TECHNOLOGICAL LEAPFROGGING BY DEVELOPING COUNTRIES

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Contents

Summary

The "leapfrogging" concept has its origin in the belief that some countries, which today find themselves in a state of relative underdevelopment, industrially and technologically, have nevertheless the preconditions, the potential and the historic opportunity to transit, in a relatively short span of time, from the condition of relative underdevelopment to that of an advanced industrial and technological state. The belief

is grounded in the argument that, being underdeveloped, they are not held down by the burden of an outdated and ageing industrial and infrastructural system, which would otherwise cripple the transition. There is historical evidence and good analytical reasoning to support this belief.

Most developing countries find themselves today in various stages and levels of ‘standard-modern’ technology, whereas most OECD countries are in various stages of several ongoing technological revolutions characterized by ‘highly-modern’ technology. We define leapfrogging as the process whereby some developing countries can jump over several stages to move rapidly from standard-modern to highly-modern technologies.

Technological leapfrogging usually occurs in three stages, a hop-step-and-jump effort, as it were, to land in the state-of-the-art situation: 1. Importing and absorbing highly-modern technology, 2. Replicating, producing and improving the imported technology, and 3. Moving on to innovations on ones own. Clearly, this does not happen on a broad front all at once, but proceeds in phases. Beginning with a few specified technologies, a developing country reinforces this process over time to spread the net wider, and to accelerate the transition.

Western Europe, North America and parts of East Asia have all leapfrogged, at different times and in various sequences during the 19th and 20th centuries, to arrive at their present highly-advanced technological state. On the one hand, one gets the feeling that the process of leapfrogging has been accelerating over the last half a century, with increased frequency, such that the next batch of successful leap-froggers is already visible on the horizon. On the other hand, one is troubled by the fact that the hurdles on the run up to the leapfrogging are today relatively much tougher to surmount for most developing countries. This article examines the hurdles, analyzes the means to overcoming them and discusses the principal instruments that need to be deployed for successful leapfrogging.

1. Introduction

Although the term "technological leapfrogging" is of recent coinage, the process it captures has occurred several times in world history over the last century and a half. Instead of slowly and painfully retracing the technological path that Britain had carved out during the first industrial revolution, France and Germany "leapfrogged" into the industrial era on the back of British technology around the middle of the 19th century. Then it was the turn of the United States and some of the smaller countries of Western and Northern Europe, which found themselves in the more advantageous situation of having several technological backs to leapfrog over. The second half of the 20th century witnessed the process repeated by Japan, South Korea, Taiwan, Singapore and Hong Kong.

On the one hand, one gets the feeling that this historical process has been accelerating, and that its frequency is increasing, and that the next batch of successful leapfroggers is already visible on the horizon. On the other, one is troubled by the fact that the hurdles on the run up to the leapfrogging are today relatively much tougher to surmount for most developing countries than was ever the case for the early leapfroggers in Europe and North America, and the more recent ones in East Asia. Section 4 provides an analysis of the nature of these hurdles.

Technological leapfrogging can be said to comprise three stages, each qualitatively higher than the preceding one. The first stage is reached by the import of the latest technologies and their widespread absorption into the economic and social systems of a country. Arrival at the next one is signalled by the creation of indigenous capacity to replicate, and to perform incremental improvements on, the imported designs. Reaching the final destination consists of attaining indigenous capability to go beyond improvement to true innovation. If one were asked to place the above-mentioned East Asian examples in this three-stage process, one would say that Japan arrived at the third stage by the 1970s, South Korea and Taiwan followed suit by the 1990s, while Hong Kong and Singapore were in the process of completing the second stage by the end of the 20th century.

