MANAGEMENT OF TECHNOLOGICAL RESOURCES FOR SUSTAINABLE DEVELOPMENT

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Keywords: Science, technology, sustainable development, innovation, economic growth, research and development, cleaner technology, organizational innovation, environmental policy, regulation, economic instruments, research and innovation policy, partnerships, foresight, clusters, information and communication technology, biotechnology, technology assessment, development, international cooperation

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Summary

Despite astounding technological advances since the industrial revolution, societies have not yet succeeded in managing the development, spread, and unintended effects of technologies efficiently and justly. Failures in management may lead to long-run unsustainability. Broad principles of management of technological resources for sustainable development may be drawn from the following discussion.

- Technology is inevitably a double-edged sword, and technological progress generates both positive contributions to human welfare and negative environmental and social impacts.
- Good management of technological resources for sustainable development should directly address the obstacles. These include the failure of the market to induce adequate investment for research and development for sustainability objectives; the systemic difficulties in the research system; and the diversity and complexity of the sustainability issues and the possible technological responses.
- Since technological resources are generated in large part in industrial firms, their management should be based on a good understanding of what drives industrial

firms to innovate for sustainability objectives. The interaction of regulatory, commercial, and social awareness factors needs to be well understood. The corporate strategies need to be linked firmly with management of research and innovation within the firm.

- Environmental policy instruments should be designed to stimulate innovation. Effective policy instruments stimulate cost-effective innovation in a flexible manner and in the long range. Good management of technological resources requires a combination of environmental policy instruments, centered upon well-designed economic instruments and voluntary agreements.
- Central to the good management of technological resources for sustainability are policies that assure the ample and timely supply of knowledge and technology. This means the promotion of broad-based basic scientific research, mainly in the public sector. More focused support for research should use the partnership approach as much as possible in setting research priorities, funding, and executing research. Concrete policy tools include technology foresight, cluster approaches, and strategic niche management.
- Technologies, especially emerging technologies, have considerable potential to contribute to sustainable development. However, they can also generate negative impacts. The positive and the negative impacts need to be carefully assessed in an open manner involving the scientific community, government, business, and the public.
- The special requirements of managing technological resources in developing countries need to be addressed. These include building capacity, developing technologies to meet local needs, and devising suitable financing mechanisms for the development of appropriate technologies based on international cooperation.

1. Introduction

Scientific advances, technological development, and economic growth have greatly improved human welfare since the industrial revolution. We enjoy better health and our daily lives have become more comfortable. However, this has not been an unmixed blessing. The technological advances that have brought about these benefits have also generated threats and risks unknown before the industrial revolution: pollution resulting from industrial production and modern transport systems, hazardous wastes, spread of hitherto confined diseases, global warming, and loss of biodiversity. Also, enhanced well-being has not spread evenly, and disparities in wealth and welfare have widened.

These new threats and risks stand in the way of achieving sustainable development, since sustainable development requires parallel enhancement of economic, environmental, and social well-being. These three pillars of sustainability are also interdependent. Economic growth depends on environmental and social sustainability, on the one hand, and economic growth is needed to achieve environmental and social well-being and sustainability.

Economic growth is a prerequisite because we need to change the way we progress and improve welfare. And if we need to change our ways, technology plays a key role in our path toward sustainable development, since new knowledge and technology has been the source of change in human history.

2. Role of Technology and Innovation for Sustainability

It is clear that technology is a double-edged sword. Advances in technology have brought both positive contributions to improving our well-being as well as negative impacts. The path toward sustainable development lies in maximizing the positive impacts while minimizing the negative ones. In the context of the present epoch in human history, this implies de-linking economic growth and environmental degradation and social exclusion.

Management of technological resources for sustainable development implies maximizing the positive impacts of technological development for economic growth, environmental sustainability, and social cohesion while minimizing their negative impacts on the environment and social well-being. What are the principles for public policy for better management of technological resources for sustainable development?

