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Toward New Rules for Science and Technology Policy for Sustainable Development¹

Keun Lee and John Mathews

1. Introduction

In June 2012, the UN Conference on Sustainable Development met in Rio for the “Rio+20” conference, just twenty years after the first conference in 1992 had adopted a far-reaching strategy on sustainable development. The new Rio+20 strategy, as elaborated in the statement that emanated from the conference, “The future we want” (and adopted by the UN General Assembly a month later, in July 2012) shows the UN’s continuing commitment to sustainable development in three dimensions, namely promotion of an economically, socially, and environmentally sustainable future for our planet and for present and future generations. Special note was given to the continued deterioration in the global environment and the failure of past strategies to halt the fossil-fuel-based “business as usual” trajectory found in both developed and developing countries.

Among the three dimension of sustainable development, economic sustainability is concerned with poverty reduction and more directly related to the Millennium Development Goals (MDGs). The second or social aspect concerns equity and has recently been formulated into emphasis on inclusive development. The third or environmental aspect is about the ecological and resource crises faced today and which threaten the development prospects of countries around the world. While all three dimensions are relevant, the economic sustainability is particularly vital to developing countries as many of them tend to be stuck in poverty or middle-income traps as their growth is not sustained.² This chapter is concerned primarily with the interaction between the

economic and environmental dimensions, and investigates the role of science, technology, and innovation (STI) in enabling developing countries to reach their potential and catch-up with advanced countries, while respecting the social inclusion goals that are highlighted in the MDGs.

Advancing a nation's capacity in STI and its effective application in economic activities are essential factors for expanding peoples' capabilities and achieving sustainable development. Globalization has implied increased competition among producers/countries and further stressed the importance of STI for the dynamic transformation of economies and sustaining growth. For example, the rapid development of digital technologies and their accelerated use in hardware (computers, mobile phones, and so on) and production processes have changed many aspects of daily lives and enhanced prospects for development. Countries and individuals lacking capacity to access, adapt, and fully utilize these technologies have lagged behind the STI frontier, while the productivity and welfare gaps between the haves and have-nots have widened.

For most developing countries, the underlying strategic objective in the area of STI is to promote technological catch-up with technological leading countries (the leader), which include not only developed countries, but also some other developing countries. This catch-up process involves acquiring, mastering, and adapting new products, technologies, or managerial structure previously developed by the leader and, eventually, breaking into new markets, expanding and consolidating participation. For many least developed countries (LDCs) that do not possess a minimal technological base to start or advance in the catch-up process, external assistance may be required to enable them to establish a minimum technological platform from which the process is initiated. The initial success of the catch-up would make it possible for a country—LDCs and otherwise—to climb up the ladder in the global technological hierarchy and eventually to participate in the generation of new technology.

These considerations call for an examination of the role of technology in economic development, and the role of STI policies in the context of national development strategy as well as the potential contribution of international cooperation in the area of technology transfer and capacity building.³ In this regard, the success of East Asian countries can be attributed to the priority in the national strategy given to policies aimed at enhancing long-term growth prospects, including policies on technology, human capital, and institutional development. STI policies were undertaken with a view toward creating or strengthening strategic industries through tax concessions, subsidies, and trade protections.

However, countries trying to catch up at present face new challenges and opportunities that the countries in East Asia did not face when they were at the initial stages of this process. First, policies promoting structural change in the economy will need to be increasingly consistent with the introduction of technologies that rely on clean energy and adapt to climate change.⁴ Second, more rapid technological progress than before implies that the target of catching up and development are constantly moving and the market opportunities of today change quickly. Thus, promoting sectors based on mature technologies, while offering a good platform for promoting manufacturing, may not lead to catch-up.⁵ Accordingly, the requirements to access and apply new technologies and to capture market opportunities may be more challenging to meet than before. Third, the inability of the conventional fossil-fueled industrial model to scale up and provide a sound source of income and wealth for all the world's inhabitants has to be confronted, and an alternative sustainable model of development be created.⁶ This means, in effect, that developing countries need to avoid the "carbon lock-in" that constrains the uptake of renewable and low-carbon technologies in the advanced world, while securing advantages from the adoption of renewable such as Brazil is able to do from its development of bioethanol from sugarcane as a domestically developed alternative fuel. Fourth, intellectual property rights are now ruled by a multilateral agreement, The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS), and also increasingly by regional and bilateral Free Trade Agreements, which may restrict the range of policy options available for developing countries. These patent-based regimes are not necessarily compatible with the technological development stage of many developing countries and may deter innovation in these countries (Kim and others, 2012).

The main objective of the present chapter is to examine what policy measures both at the domestic and international level are effective in facilitating technological catch-up or leapfrogging by developing countries. Analysis will be based on the experience of some successful developing countries, but with paying due considerations to the new challenges and opportunities in the twenty-first century. The focus should be not only on policies for advancing science, technology, and innovation, but also on their application in the upgrading and transformation of production structures in developing countries to drive job creation and poverty reduction. In the context of greening of development strategies and the role played by STI, our concern is to demonstrate how developing countries can formulate policies to access and utilize the accumulated

knowledge regarding the technical means of getting off a fossil fuel trajectory to a new, sustainable trajectory.

In what follows, Section 2 reviews issues and challenges related to these two dimensions of economics and environmental sustainability, and Section 3 discusses the role of STI in coping with challenges in this regard, and the necessity and feasibility of switching to an alternative growth paradigm. Section 5 discusses specific policy strategies in building up capabilities of developing countries as well as how to use STI in dealing with the problems in sustainable development. Section 6 concludes the chapter by providing the UN or international-level policy suggestions.

2. Issues and challenges in sustainable development

2.1. The middle income trap, poverty trap, and the adding-up problem

While some latecomer economies have been making a remarkable success of catching-up, many others have not been able to join the catch-up club (Lee, 2013). Despite the huge amount of development aid that has been transferred as well as policy reforms along the lines of the Washington Consensus, poverty and the widening gap between rich and poor countries still prevails. Some have blamed this on poor institutional conditions, including insecure property rights, rule of law, and so on in these economies (Knack and Keefer, 1995). Recent literature in economic development has debated the relative importance of institutions, policy, and geography as competing determinants of economic growth or as factors responsible for the reversal of fortune between former colonies and others. A stream of research, such as works by Acemoglu, Johnson, and Robinson (2001), Rodrik, Subramanian, and Trebbi (2004), and Acemoglu (2012), has emerged verifying the importance of institutions. However, cross-national empirical literature has failed to establish a strong causal link between any particular design feature of institutions and sustained economic growth (World Bank, 2005). Furthermore, Glaeser, and others (2004) proposed human capital as a more robust variable for long-run economic growth. In the meantime, the Commission on Growth and Development acknowledged the importance of government activism and industrial policy, while expressing caution over hasty liberalization and privatization initiatives (Commission on Growth and Development, 2008).

