SUSTAINABLE DEVELOPMENT OF TECHNOLOGICAL RESOURCE CAPITAL

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Contents

Summary

This article investigates the role that technology has played, and may play in the future, in overcoming constraints for economic growth and development. Special attention is given to: the coevolutionary nature of the development of technological resource capital and socioeconomic and environmental change; the roles of science, policy, institutions and environmental change in the development of technological resource capital; and opportunities that exist nationally and internationally to promote sustainable development of technological resource capital, and the socioeconomic conditions under which it operates.

1. Introduction

Technology has often been perceived as the solution to problems faced by humanity. For example, food shortages, the need for shelter and protection, economic and social necessities to interact over long distances, or to exchange efficiently and effectively and to store information, have triggered the development of irrigation technology, fertilizers, and pesticides, high-rise buildings, automobiles, trains and airplanes, and computing and communication technologies, to name but a few. In many cases, technology is put in place to leverage humanity's influence over its environment by alleviating existing natural resource and environmental constraints, and by opening up new opportunities for social and economic activities. Damming the flow of streams, for example, not only helped to exert some control over periodic floods of low-lying areas, but helped to harness kinetic energy to power mills and looms, and more recently, to generate electricity.

Through history, humanity has come to realize increasingly that technological solutions can bring with them new, unanticipated problems. Development and the use of chlorofluorocarbons (CFCs), for example, has been a response to the need for highly effective coolants in refrigerators and air conditioners. Their use, and eventual escape into the environment, has resulted in large-scale depletion of stratospheric ozone, increased cancer rates, and subsequent research and development of a host of new, technology-based solutions—from development of alternatives to CFCs to ultraprotective skin lotions and chemical cancer treatment methods.

This article investigates the role that technology has played, and may play in the future, in overcoming constraints for economic growth and development. Special attention is given to opportunities that exist nationally and internationally to promote the sustainable development of technological resource capital, and the socioeconomic conditions under which it operates. The following section provides a brief perspective on the coevolutionary nature of economic and environmental change. The article then turns to the long-term nature of technological solutions, and the challenges that decision-makers face when trying to plan for, or stimulate, sustainable development of technological resource capital. The article closes with a summary, and a research and policy agenda.

2. Coevolutionary Development of the Economy and its Environment

In a narrow sense, technological resource capital consists of the human artifacts that are created to reduce or overcome existing resource constraints—such as constraints imposed by the availability of:

- materials and energy to contribute to production and consumption processes;
- environmental waste absorption capacities to dilute and degrade residues from production and consumption, and thus contribute to human and ecosystem health; and
- time and information to meet people's needs for
  - personal and professional interaction, and
  - goods and services that support and add quality to life.

This article will simply refer to "technology" for such a narrow interpretation of the concept of technological resource capital. In a broader sense, technological resource capital consists not only of the product of human ingenuity to overcome constraints, but is part and parcel of culture and geography. A society that perceives its role on Earth to increase its influence over the biophysical environment so it can foster the growth and welfare of its own population tends to choose different technologies to interact with the environment—technologies that are often more intrusive or destructive in the short-run—than societies that view their welfare as dependent on natural resources and environmental waste absorption capacities, whose choice of technology may show heightened concern for long-term negative environmental effects, issues of equity and justice, and intergenerational fairness. This article refers to "technological resource capital" when the broader socioeconomic, institutional and environmental aspects surrounding the development and use of technology are taken into account.

2.1 Science and Technological Resource Capital

Science has a leading role to play in the process of developing technological resource capital, and the way science is conducted is reflective of, and influences, society's view of its role in the environment. For example, science in the Western hemisphere developed to probe deeper into individual aspects of complex systems in efforts to find what makes them tick. Less attention has been given to context than to the search for immutable laws. The applicability of the newly found principles often helped improve upon the performance of existing systems—ranging from mechanical systems to social institutions—and through this raised the social recognition of the scientist-inventor. In contrast, in the East, and in China in particular, technological advancement was viewed by its early scholars with skepticism or even contempt, discouraging the intellectual elite from engaging themselves in the recursive processes of abstraction, model development, experimentation, and model revision, that became so fashionable in Western science. Instead, early Chinese scholars concentrated on the holistic properties and the harmonious and hierarchical relationships of natural and social systems. The two philosophical systems indigenous to China—Taoism and Confucianism—were concerned, respectively, with the order of Nature and the proper ordering of human society. The two philosophies were merged with Buddhism by the neo-Confucian philosophers of the eleventh and twelfth centuries. That fusion provided a comprehensive spiritual and analytical perspective on humans and their environment.

The attempt of many Chinese masters to balance intuition and abstraction, i.e., to live and to see the tension between context and general principle, predates some of the pessimism of the nineteenth and twentieth centuries about science and technology. The most notable components of this pessimism are:

- the recognition that scientific progress not necessarily promotes the happiness of humankind;
- the skepticism that technology—if disconnected from broader social, economic and environmental issues—will be a viable long-term solution; and
- the doubts whether scientific progress is indeed leading to the discovery of "eternal truths."

