolving.

Annex

LIST OF PARTICIPANTS

Chairman

Donald JOHNSTON
Secretary-General
OECD

Participants

Werner ARBER
Nobel Laureat
Professor of Genetics
Biozentrum
University of Basel
Switzerland

Walter S. BAER
Vice President
RAND Corporation
United States

Simon BEST
CEO and Managing Director
Zeneca Plant Science
United Kingdom

Walter BRINKMANN
Senior Vice President
Coca Cola Europe
Belgium

Roberto CARNEIRO
President
Grupo Forum
former Minister of Education
Portugal

Joseph F. COATES
President
Coates & Jarratt, Inc.
United States

P.S. DEODHAR
Chairman
Mahanager Gas Ltd
former Chairman of the Electronics Commission
of the Indian Government
India

Frederik A. von DEWALL
General Manager and Chief Economist
ING Bank
The Netherlands

Meinolf DIERKES
Professor and Director
Abteilung Organisation und Technikgenese
Wissenschaftszentrum Berlin
Germany

Emilio FONTELA
Professor of Economics
University of Madrid
Spain

Hervé GALLAIRE
Vice President
Xerox Research Centre Europe
France

Orhan GÜVENEN
Undersecretary
State Planning Organisation
Prime Minister's Office
Turkey

Ian HARVEY
Chief Executive
BTG plc.
United Kingdom

Makoto KURODA
Secretary-General
Japanese Association for the 2005 World Exposition
former Vice-Minister, Ministry of International Trade and Industry (MITI)
Japan

Reinhold LEITTERSTORF
Director General
Federal Ministry of Education,
Science, Research and Technology
Germany

Wolfgang LIEB
Secretary of State
Ministry for Science and Research
Northrhine-Westfalia
Germany

Ulf MERBOLD
Scientific Astronaut
European Astronaut Centre
European Space Agency (ESA)
Germany

Wolfgang MICHALSKI
Director, Advisory Unit to
the Secretary-General
OECD

Paolo MONFERINO
Executive Vice President
FIAT Spa
Italy

Hans Henning OFFEN
Vice Chairman of the Managing Board
Westdeutsche Landesbank
Germany

Erik ØVERLAND
Advisor
Ministry of National Planning and Coordination
Norway

Werner POLLMANN
Senior Vice President
Daimler-Benz AG
Germany

Grégoire POSTEL-VINAY
Chef de l'Observatoire des Stratégies Industrielles
Ministère de l'Economie, des Finances et de l'Industrie
France

Bernard ROCQUEMONT
Président Directeur Général
Thomson CSF
France

Jorma ROUTTI
Director-General
DG XII: Science, Research and Development
European Commission

Hanspeter SCHELLING
Chairman, Research Advisory Board
Novartis International AG
Switzerland

Walter SCHUSSER
Vice President
Siemens AG
Germany

Luc SOETE
Director
Maastricht Economic Research Institute
for Innovation and Technology
The Netherlands

Ms Tayce A. WAKEFIELD
Member of the Board of Directors
General Motors of Canada Ltd.
Canada

Huijiong WANG
Vice President, Academic Committee
Development Research Center
The State Council
China

OECD Secretariat

Barrie STEVENS
Deputy Head, Advisory Unit
to the Secretary-General

Riel MILLER
Principal Administrator, Advisory Unit
to the Secretary-General

Pierre-Alain SCHIEB
Principal Administrator, Advisory Unit
to the Secretary-General