Table 3.1 Three patterns of technological catch-up

Path of the Forerunner:	stage A --> stage B --> stage C --> stage D
1) Path-Following Catch-up: eg.) Consumer electronics in Korea during analogue era, PC, Machine tools	stage A --> stage B --> stage C --> stage D
2) Stage-Skipping Catch-up (leapfrogging I): eg.) Engine development by Hyundai Motors; DRAM development by Samsung (Lee and Lim, 2001); Digital Telephone Switch development by China (Mu and Lee, 2005)	stage A -----> stage C --> stage D
3) Path-Creating Catch-up (leapfrogging II): eg.) CDMA mobile phone, Digital TV (Lee, Lim, and Song, 2005)	stage A --> stage B --> stage C' --> stage D'

Notes: In stage C, the two technologies, C and C', represent alternative technologies.

Source: Lee and Lim (2001).

Recently an increasing number of scholars have been paying attention to the fact that many developing countries were able to show growth spurts for a certain period of time (usually less than a decade) but were unable to sustain it over a longer period, as noted by Jones and Olken (2005), Hausmann, Pritchett, and Rodrik (2005), and Rodrik (2006). We view this question of sustaining growth especially for middle-income countries as important, because many countries were able to grow and attain middle-income status but subsequently failed to go on to achieve high-income status. While there have been many studies of the poverty trap and its relevance for low-income countries, few empirical studies focus on sustaining economic growth beyond the middle-income level.⁷

We find instances in Latin American countries such as Brazil and Argentina where growth was more or less stalled during the 1980s and the 1990s (Lee and Kim, 2009, Table 3.1; Paus, 2011). These countries have arguably been caught in what could be called a middle-income country trap—defined as a situation where middle-income countries struggle to remain competitive as new countries with low-cost, high volume production take over their industries while they lack the capacity and capabilities to move to advanced industries. In contrast, several countries moved beyond the middle-income status to join the rich-country club. Examples of these include Republic of Korea and Taiwan Province of China, whose per capita income increased thrice as much over the two decades (the 1980s and the 1990s), whereas their levels used to be at par with those of Latin American countries in the early 1980s.

This trend of declining growth rates as a country that moves on from lower-middle income to upper-middle-income level suggests that sustaining catch-up growth becomes more difficult when a country is closer to the technological frontier. How can we explain the difficulties faced by middle-income countries, and what would be the possible breakthrough in this difficult situation? It also raises the important question of how a few countries such as Republic of Korea and Taiwan Province of China were able to escape this trap and continue their catching-up trajectory.

As verified in Lee and Kim (2009), the answer appears to lie in the level of expenditure on research and development (R&D) and related innovation capabilities; their country-panel analysis shows that during the first transition from low- to middle-income level, basic factors like institutions and primary/secondary education are significant, whereas in the upgrading from middle- to high-income stage, more advanced factors like tertiary education and technological innovation come to play a significant role.

This econometric finding, controlling the so-called endogeneity problem, is consistent with descriptive data. Lee and Kim (2009) show that in the early 1980s, measures such as R&D to gross domestic product (GDP) ratio as well as a number of US patents registered attained similar levels in Asian countries (e.g., Republic of Korea and Taiwan Province of China) and Latin American countries such as Brazil and Argentina. However, twenty years later or by the early 2000s, while the Asian countries passed the threshold of 1 percent ratio of R&D to GDP and filed about 6,000 US patents, the Latin American countries' R&D intensity rarely reached 1 percent while their filing of US patents never exceeded 500. The Latin American countries appeared to be caught in the middle-income trap.

Growth beyond the middle-income level is important because without a clear prospect for further development countries have less incentive to promote growth beyond the low-income level. Economic growth in middle-income countries is important in terms of poverty reduction (given that about 70% of the poor in the world live in these countries) and in terms of greening, since countries cannot switch to green technologies without achieving a certain minimum-income level. Growth of the current low-income countries may be more possible and sustained as the so-called adding-up problem is attenuated.

The adding-up problem happens when all the developing countries flood the market with similar goods that they tend to be good at producing—thus relative prices of these kinds of goods would decrease, making these sectors less profitable (Spence, 2011). Only when more successful middle-income countries move on from selling these low-end goods to the next stage of making and selling

higher-value-added or high-end goods, do they leave room for the less successful or low-income countries to continue to sell low-end goods and maintain their footing on the development ladder.

In general, sustaining economic growth in the South is important because growth is one necessary condition for job growth and poverty reduction although it might not be sufficient. However, role of STI has been limited in economic growth in the South, despite that being an important ingredient for sustaining economic growth. We will turn to how to improve this situation in the following sections.

2.2. Challenge of environment- and climate-friendly development

While sustaining economic growth is vital for poverty reduction, job creation, and avoiding the middle-income trap, the world has reached the stage where the environmental costs of economic growth have to be reconsidered seriously (UN-CDP, 2012). In other words, trade-offs between the economic and environmental dimensions of sustainable development has been increasingly felt. The related increase in the level of human activity is threatening to surpass the limits of the Earth's capacity as a source and sink (UN-CDP, 2012; Vos, 2013).

While it results from both natural factors and human activities, climate change itself is a major challenge, too. Human activities contribute through emissions of “greenhouse gases” (GHGs)—carbon dioxide (CO₂) being the major one of them. Energy use is the main source of CO₂, followed by land use change and deforestation—but in China it is power production and cement production that generate most GHG emissions. The impacts of climate change affect livelihoods and societal welfare, such as sea-level rise, changes in weather regimes, declining agricultural output, and health effects. Developing countries will be confronted with 75 percent or more of the potential economic losses at the global level in relation to climate change and have a relatively limited capacity to respond (Opschoor, 2013).

In general, this unsustainability has distributional aspects, as poor groups and countries depend relatively more on the direct use of natural resources to secure livelihoods and development whereas there are diverse asymmetries in environmental burden bearing. For instance, 1.4 billion people are “energy-poor,” that is, lacking access to forms of modern energy or electricity in particular, which in turn is hampering their economic opportunities and options to emerge from income poverty (Vos, 2013). Environmental pressure (including on natural

resources) is driven by economic growth, population dynamics, and technological change, and thus there are three basic routes to reducing environmental pressures: technological innovation, reduced economic growth, or reduced population size. Given that reducing population growth evokes a range of ethical issues and we need economic growth for poverty reduction and jobs, the least controversial way of tackling unsustainability should be to rely on the potentials of STI which may then lead to changes in the patterns of consumption.