There are many sources of doubts that plague the image of science as the proponent of truth. Among these sources is the recognition that scientific and technical knowledge in a number of scientific fields seems to have an ever-shorter half-life. Calls for increased attention to uncertainty, and for new strategies to deal with scientific ignorance, abound not just in the social but also the natural sciences. At the same time, scientists notice that additional research makes it often harder, not easier, to answer scientific questions. Some scientists find themselves trapped in the hamster wheel of their discipline—encountering ever more questions while running faster after the truth.

As scientists probe deeper, the scientific community becomes increasingly aware that knowledge is established not just by controlled experiment and "objective scientific criteria" but through social interaction. The questions people ask and the answers they accept are very much products of their education, the social context in which they ask the questions, and the cultural dynamics within society at large, and the scientific community in particular.

Scientific paradigms emerge in the social discourse through which observations are organized and accepted as fact. The reputation of scientists then depends on their ability to provide details for the refinement of existing paradigms. The influence of this consensus building process is often so strong that anomalies, which do not fit the paradigm, are not noticed, or are disregarded. To be more precise, anomalies can only be perceived against the background provided by the paradigm. Once they are perceived as not fitting the paradigm, anomalies may be explored in more detail, and this exploration may lead to adjustments in the perceptions, methods, and experiments by scientists, and they may ultimately help adjust, or shift, the predominant paradigm.

Difficulties of interpreting "scientific fact" are perhaps most prominent when science is used in public and policy debate, when the stakes are high, and uncertainties abound. The traditional procedures of hypothesis testing, and "falsification"—important as they are—may be moved to the background, and new measures of the success of science emerge to judge the contribution of science to socioeconomic and environmental systems in general, and to the sustainable development of technological resource capital in particular. Among these new measures are the ability of scientists:

- to apply their knowledge to a wide range of challenges in the policy and investment arena;
- to contribute value to society in the light of uncertainties and surprises; and
- to effectively interact and communicate with stakeholders, i.e., the people who affect and are affected by policy and investment decisions.

2.2 Policy and Technology Decision Making

There are strong linkages among technology, policy and investment-relevant sciences, the development and use of technological resource capital, and the development of institutions dealing with decision-making on issues of science, policy, and investment. Specifically, each technological solution requires its own institutional and infrastructure context within which it is developed and used. For example, the emergence and implementation of modern transport technologies have:

- led to institutions such as highway and aviation authorities, which control further development and application of the respective technology;
- contributed to economic specialization of regions by leveraging their comparative advantages;
- altered the interactions among people by allowing, for example, for more rapid short, medium and long-distance movement; and
- opened up markets for labor, energy and material inputs and products, and as a consequence created an economic stimulus to further invest in that technology.

As technology and socioeconomic systems change, so does the environment in which they operate.

Damming of rivers can stabilize flow rates, reduce flooding, enhance agricultural production, and stimulate expansion of settlements in floodplains. Damming of rivers can also increase the susceptibility of local ecosystems and economies to severe weather events, by reducing the extent of floodplains and their ability to absorb water. Here is a case in which, akin to an arms race, increased economic activity leads to environmental responses that trigger additional economic activities. Higher dams may mean an increased, but false, sense of security of local populations.

Occasional, increasingly catastrophic floodings may call for larger dams, extended insurance systems, and other technology and policy responses that may reduce the perceived need to rethink "technological solutions."

However, in the long run, a rethinking of "customary" technological solutions often emerges. For example, advances in nuclear physics, combined with the hope to find abundant and cheap supplies of energy for rapidly growing industrialized countries, has led to a speedy adoption of nuclear power in many countries during the 1950s and 1960s. Subsequent encounters of technological hurdles (irreducible risks of managing highly complex technology or treating its waste products), long-term environmental ramifications (lack of sufficiently safe long-term storage facilities for wastes, combined with long half-life and serious environmental and health impacts of nuclear materials), and social skepticism ("not-in-my-back-yard" syndrome) have led to all but abandonment of nuclear power in many countries since the 1980s.

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Biographical Sketch

Dr. Matthias Ruth is the Director of the Environmental Policy Program at the School of Public Affairs, University of Maryland, and Professor of Environmental Economics and Policy. His research focuses on dynamic modeling of nonrenewable and renewable resource use, industrial and infrastructure systems analysis, and environmental economics and policy. Over the last decade, Professor Ruth has published 5 books and approximately 50 papers and book chapters in the scientific literature. He collaborates extensively with scientists and policymakers in the US, Canada, Europe, Asia and Africa. Professor Ruth's recent interdisciplinary research projects include an assessment of impacts of climate change policies on selected industries, their technology choice, resource use and emissions, and an integrated assessment of climate change impacts on infrastructure systems and services with specific focus on the Boston Metropolitan Area. The former project is targeted towards an identification of "smart" industrial, energy and climate change policies—policies that promote significant efficiency improvements in industry without jeopardizing economic performance. The latter project involves collaboration with more than 20 researchers from the social and engineering sciences, planners, policymakers, and the public, with the goal of generating consensus about mitigation and adaptation strategies to address climate change in an urban context. Professor Ruth teaches nationally and internationally courses and seminars on economic geography, microeconomics and policy analysis, ecological economics, industrial ecology and dynamic modeling at the undergraduate, graduate and Ph.D. levels, and on occasion conducts short courses for decision-makers in industry and policy.