It is at the level of the firm and its skilled personnel that operational decisions are taken on the import, use, production and innovation of technology, whether in the private or the public sector. (The exceptions to this rule were the highly centralized command economies of the Soviet type, which are now defunct.) Therefore, when governments formulate industrial and technological policies, they extrapolate, either implicitly or explicitly, from what they think firms are likely to do under various scenarios. Further, macro-level theories of technical change are testable only at the micro-level of firms. In studying how countries will respond to the leapfrogging challenge, we will therefore often use firms as proxies.

Further, leapfrogging proceeds by way of specific technologies. It can take decades before so much of the transition accumulates as to warrant the judgement that a country has leapfrogged from one technological era to another. The process becomes very much faster if the leapfrogging is led by the new generic technologies: information and communication technology (and the associated generic skills of new management and organisation practices); biotechnology; and new materials technology. They have the power to radically transform vast areas of the economy in relatively short periods of time. In this article, we therefore generalise from analyses made at the level of specific technologies and the level of the firm, as well as at the level of the government.

2. The Technological Gap Between Industrialized and Developing Countries

2.1. Analytical framework

The concept of modern technology we adopt is a broad one. Its 'embodied' or 'hardware' form consists of tools, machinery, equipment and vehicles, which together make up the category of capital goods (see Appendix 1 for a classification of industrial commodities under the three functionally defined broad categories of "consumer", "intermediate" and "capital" goods). Its 'disembodied' or 'software' form encompasses the knowledge and skills required for the use, maintenance, repair, production, adaptation and innovation of capital goods, which are often also labelled in the literature as the know-how and the know-why of processes and products. In our usage, knowledge and skills refer not only to scientific, engineering and technical abilities, but also to the skills associated with management, organization and information. Hereafter we use the terms "knowledge" and "skills" interchangeably, and the concept "technology" as connoting an integrated combination of capital goods and skills.

We find it analytically useful to classify modern technology into two broad types, ‘standard-modern’ and ‘highly-modern’, on the basis of five indicators: automation, science-relatedness, research-intensity, dominant innovative skills and leading sectors. These two broad types, which we hereafter denote by "standard- tech" and "high-tech", are characterized respectively by "medium" and "high" values in their degrees of automation, science-relatedness and research intensity.

The range of professional skills required for the regular use, maintenance, repair and production of the capital goods belonging to these two types of technologies depends of course on the specific industrial and infrastructural branches that one is looking at. In general, they comprise a large number of the skill categories listed under the International Standard Classification of Occupations (see Appendix 2), excluding those that come under sales, services and agriculture.

A country’s capacity to innovate in standard–tech and high-tech pre-supposes the existence of a good base in the skills mentioned above. However, that is not enough. In addition, one has to acquire capacity in certain areas that are specifically innovation-oriented. Research-scientists and research-engineers represent the class of people with leading innovative skills. For much of the hundred-year duration of the standard-tech era in the West (1860-1960), the research-scientist and the research-engineer worked independently without being tied to "systems approaches". The transition from standard-tech to high-tech, both in "old" products (say, textile machinery) and in entirely new ones (say, digital telecommunication), depends crucially on systems approaches to solving problems. The innovations associated with the high-tech area, and with the transition from standard-tech to high-tech in already known products appear impossible without professionalized R&D entities in which research scientists and engineers, as well as system and symbol analysts, work as teams.

Roughly speaking, the transition from the standard-tech to the high-tech era began in Western Europe and North America in the 1960s. Some examples of the leading sectors that exemplify standard-tech capital goods and skills are steel, railways, electricals, automobiles, plastics, synthetic textiles and synthetic dyes. However, all these "old" products have made the transition and are now available in their high-tech forms. Examples of entirely new leading sectors that have arisen with high-tech are microelectronics, computers, digital and satellite-based telecommunications, robotics, informatics, biotechnology and new materials.

2.2. Differences in the Technological Levels of Countries

There are many ways of conceptualizing and measuring the differences in the technological levels of countries. These can be done at the macro-levels of industry, infrastructure and education as aggregated sectors, or at the meta-levels of specific branches within sectors, or at the micro-levels of enterprise-types. It suffices our purpose here to limit ourselves to macro-level comparisons.