Traditionally, it is thought that countries of the North will be the supplier of eco-innovations. However, with increasing globalization, and the growing strength of the technological capabilities in the countries of the South, the integration of these innovations into the development process in the rapidly growing economies becomes an additional option which combines both economic catch-up with environmental sustainability (Walz and Krail, 2012). Indeed, eco-innovations are seen as a possible field in which some latecomer economies might more rapidly achieve a leading position, due to lower path dependency or lock-in. An example might be the wind turbine industry which used to be dominated by European firms but has now seen significant and successful entry by firms from China and India. Although China relied heavily on European firms for most of the parts, supplies, and equipment at its early stage, it soon localized much of the production process owing to nationalistic procurement policy and local content requirements (Lema, Berger, and Schmitz, 2012). We see this as an option for other developing countries as well.

Policy frameworks thus need to be framed so as to promote widespread use of available eco-friendly technologies. Because many of such technologies are still far from commercial maturity, Governments may need to create rents to make investments in these technologies “artificially” attractive (Altenberg and Engelmeier, 2012). Temporary rents allow for testing new technologies, learning, and building up economies of scale that are necessary for commercial success. Solar energy technologies are a prominent example. While solar energy is climate-neutral and abundant, solar energy cannot yet compete with fossil fuels, especially as long as environmental costs are not accounted for (but see discussion on costs below).

2.3. Intellectual property rights: Incentives or barriers for innovation?

The subtle balance between incentive provision for knowledge production and providing access to knowledge has long been the source of conflicting views

on the role of Intellectual Property (IP) for the economic well-being of human society. History has witnessed a pendulum between more- and less-protection of IP rights (Reichman, 2009). Since the 1980s, the period for pro-protection bias had driven the IP field with the agenda of global harmonization of IP regime and TRIPS. Recent decades, however, have seen a revived concern for the anticompetitive effects of IP overprotection. Such turnaround has led to the formulation of the World Intellectual Property Organization (WIPO) development agenda and forty-five recommendations.⁸ This shifting emphasis from more protection to more use of IP has coincided with a newly emerging innovation paradigm (Lee and others, 2013).

It is important to understand how the evolving nature of innovation has affected the way an economist thinks (or should think) about the role of IP rights and what policy implications these changes hold for developing countries. Developing countries are concerned more with the utilization and commercial use of IPs for the development of their societies. While protection of knowledge provides innovators with economic incentives, such incentives are to be given more priority at the later stage of economic development where these countries enjoy a higher level of technological capabilities.

Although some evidence of the IPR effects on economic growth exists, particularly with regard to patent protection (Kanwar and Evenson, 2003), the evidence is mixed. Some studies have dealt with the impact of IPRs contingent on certain conditions, stages of economic development or capabilities (Kim and others, 2012; Falvey, Greenaway and Foster, 2006; Schneider, 2005). It seems reasonable to summarize that the impact of IPRs on economic growth depends on many other factors that vary over time from country to country, including the stage of development (Fink and Maskus, 2005). More recent studies, furthermore, point out that an IP system is only one of the many factors that affect economic growth and developing countries, in particular, have more critical or binding factors than IPRs for economic growth (Odagiri and others, 2010). This latter statement is supported by the experiences of successful catching-up economies that have achieved growth without strong protection for IPRs. Also, simply raising the level of IPR protection level would not encourage more innovation expenditure or efforts in the context of developing countries where innovation capabilities are lacking. In other words, more stringent IPR protection leads to higher R&D expenditure only when there are preexisting R&D capabilities, which is not the case in typical developing countries.

Furthermore, strong IP enforcement with regard to firms may seriously reduce the catching-up probability of latecomer firms, especially small and

medium enterprises (SMEs) from developing countries. Lee and Kim (2010) and Odagiri and others (2010), in fact, cite stories of such firms having trouble with IPR lawsuits by forerunning companies, though bigger firms in developing countries have had relative success in overcoming the barriers after some troubles. Moreover, while antidumping suits were the main tools of trade disputes among countries in the past, IP litigation has become the rapidly increasing areas for trade disputes (Lee and others, 2013). The increased patent litigations over fragmented IPRs and the emergence of patent trolls are also a matter of concern for policy makers in both developed and developing countries because these create numerous regulatory and antitrust issues, and threaten the wider usage of IP for innovation and knowledge creation.

In general, it can be concluded that latecomer firms are currently facing more difficult challenges than in the past. This problem is more serious and burdensome for SMEs with limited financial and human resources to respond to litigations from forerunning companies. In such circumstance where the capabilities of firms, especially SMEs, are weak, there can be a case for the active role of the Government or public research institutes. This should be an important policy agenda. Each country should be allowed certain room to tailor its own IP system to its specific needs. In general, the developing countries at an earlier stage of growth may be encouraged to adopt a petit patent (utility models) system,⁹ in addition to regular invention patents, because this secondary IP system has turned out to be successful in the past of currently successful catching-up countries like Japan, Republic of Korea, China, and most recently in Thailand after 1999 (Kim and others, 2012).

3. The search for and feasibility of a new paradigm of development

3.1. New strategic thinking about development

Development is, in essence, a process of capability building, not optimization. The difference in the income level across countries comes basically from the differences in capabilities in many aspects, including the capability to produce and sell internationally competitive products for a prolonged period of time. Then, we can reason that the Neoclassical economics cannot be a good development economics because it is all about optimization or optimal uses of (existing) resources. It also implicitly assumes that all resources are accessible

and we only have to consider how to utilize them most efficiently. But, in reality of most of the developing countries, we do not have to worry about the optimal usages of the resources, simply because we do not have them at hand. For us, the more critical issue is how to build up such capabilities, especially the private sector (Lee and Mathews, 2010).

In this view, the existing framework of overseas development assistance (ODA) is limited in helping developing countries upgrade their industrial structures to ease the adding-up problem, because it tends to focus on the public infrastructure and the nongovernmental organizations, rather than on the capacity building of private firms and entrepreneurship strengthening. A famous example involving the ODA program giving out antimosquito nets leading to collapse of the private business of producing and selling the nets illustrates this point (Moyo, 2009).