3. Obstacles to Good Management of Technological Resources

Good management of technological resources for sustainability objectives is a formidable challenge for public policy. First of all, because of the spillover effects of knowledge, industrial firms do not invest adequately in research and development. In addition, because of the "public good" nature of environmental benefits, private investments in environmental improvement also remain at a sub-optimal level. This article mainly addresses the environmental pillar of sustainability in its discussion of the role of technology and innovation. This is because our state of knowledge is more advanced on this aspect than the role of technology and innovation for social sustainability. However, it is understood that innovations that contribute to social sustainability share many characteristics with environmental innovation. Management of technological resources needs to overcome these inadequacies, often termed *market failures.* Measures need to be in place to motivate industrial firms to undertake research and innovation aimed at enhancing sustainability. Where private sector efforts inevitably fail, public sector activities must complement them.

Technology and innovation to improve the environment often arise from insights gained from research and development (R&D) in different scientific and engineering disciplines. This adds an important *systemic* difficulty. New knowledge resulting from advances in various basic and applied sciences and engineering disciplines needs to be combined to generate optimal solutions to enhance environmental performance. Cooperation and collaboration between researchers and institutions in different areas in universities, public research institutes, as well as industrial firms are needed to increase the rate of knowledge advances and innovation arising from transdisciplinary efforts. However, research systems and institutions in most countries are not yet well adapted to facilitate interdisciplinary and intersectoral approaches to scientific research and technology development.

R&D typically requires long time horizons, and innovations serving sustainability cannot be generated overnight, but need to be fostered through R&D focused on that objective. Focusing is important especially because technology useful for sustainability is diverse and diffuse. This is yet another obstacle in managing technological resources

effectively. Until recently, the concept of "environmental technology" pointed to pollution control or "end-of-pipe" technology and equipment, such as desulfurization plants, that were developed to control polluting emissions at the "end" of the production process. Since then, technology to counteract pollution and improve the environment has considerably diversified. To a large extent, this is due to the shift in emphasis toward cleaner technology, which can be any technology applied for the objective of enhancing environmental sustainability. This makes it difficult to identify and define clearly the types of technology and innovation required to develop and distribute. Management of technological resources for sustainability therefore needs to take into account the diverse and diffuse nature of the relevant technologies.

The shift in emphasis towards cleaner technology also highlights the importance of organizational innovations. Enhancing resource efficiency depends not only on machines and equipment but how the production processes within a firm or industry are organized. Also, designing more environmentally friendly products requires better design capacity, which can be fostered through organizational innovation as well as R&D.

The discussion so far points to the importance of R&D in managing technological resources for sustainability. As yet, government R&D budget appropriations for environmental research among the Organisation for Economic Co-operation and Development (OECD) countries remain small at about 2%. It may be noted that if the boundary of "environmental research" is extended to include appropriations for environment-related research on other objectives such as energy and agriculture, this percentage rises to about 5%.

However, the boundaries of environmental research are unclear, and are defined differently in different countries. More reliable and internationally comparable information on environmental R&D is needed to assess whether it is sufficient, since a low level of R&D investment for environmental innovation clearly is an obstacle in accelerating the rate of technological change.

The complexity of the issues that environmental sustainability poses is yet another obstacle. Environmental changes result from interactions of overlapping ecological, physical, and human systems that are entangled. This again demands cross-disciplinary and cross-organizational efforts in finding responses.

The increasing importance of global environmental issues, such as climate change and loss of biodiversity, adds to the complexity. Also, the sources of these problems are less associated with specific and localized production processes, and more with diffuse sources associated with consumption and post-consumption, such as carbon dioxide (CO_2) emissions, wastes, and pollution arising from use of transport. The increasing complexity and diffuse nature of environmental issues is giving rise to a growing perception that managing the flow of materials through the economic system is the key to making societies more sustainable. This focuses attention on identifying common technological issues underlying environmental problems, whether global, regional, or local, making technology a unifying element in policy responses for sustainable development.

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Biographical Sketch

Yukiko Fukasaku received her first university education in chemistry and biology and worked in the Mitsubishi Kasei Institute of Life Sciences in Tokyo for a few years before turning to studies in the history and social studies of science and international relations. She received her Ph.D. from the University of Sussex in the U.K. in science and technology policy studies. She has worked for international organizations and research institutes including UNESCO, ILO, JETRO, and Centre de Sociologie de l'Innovation of the École Nationale Supérieure des Mines either as staff or independent researcher. She currently works in the Science and Technology Policy Division, Directorate for Science, Technology and Industry of the OECD.