Technology can be measured, for instance, in terms of the existing stock of (i) capital goods and its most skill-intensive part, i.e., the machinery sub-sector, (ii) professionally skilled people, and in particular, scientists, engineers and technicians, and (iii) R&D personnel and R&D investment. It can be computed in terms of the magnitudes and growth rates of the domestic production of capital goods, skills and R&D inputs. One can also work out the "technology complexity index" by adding up weighted values of technology producing activities and so forth. Thus, there are static (technological snapshot) and dynamic (technological change) indicators, both kinds being essential for an understanding of the relative positions of countries in a comparative perspective.

Although there is at present a blend of standard-tech and high-tech in the OECD countries, the latter type is the most dominant and dynamic. The transition to the high-tech era is much advanced, with new generic technologies in the lead. The OECD countries display very high values, in global comparative terms, in all the quantitative and qualitative indicators mentioned above.

There is, as expected, a great diversity among developing countries. A few are relatively strong in science and technology, while the great majority are very weak, with some taking a midway position. We can denote them, respectively, as the technologically "strong", "medium" and "weak" South.

The "strong" South has made the transition to the standard-tech era, but has just embarked on the road to the high-tech destination. It is nearly self-reliant in meeting its domestic demand for standard-tech through domestic production, and also exports some of that technology to the world market.

However, its technological indices are between one and a half to three times lower than that of the OECD, and it has some considerable distance to leapfrog over before reaching the OECD levels, but the leapfrogging effort has begun in earnest. Examples of the "strong" South are: Brazil, China, India and Mexico. (We regard South Korea, Taiwan, Hong Kong and Singapore as having already made the transition to the economic status of the rich North on a per capita income basis.)

The "medium" South has not yet the same degree of self-reliance in standard-tech that the "strong" South has achieved, but is firmly on the road to it. At present, it imports not only all of its high-tech from the OECD, but a good deal of its standard-tech as well. Its technological indices are lower than that of the "strong" South by a factor of two to three. Examples are Indonesia, Malaysia, Pakistan, Thailand, Turkey, South Africa, Argentina and Chile.

The "weak" South has very little capacity to produce the technology it needs and imports almost all of it from the OECD region, with perhaps a smattering from the "strong" South. Its technological dependence on the North is as heavy today as it was before de-colonization. Its technological indices are roughly one-half of the "medium" South. Sub-Saharan Africa (with the exception of South Africa), parts of South and West Asia, the Caribbean, Central America and the Andean region fall into this category.

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Biographical Sketch

M. R. Bhagavan is a Senior Research Fellow at the Stockholm Environment Institute (SEI). Before joining the SEI, he was working as a Senior Research Adviser in the Science, Technology and Industrialisation Section of the Division for Research Cooperation (SAREC) in the Swedish International Development Cooperation Agency (Sida). He is a policy researcher, of many years standing, in technology and energy policies in the context of developing countries, in particular Asia and sub-Saharan Africa. While at Sida/SAREC, he initiated and looked after, *inter alia*, large research cooperation programmes in Asia and Africa.

M. R. Bhagavan took a doctorate degree in physics from the University of Munich. He worked for ten years as a university teacher in physics and mathematics in the universities of Manchester and London, before switching to development studies in the areas of science, technology and industrialisation, which he taught for several years in the universities at Dar es Salaam in Tanzania, and Lusaka in Zambia. He spent a year as an energy policy expert in Luanda in Angola, appointed by the European Economic Commission /EEC (now the European Union/EU), Brussels, to assist the energy secretariat of the Southern African Development Cooperation Conference/SADCC (now the Southern African Development Community/SADC). Dr. Bhagavan has spent brief periods as a visiting researcher and professor in research institutions in Western Europe and India. He has worked as a consultant to ILO, UNCTAD, UNIDO and WIDER/UNU.