3.2. From removing the binding constraint to creating the growth poles/drivers

The concept of the binding constraints refers to those economic distortions whose removal would make the largest contribution to economic growth (Hausmann, Rodrik, and Velasco, 2008, p. 331). They suggested to undertake a diagnostic analysis to detect where the most significant constraints on economic growth are (hence where the greatest return is) and then to address them by adequate policies. But, the stark reality in developing countries is that there are too many problems or binding constraints. An idea consistent with the binding constraint is that of the investment or doing business climates. For example, many studies on the so-called investment climate report so many problems in so many areas, from telecommunication, transportations, electricity, corruption, opening businesses, financing, and so on. However, the idea that if you remove those, then growth will take off sounds somewhat naïve (Lin, 2012). It is naïve in that sense that these concepts still do not put the capabilities of the private sector at its center of discussion. In other words, the priority should be not only on improving the business climates but also on directly cultivating their capabilities. As they grow, they will come up with their own priority idea on which investment climates area to be improved first.

If there is only one universal binding constraint for developing countries, it should be the hard currencies. This is because that growth depends in a most robust manner on investment, and you need to have hard currencies to pay for the investment goods which are mostly to be imported from abroad and not produced locally in developing countries. Then, we can reason that developing

countries should promote export industries to earn the foreign currencies that are most binding for investment and growth. Despite importance of export growth, the development literature tends to emphasize the just openness measured by the trade to GDP ratio. However, several empirical studies do not find robustness of this openness variable as a determinant of growth.

Along this line of thought, the developing countries are advised to pick up and specialize into a few selective sectors or industries as growth poles or growth drivers (UN-CDP, 2012). Initially, it can be tourism, labor-intensive manufacturing, or exports of primary products like coffee, although the industrial structure had better to be diversified and upgraded along the stage of development. Focusing on a few growth poles are important because many resources are constrained and thus to be mobilized into a few strategic areas. Improving business environment can also be done first in these target sectors, rather than in every sector. Then, STI can have an important role in enhancing the possibility of upgrading capabilities and industrial structure of developing countries so that we may attenuate the adding-up problem.

3.3. Potential of science, technology, and innovation in catching-up development

While developing countries have many deficiencies, such as poor endowments of skilled labor, infrastructure, or financial capital, they do have certain advantages that they can draw on the accumulated knowledge of the developed world, and do so without the inherited constraints and inertia of the industrial leaders. This provides a clear focus and strategic goal for the latecomers. The great Russian economic historian, Gerschenkron, introduced the notion of the “latecomer effect” (Gerschenkron, 1962), which includes the fact that these countries may start to use the technology only after it become matured enough to have the standardized capital goods suitable for mass production.

However, this discussion was confined to the catching-up in the mature technology. It is Freeman and Soete (1985) and Pérez and Soete (1988) that suggested the idea of leapfrogging with focus on the role of the new technological paradigm which brings forth a cluster of new industries. It is observed that emerging technological paradigms serve as a window of opportunity for the catching-up country, not being locked into the old technological system and thus being able to grab new opportunities in the emerging or new industries. Pérez and Soete emphasize the advantages of early entry into the new industries, such as low entry barriers in terms of IPRs given that knowledge tends to reside in

public domain during its early days, as well as that there is no firmly established market leaders. During the initial stage of new technological paradigm, the performance of technology is not stable and not parochial to a firm. Therefore, if there are only the human resources who could access the sources of knowledge and create new additional knowledge, entry into emerging technology can be easier than during the later stage of technological evolution. Furthermore, catching-up countries can be said to be in a rather advantageous position as they are not locked into the existing technologies. The advanced countries tend to be locked into the current existing technologies due to the currently high productivity with the existing technologies while unsure about the profitability of emerging technologies.

The above discussion identifies two different advantages of the latecomers, the one in the mature industries and the other in emerging industries. The former is about the possibility of low cost-based entries at mature stages or into mature industries by the latecomers without bothering to bear the burden of R&D costs. The latter is about entry into new emerging industries (such as new renewable energies, and so on) at an earlier stage with the same entry costs but without being locked into existing technologies. In the former, the latecomers tend to inherit the mature industries or segment, while in the latter they leapfrog into emerging industries. The concept of the forerunners' trap applies to the latter case because the forerunners want to stay with the existing technologies until they fully recover their investment costs and benefits and thus might be late in entering new fields. Under such trap, the incumbent would allow some chance for the latecomers becoming the first mover in these new industries. Leapfrogging in new sectors such as clean technology has particular advantages (such as avoidance of carbon lock-in) but also particular barriers, as discussed, for example, by Perkins (2003).

The above discussion is consistent with the idea that there can be several different paths of the latecomer in catching up with the forerunners. Actually, Lee and Lim (2001) have identified the three different patterns of catch-up (Table 3.1): a path-following catch-up, which means the latecomer firms follow the same path taken by the forerunners, a stage-skipping catch-up, which means that the late-comer firms follow the path but skip some stage, and thus save the time, and a path-creating catch-up, which means that the late-comer firms explore their own path of technological development.

To take an example, Samsung's achievement in memory chips (Dynamic random access memories, or DRAMs) can be considered as a case of stage-skipping catching-up. Seeing the potentials of memory chip business, Samsung

decided to enter this new industry as a latecomer to the US and Japanese leaders. The time that Samsung was considering entering memory chip production was the transition period in the world DRAM industry from 16 kilobit (16 K) chips to 64 K chips. Government's advice was such that Korean firms had to start from 1K DRAM, but it was private firms' decision to skip the 1 to 16K DRAM and enter directly into 64K DRAM production. Owing to this strategy of stage-skipping, Samsung was able to save the time to catch up with the incumbent and actually become the market leader in the 2000s. A typical example of a path-creating catching-up or leapfrogging is the case of digital television (TV) development in Republic of Korea (Lee, Lim, and Song, 2005). They actually succeeded by forming the public-private R&D consortium, which was the beginning of the Korean rising ahead of Japan as in today's display market in the world. Without such risk-taking and leapfrogging, Korean catch-up with Japan would have taken much longer time or never happened.

Leapfrogging is, thus, more likely to happen when there are more frequent changes in technologies or generation changes in given products or markets, and there are certain technological sectors with such features. Lee (2013) and Park and Lee (2006) show that such features are closely linked with the variable of the length of cycle time of technologies which means the speed of how quickly technologies change or become obsolete over time and the degree that new technologies thus tend to emerge frequently. Then, we can reason that it is advantageous for qualified latecomers to target and specialize in such sectors. It is a risky venture but makes sense because the latecomers do not have to rely much on the existing technologies dominated by the incumbents and because there is always more growth opportunities associated with ever-emerging new technologies. Thus, Lee (2013) suggests, for the middle-income countries, the short cycle technology sectors as a criterion for specialization because short cycle time means a sector with less reliance on the existing technologies but with greater opportunity for emergence of new technologies. This property of new opportunities indicates more and new growth prospects, and the property of less reliance on existing technologies may lead to faster localization of knowledge creation mechanism. It also indicates lower entry barriers and the possibility of higher profitability associated with less collision with the advanced countries' technology, less royalty payments, and even first/fast mover advantages or product differentiation.

The strategy of leapfrogging makes more sense during the time of paradigm shift because every country or firm is a beginner in terms of the newly emerging techno-economic paradigm and entry barrier tends to be low while the incumbent

tends to ignore new technologies and stay with existing dominant technologies. Industrial latecomers can capture latecomer advantages by adopting green technologies, leapfrogging the stage of “carbon lock-in” that is holding back the developed world (Mathews, 2013).

Thus while almost all the technologies involved in renewable power generation, energy efficiency, heat and power cogeneration, development of alternative fuels and transport systems emanate from the advanced world, the possibilities for applying them are found for the most part in the tropical developing world, where “carbon lock-in” does not act as a constraint. There is an historic opportunity for developing countries to build new industrial systems based on renewable energies and resource efficiency that will generate advantages for the countries concerned (and serve as export platforms for their future development) as well as provide a pathway of sustainable development for the planet as a whole.

One may say that existing advanced countries also try to effect entry into new emerging or renewable industries, and there will also be fierce competition between the advanced and emerging countries. However, those from the advanced countries tend to be new or small entrants rather than big giants, which is typical of early stage in growth of new industries. Thus, during the period of paradigm change or emergence of new industries, early entrants tend to be small firms, and everybody is starting from the same start line. Thus, there will be a period of experiment and turbulence and periods of ups and downs of many companies. It is thus a period of opportunity for the firms from the developing countries, especially when they are backed by the government support in R&D and financing. Newly emerging or short-cycle technology sectors do not necessarily mean that there is no entry barrier but lower barriers, and that there is less disadvantages for the developing countries. An example might be the wind turbine industry which used to be dominated by European firms but now saw significant and successful entry by firms from China and India (Lema, Berger, and Schmitz, 2012).

For this leapfrogging strategy to work certain conditions need to hold, not only availability or access to new technologies but also management of the two important risks of choice among alternative technologies and the creation of initial markets which are discussed in relation to the digital TV development by Korean makers in Lee, Lim, and Song (2005). To handle these risks and also to create certain locational advantages, the government activism is called for.

IPRs constitute another potential obstacle. Theoretical argument has been made that IPRs tend to remain in the public domain and thus less subject to infringement issues. This has been pointed out as one of the advantage of

adopting leapfrogging strategy when there is an emergence of new technologies. However, a worrying emerging sign is that new knowledge in this area has been registered as patents in an increasingly fast manner. If this is the trend, this implies a serious damage to our goal of achieving more sustainable development with the helping hand of STI.

To build a bridge across the gap between developed and developing countries, there needs to be a certain level of capabilities to understand the risks and potentials of leapfrogging. We now turn to these issues in the next section and try to learn lessons from the existing or on-going cases and experiments.

3.4. Feasibility of new growth models

The industrialized countries today share a common pattern of energy consumption and production, involving access to new energy sources of unprecedented power (steam power, then electric power, based on fossil fuels), access to resources at unprecedented levels of exploitation (largely through exploitation of extra-territorial colonial possessions), and the targeting of finance to facilitate the construction of a vast industrial infrastructure (through new industrial banks such as the Deutsche Bank). The problem—or inconvenient truth—is that the conventional industrial model will not “scale” to satisfy the aspirations of these twenty-first-century industrial giants—let alone the aspirations of the many countries in the South that are looking to upgrade their wealth and income through industrialization. The earth’s resources are already overstretched by the actions of the “first” industrializers, which have led to about 1 billion people enjoying a prosperous lifestyle. To bring up to 6 billion people to a middle-class lifestyle by mid-century (as foreseen by economists such as Michael Spence) would call for a sixfold expansion of these activities, with intensity multiplied by the accelerated pace of change. China and India are both courting disaster, from rising oil prices, increasing vulnerability to a handful of oil suppliers, and exacerbating tensions with existing industrialized countries and their “carbon lock-in.”

The answer to this conundrum is not for China and India to turn their back on growth and industrial development, but to build a new kind of industrial system. This is what is known as the “green” industrial system—and the current interest of the UN and all development-oriented agencies is to ascertain to what extent a green industrial system really is being fashioned and implemented in these countries, and to what extent it may represent a fresh option for the many developing countries coming after them. Such a green development strategy is

the inevitable choice for China because it is lagging in conventional fossil-fueled technology but can leapfrog to the lead with green technology because it has such a huge population for which the traditional model would not scale. Now China has been taking important initiatives in new green growth strategies, for example, by building its renewable energy industries in earnest, and so far with notable success. In wind power, for example, China has risen from a marginal position in 2005, doubling its wind power capacity each year, to the point that it was world leader in terms of production of wind power generators and size of domestic wind power market, by the end of 2010 (Lewis, 2012).

The issue is: can the costs of shifting to a renewable energy pathway (as called for in the UN Secretary-General's Sustainable Energy for All Programme) be moderated so that developing countries are enabled to enjoy the advantages of shifting to such sources, while not paying a penalty in terms of excess costs and reduced competitiveness. Now, an emerging fact is that the costs of renewable are relentlessly coming down (due to the learning curves) while the costs for fossil fuels can only be expected to rise (driven by rising demand from the newly developing countries). This is the factor that is going to give latecomers who build their industrial strategies on green development a decided advantage. Consider the situation for solar photovoltaic power (PV). According to Bazilian and others (2012), the costs for solar PV are falling at 45 percent per year, and grid parity will be achieved (or is already being achieved) by 2015.

The message for developing countries is clear: In many low-income developing countries, with above-average isolation (which means countries right across the tropical belt), this means that producing electric power from solar PVs is now cheaper than producing power from, for example, stand-alone diesel generators. Thus the way is opening for the realization of the UN Secretary-General's *Renewable Energy for All* program.

4. Strategies and policies for sustainable development

4.1. Building technological capability

We can suggest several stages of learning and capability building which can involve eventually the final stage of leapfrogging.

The first stage is the initial stage, in which the latecomer countries tend to specialize in mature industries or the low-end segment of short-cycle technology-based industries. An example of longer-cycle technology-based sectors is textile

products, which the latecomers produce for the export market via an original-equipment-manufacturer (OEM) arrangement with the firms from advanced countries. Original equipment manufacturing (OEM) is a specific form of subcontracting under which a complete, finished product is made to the exact buyer specifications. An example of the low-end or low value-added segment of the shorter-cycle technology-based sectors is the OEM- or FDI-based assembly-type products in consumer electronics, automobiles, or telecommunication equipment. These arrangements are typical of low-income or several middle-income countries. In the early days of Taiwan Province of China and Republic of Korea, like during the 1970s, 1980s, and even 1990s, OEM accounted for a significant share of electronic exports, and served as one of the institutional mechanisms to enter into and facilitate technological learning (Hobday, 2000).

At this stage, the developing countries are learning-by-doing or exporting, and the by-products are job creation and foreign exchange earnings. Thus, policy tools often include tariffs and undervaluation of currencies that are less sector specific or horizontal. Specifically, tariff had better be asymmetric, namely higher tariffs for sectors to be promoted and lower tariffs for capital goods to be imported by the latecomers, and Shin and Lee (2012) find such tariffs had the impact of increasing the world market share of Korean products. Other forms of horizontal intervention are needed in the areas of hard infrastructure (e.g., transportation, energy, and communication). While the OEM is definitely an effective way of catching up at the early stage of economic growth, it is somewhat uncertain as a long-term strategy because the foreign vendor firms may move their production order to other lower-wage production sites (Lee, 2005). Nowadays a similar situation is happening among flower producers in neighboring East African countries as foreign vendor firms are buying flowers not only from Kenya but also neighboring countries which emerged later than Kenya.

Therefore, the OEM firms should prepare a longer-term plan of making a transition to the original design manufacturer (ODM) and finally even original brand manufacturer (OBM). The original design manufacturing (ODM) firms carry out most of the detailed product design, and the customer firms of ODM companies continue to carry out marketing functions. Meanwhile the original brand manufacturing (OBM) firms carry out manufacturing, design of new products, R&D for materials, processing of products, and conducting sales and distribution for their own brand. Thus, the path from OEM to ODM to OBM has become the standard upgrading process for the latecomer firms. A modified example of such upgrading in flower firms in Africa would be producing flowers

that can last longer with specific smells and with less insects, which require inputs of STI. Transition to OBM in flower industry means that African firms enter into marketing segments, setting up their own outlets with its own brands in Europe. Such transition to ODM or OBM is not easy but has been a narrow path toward the middle or even higher-income status in some Asian countries. Another development model available for low-income countries endowed with rich resources is a combination of black and green development, with Mozambique as an example, where cash from exports of resources can be used to pay for entry into green industries.

In general, transition to the middle-income stage and beyond calls for more sector-specific or vertical intervention policies because the country must now identify its niche between low-income countries with cost advantages in low-end goods and high-income countries with quality advantages in high-end goods. At this stage, public policy should focus on the two kinds of upgrading, namely entry into new industries as well as upgrading into higher value-segment in the existing industry, which is to upgrade the overall industrial structure (Lee and Mathews, 2012). We can suggest short-cycle technology-based sectors as a niche for latecomers, and the issue is how to break into medium short-cycle technology-based products or into the higher-valued segment of the existing sectors. Good targets for such an (import substitution) entry are those products that the latecomers had to import at higher prices due to oligopolistic market structure dominated by the incumbent countries or firms. A best existing example is the telephone switch development in the 1980s or 1990s, discussed in the preceding section (Section 4). The above experience can have implication, for example, for Nigeria or Cameroon, which produce oil but export it as crude oil without refining it. They can target to build more oil refineries which are mature or medium short-cycle technologies. The task is not impossible given that the technology needed to build an oil refinery is old and mature and is, therefore, easily available at cost. The process would be similar to the Korean entry into steel in the form of a State-owned enterprise in the early 1970s.

The final stage of leapfrogging involves public-private R&D efforts that target emerging, rather than existing, technologies. In this case, the role of the Government and public labs is to share the risk involved in the choice of technologies and to promote the initial markets. Specifically, coordinated initiatives on promoting locally developed technological standards and incentives for early adopters would be essential in reducing the risk faced by the weak initial market. In reality, larger, latecomer economies, such as those of China, Brazil, and India, have already been seeking a new development path

powered not by traditional fossil fuels but by alternative energy sources, such as biofuel and other renewable energies. Such countries are trying to move into a new low-carbon economy by developing a range of alternative energies such as wind, solar, and thermal energy, as well as photovoltaic and biogas digesters.

The three stages in the above scheme can be further elaborated with focus on the changing roles of the government research institutes (GRI) or public research organizations (PRO). The essence of such a latecomer model of technological development is the three party cooperation (*G-P-G model*), namely cooperation of the *Government research institutes (G)*—*Private firms (P)*—*Government ministries (G)*, with possibly different roles of each party, depending upon the stages of development. Given that whatever case of technological development should involve the three things of R&D, production, and marketing, the GPG model implies that government research labs in charge of R&D, private firms in charge of production, and the Government in charge of marketing help in the form of direct procurement or protection by tariffs and exclusive standards.

First, the case of telephone switch would be the most typical representation of this GPG model (let us call this GPG1), where R&D is mainly done by the GRIs or public research organs (see Figure 3.1). In this GPG1, private firms are in charge of manufacturing and the Government helped marketing by procuring the domestically made products. Then, there are other variations depending upon the level of capabilities of private firms and public agents involved. The

Figure 3.1 The G-P-G model of technological development

Source: Keun Lee and John Mathews (2013).

case of digital TV and code division multiple access (CDMA) mobile phone in Republic of Korea (Lee, Lim, and Song, 2005) is another variation that can be called a GPG2. In the GPG2, costs and risk of R&D are shared between government research institutes and private firms, and the GRIs do the role of technology-trend watching and coordination to bring in diverse actors into the consortium. This GPG2 model can be considered as a more advanced form of the GPG in that it is possible only when the capabilities of private firms are more advanced to be able to more R&D.

Another variation of the GPG model is the case of government agents doing both R&D and production, and this is possible when capabilities of private firms are nil or the nature of projects tends to involve more production and less R&D but some start-up costs. This variation can be called GPG0 but is actually not GPG but GG without P (without involvement of private firms), and the case of POSCO or steel development in Republic of Korea by the government-owned enterprise is the representative.

The opposite case to this GPG0 mode is that of GPG3 or PG, where government research institute is missing. An example is the case of development of automobile industry spearheaded by Hyundai Motors. As discussed in Lee and Lim (2001), in this case, the Government or a government research institute was not involved in R&D but its role was limited to providing protection of infants by tariffs. As R&D was done by private firms or Hyundai Motors, it is the GP model, not GGP model, with private firms doing both R&D and production.

In sum, based on the cases in the Korean experience, we have identified the four modes of State activism for technological development, and in the increasing order of more roles for a private firm, they are (1) the GPG0 (or GG) mode with the Government doing market provision and government-owned enterprise doing both R&D and production, (2) GPG1 mode with R&D by GRIs and production by private firms, (3) the GPG2 with more R&D shifted to the hands of private firms who are cooperating with the GRIs, and finally (4) GPG3 (or PG) mode where private firms are doing both R&D and production. In all of these variations, the role of the Government (or ministries involved) tends to be guaranteeing the initial markets in the form of procurement policies, and/or local market protection by tariffs or exclusive standard declarations.

In the above discussion of the modes of technological development, the focus has been on the roles of government ministries or research labs. However, we also note that one common element across the four modes of technological development is that they have all involved arranging access to foreign knowledge in diverse channels. As discussed in many literature (Lee, 2005), the role of

foreign knowledge is very critical, without which the latecomers' catching-up effort is often at risk and takes too much time and cost. In general, the diverse channels of knowledge access and learning included such modes as training in foreign firms and institutes, OEM, licensing, joint ventures, co-development with foreign specialized R&D firms, transfer of individual scientists or engineers, reverse brain drains, overseas R&D centers, strategic alliances, and international merger and acquisitions (Lee, 2005). Then, we can say that successful technological development by the latecomers tends to involve the three things, namely, government supports, access to foreign knowledge, and finally private firms' effort, and the weight and specific role of the three elements would differ by the sectors and levels (or stages) of economic development.

The above GPG model can be modified as the model of technological aid to the lower-income countries, in the name of the FLG or F (foreign actor)-L(local firm)-G (Government) Model (see Table 3.2). A simple idea of this is to put foreign actors (foreign research organization invited by the donor Government or UNs) in the place of the GRI/PRO in the GPG model so that foreign actors (cooperation partner) conduct R&D to transfer the results to, or solve the technical problems

Table 3.2 From GPG model to FLG (foreign actor-local firm-government) model

1st stage	GPG0	F-L-G0
Tech transfer/R&D	PRO/foreign actor	Foreign cooperation partner
production	SOEs/private firms	Local firm (private, SOEs)
market promotion/protection	Gov't	Gov't
2nd stage	GPG1	FL-P-G (FLG1)
R&D	PROs	Joint R&D by foreign & local PROs/firms
production	private firms	Local private firms
market promotion/protection	Gov't	Gov't
3rd stage	GPG2	G-P-G2 (FLG2)
R&D	public & private joint R&D	Local public & private joint R&D
production	private firms	Local private firms
market promotion/protection	Gov't	Gov't
4th stage	GPG3 (PG)	G-P-G3 (FLG3)
R&D	private firms	Local private firms
production	private firms	Local private firms
market promotion/protection	None	None

Source: Keun Lee and John Mathews (2013).

of, the local (private or State-owned) firms in developing countries (stage FLG0). Then, in the next stage or FL-P-G, foreign partners conduct joint R&D with local R&D organization or firms. Then, in stage 3, the aid-receiving developing countries become able to conduct R&D locally as private-public partnerships, which is equivalent to GPG2. The final stage is, of course, where all functions are performed by private actors.

4.2. Intellectual property strategies for latecomer firms

As discussed in the preceding section, how to handle IPRs has emerged as a vital concern for the latecomer firms as it affects their learning and catching-up possibilities. It is our view that each country should be allowed certain room to tailor its own IP system to its specific needs, which is especially true of the middle-income countries as they face more complicated and dynamic situations. In general, the developing countries at an earlier stage of growth may be encouraged to adopt a petit patent (utility models) system, in addition to regular invention patents, because this secondary IP system has turned out to be successful in the past of currently successful catching-up countries like Japan, Republic of Korea, China, and most recently in Thailand after 1999 (Kim and others, 2012).

For more specific policy lessons, we can try to learn from the more successful cases.¹⁰ One case of government activism helping SMEs is the Industrial Technology Research Institute (ITRI) in Taiwan Province of China. The main role of the ITRI has been to conduct R&D services for, and to transfer R&D results to, industries in Taiwan Province of China. In ITRI, IP and its management is the key part of its success (Shih, 2005). The patents owned by the ITRI are classified into three grades to be a basis for the diverse uses of IPs, such as internal uses including in-house start-ups, exclusive and nonexclusive licensing, and public auctioning, among others. There have been many cases of using such IP as a basis for start-ups initiated by the ITRI staff.

ITRI has also played a vital role in promoting Taiwan Province of China's strategic industries and overcoming the entry barriers. For instance, when Taiwan Province of China entered the semiconductor industry as a follower to Japan and Republic of Korea, it had already initiated related R&D and produced many patents which were transferred to the firms. In such roles, the strategic use of IPs has been quite important. A strategy used by the Taiwanese is "patent combinations" (Shih, 2005, p. 293). There are two exemplar cases for this strategy: biochip R&D alliances and thin film transistor-liquid crystal display (TFT-LCD)

patent alliance. In the latter case, ITRI has formed an alliance with the Taiwan Province of China TFT-LCD Association (and its seven key companies) to share a portfolio of 232 key patents for large-size flat panels. With this patent pool, the Taiwanese companies were able to stage a late entry to an industry dominated by Japan and Republic of Korea because some of these patents were used to strike a cross-licensing deal with them (Shih, 2005).

There is an example from Republic of Korea in terms of several measures to help the SMEs in IPR disputes. One early initiative included the direct sharing of costs for legal IPR disputes by the SMEs. This initiative has now been changed into creating and selling commercial insurance against possible IPR lawsuits, where the Government pays 70 percent or more of the insurance premium with the maximum amount set for a company. Other ex-ante measures include a service to conduct pre-marketing/exporting investigation of the possibility of legal disputes when the SMEs plan to export to some countries. Ex-post measures included package consulting for SMEs who faced IPR lawsuits with foreign entities. Most recently, a public-private consortium fund, the so-called patent angel, was created to purchase, manage, license, and sell various types of IPRs, and help the SMEs that joined this fund either as a fee-based membership or as an equity holder; the fund was supposed to act as a patent umbrella for SMEs exposed to possible claims by patent trolls.

5. Concluding remarks and policy suggestions

In this chapter we have argued that STI can play a critical role in expediting transition to a sustainable mode of development, through the vehicle of industrial restructuring and fostering of green growth. A critical concept in this transition is leapfrogging including stage-skipping whereby the developing country can jump into a new eco-friendly techno-economic paradigm. In the case of inclusive green growth this concept has intuitive appeal because it is the developed countries that have the most infrastructural inertia in terms of business models based on fossil fuels (carbon lock-in) while developing countries have the opportunity to leap to new green energy and resource systems unconstrained by such lock-in. They also have powerful competitive advantages based on their abundance of resources (sun, land, water) which can be utilized as sources of energy, both to power the industrial development of the latecomer itself and also provide an export platform. Republic of Korea's initiatives in green growth are exemplary in this regard (Mathews, 2012).

However, if developing countries are to realize this potential they need to build up technological capabilities, accessing the knowledge store available in the developed world. There can be several roles for the international organizations like UN in helping cultivation of firm-level technological capabilities in developing countries. First of all, a renewed discussion of how to reform international trade architecture may be conducted to help the latecomer build innovation capabilities that can be started by the UN's initiatives. In domestic setting, developing countries are to be allowed certain policy space to nurture their local firms, which is not possible to emerge if they are exposed from the beginning against competition with foreign goods. Having elementary school players competing in the same soccer tournament with the professional players is not a fair game. In the international setting, the new emphasis is needed in the area of providing "access to developed country markets," and at the same time, their aid should be reformed so as to encourage capacity building of the private sector in developing countries.

Second, to further facilitate cultivation of firm-level technological capabilities in developing countries, the UN may consider starting a new initiative to promote *local-foreign partnerships (LFPs)* which can be regarded as a modification of private-public R&D consortium/partnerships (PPPs). While the latter involved private firms and public research units and was quite effective in solving innovation bottlenecks in several successful countries in East Asia, the LFP involves private firms in less-developed countries and public R&D units from developed countries in solving the existing production problems as well as in executing new business projects which may be an import-substituting or export-generating items in mature or emerging technology sectors. An UN-initiated international assistance program that might be called "STI doctors" can be mobilized to help the firms in the developing world. The STI doctors are a team of foreign experts from public R&D units, retired engineers from private sector, and policy practitioners from foreign governments. Such teams can help solve technical bottlenecks of the developing country firms in the area of innovation and management consulting and know-how. The Korean Government has promoted such programs to help the SMEs, and the UN Industrial Development Organization has already a similar program that can be extended further.

Technological leapfrogging has been practiced around the world including countries in Africa and has had tangible impacts on the pattern of production and consumption. However, a greater policy intervention is called for to expedite the diffusion of new technologies needed to maintain the upgrading momentum. Various forms of incentive or subsidy provision are needed to correct market

failures and coordination failures and to achieve economies of scale. The international community including the UN may consider setting up a global fund to support R&D activities into new environment-friendly technologies and to promote their diffusion.

Finally this chapter has considered the role of IPRs and argued that IPRs (particularly patents) can be a serious interfering factor in countries' efforts to make a transition into sustainable mode of development with the help of STI. We argue that IP systems need to evolve further from an institution to protect IP to one that fosters dissemination of technology. Each country should be allowed certain room to tailor its own IP system to its specific needs. There is a pressing need for global dialogue on the reform of the patent system. Developing countries as a group are well positioned to undertake a leadership role in adapting traditional IP laws to new technological challenges that current advanced countries have failed to address, and thus undermined markets for technology in these economies (Reichman, 2009).

The rise of innovation models utilizing multi-field and outside knowledge, and the associated rise of patent licensing have indicated a need to consider a whole new set of policies. International community including the WIPO should discuss several policy issues, such as a broad research exemption for experimental users and judicial power to require nonexclusive licensing in the spirit of antilocking or public interests. Regarding the patenting of publicly funded research results, there is a need to install a minimum safeguard of public interests by ensuring transparency in licensing and allowing wider use of nonexclusive licensing. Also, the increasing mobility of knowledge works indicates a need for a reform in IP regime to guarantee inventors' continuing research, especially noncommercial ones, and activities regardless of affiliation changes. Various schemes such as the Inter-Institutional Agreement and the Material Transfer Agreement could be further improved and diffused, together with appropriate rules for benefit sharing.

Finally, our chapter argues that inclusive green growth is a feasible development goal that can deliver "sustainable energy for all" (in the terms of the UN Secretary General's program). Growth is essential to enable the balance of the world's population to aspire to and achieve the living standards enjoyed by the 1 billion living in the currently advanced world. Latecomers have potential advantages that, if utilized adroitly (as practiced by East Asia over the past half-century) can enable developing countries to accelerate their catch-up with the West. But they cannot do so by utilizing the traditional model of development powered by fossil fuels, since this would lead them to gross energy insecurity and

probable resource wars. The way around this supremely “inconvenient truth” is to fashion an alternative “green development” model, as arguably China is doing, and to some extent India and Brazil likewise. Green growth is thus a feasible goal for developing countries, enabling them to leapfrog the advanced world with its carbon lock-in and move to the exploitation of abundant resources in tropical developing countries. Tropical countries such as Mozambique are demonstrating that they can utilize revenues from fossil fuel resources to build a “black development” platform in order to finance entry to green sectors which promise long-term economic and energy sustainability. And green growth offers the best chances for social inclusiveness, given that almost all the renewable sources of energy will have to be developed in rural areas and can offer employment and social infrastructure development for rural communities. This would appear to be a promising way forward for developing countries.

Notes

- 1 This chapter is based on Keun Lee and John Mathews (2013), “Science, technology and innovation for sustainable development” CDP Background Paper No. 16. We thank Hiroshi Kawamura, Ana Cortez, and Jose Antonio Alonso for providing valuable comments for the CDP working paper.
- 2 See CDP Policy Note, *The United Nations Development Strategy Beyond 2015* (United Nations publication, Sales No. (E.12.II.A.3)).
- 3 Here technology or innovation is considered in a broader perspective in which some improvements in products, processes, or ways to do things are included.
- 4 Economic and Social Council, *Report of the Committee for Development Policy on Its Fourteenth Session (12–16 March 2012)* (E/2012/33).
- 5 See Pérez (2001), available from http://www.intech.unu.edu/events/herrera_lectures/herrera_lectures/2001_perez.pdf.
- 6 Economic and Social Council, *Report of the Committee for Development Policy on Its Fourteenth Session (12–16 March 2012)* (E/2012/33).
- 7 This issue of the middle-income trap has attracted increasing attention in a number of recent studies, including one by the World Bank (2010). Other than innovation issues, there might be various sources of the trap, such as an institutional trap (as long as institutions are not able to modify at the same pace as economic reality in middle-income countries) and a financial trap (as long as middle-income countries have to integrate in financial markets but that process turns more difficult for them to preserve macroeconomic stability).
- 8 The forty-five adopted recommendations under the WIPO development agenda are available from <http://www.wipo.int/ip-development/en/agenda/recommendations.html>.

- 9 While patents protect innovations of relatively high inventiveness, utility models protect those of relatively low inventiveness. Utility models are second-tier protection for minor inventions, such as devices, tools, and implements. See Kim and others (2012) for detail.
- 10 The cases from Republic of Korea and Taiwan Province of China are taken from Lee and others (2013).

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