UNIT 17 ECOLOGY AND GREEN TECHNOLOGY

Structure

17.1 INTRODUCTION

Technological progress has been a crucial determinant of the pace and direction of economic development. The discovery of steam power and the innovations that it led to in 18th-19th century Europe allowed the continental economy to break free from natural and demographic constraints, thus achieving barely imaginable development levels in any preceding era. For centuries before the industrial revolution, human societies grew, invented and progressed, but the revolutionary changes in science and technology that the 18th century inaugurated(along with Europe's growing colonial empire) allowed this one-time periphery of the globe to grow at the rates and in a sustained fashion that it had never done before. One does not, of course, have to go back so far in history to understand the importance of technology because even in the more immediate past, technology has been a key aspect of successful development experiences like South Korea, Taiwan and more recently, China. In India too early, policymakers focused on developing science and technology capabilities by investing in labs, R&D facilities, and technical academic institutions. As a measure of just how vital technical progress has been, Table 1 indicates the number of patent filings by residents for a select group of countries. As is clear from the figures, the most powerful economies of our times are precisely those that are also technological leaders. As of 2018, residents of the United States filed for over 2 lakh patients. For China and Germany, the numbers were 1,393,815 and 46,617, respectively. While the Indian economy has yet to reach such high numbers, it is worth noting that three decades of sustained economic growth between 1980-2010has largely been built based on its high-tech manufacturing and service sub-sectors, especially IT.

Even as technological progress has become a *sine qua non* of economic growth, its effects on society have been double-edged, and it has become abundantly clear that technology has a dark underside to it as well; a point that several thinkers ranging from Ricardo in England, Gandhi in India to Jose Carlos Mariategui in Peru had repeatedly emphasized. The technologies that drove the Industrial Revolution, for instance, did bring about a massive shift in Europe's economic fortunes, but not without imposing terrible costs. David Ricardo, a crucial figure of classical political economy, warned his countrymen as early as 1821 about the negative consequences of labour-saving machinery for employment and wages of European working classes. Similarly, Gandhi, in his now-famous *Hind Swaraj* warned of the many evils of unregulated technological change on poor, labour abundant economies like India and emphasized the importance of cottage industries in contrast to the growing popularity of heavy industries. Indeed, these warnings became even more prescient as time went along because the technological superiority of the West brought along with it numerous social and ecological costs. The development of steam power and the mechanization of industrial processes for example, required heavy use of fossil fuels (especially coal) which while increasing efficiency of production in a narrow sense, also unleashed a plague of air pollution, deforestation and complete pillage of ecological wealth in Europe and its colonies. The rise of modern science and technology emphasized the need to conquer nature and narrowed down the notion of wealth itself to a concept of exchange value, completely divorcing it from broader concerns of the use-value of society. Indeed, in colonies and the advent of modern technological changes brought along their own set of travails. The development of railway lines while revolutionizing transport in colonies like India at the same time led to food shortages, the spread of diseases, deforestation and massive environmental and epidemiological changes, all of which changes adversely affected local populations and indigenous inhabitants. These changes were often so destructive that they led to massive social revolts like that of the famous Luddite riots in England, which arose due to the large scale closure of artisanal workshops due to the large scale adoption of modern textile machinery. In 19th and 20th century India, too, the destructive effects of western technological change were so keenly felt that technological superiority of the West came to be at the centre of nationalist politics, and an entire generation of nationalist thinkers complained about its destructive effects on the Indian cottage industries.

This Janus faced the nature of technology that invited Joseph Schumpeter to underline the "creative destruction" of modern innovation processes. To Schumpeter, the very nature of technological progress involved the destruction of old markets, institutions, industries, jobs and social mores. Still, it at the very same time also involved a regenerative process of structural change so essential for human progress. Today more than ever, the dual nature of technology- as a threat and as an invaluable tool of progress-is becoming more and more evident. This particularly true of the relationship between technology and our environment. We are living amid a defining moment of human history where the threat of ecological catastrophe looms more prominent than ever before. To a large extent, the current conjecture has been a result of capitalism's productivism, its emphasis on profits, its incessant tendency towards technological progress and the concomitant devaluation of nature and labour. Over the last three odd decades, there has been cataclysmic destruction of flora and fauna species, even as sea levels have been rising at rapid rates. The 5th assessment report of the Intergovernmental Panel on Climate Change (IPCC) has suggested that average temperatures have risen by 0.85 degrees centigrade between 1880 and 2012. It predicts that the temperatures are likely to rise faster in the coming years unless immediate action is taken. The report notes that we are witnessing the most rapid rate of climate change in the past ten millennia.

Moreover, the impact of such changes on food security and billions of people's livelihoods is likely to be devastating. Technological progress has a paradoxical role here because it has enabled the massive ecological destruction that we see before us. Yet, it also presents a powerful tool without which it is impossible to mitigate the fallouts of climate change. Therefore, the dialectics between the destructive and creative role of technology is a striking feature of economic development and the complexities of innovation and technology that the rest of the chapter turns towards.

17.2 OBJECTIVES

After studying this Unit, you would be able to:

- Examine the complex nature of the relationship between technology and ecology;
- Provide a grounding in basic concepts; and
- Build towards the linkages between technology, development and environment.

17.3 DEFINING CONCEPTS: KNOWLEDGE, TECHNOLOGY AND INNOVATION

Before analysing the explicit relationship between green technology and ecology, it is worthwhile to develop some fundamental concepts and understand basic issues when it comes to studying technology. To begin with, it is necessary to differentiate between "knowledge", “technology ", and “innovation”. Knowledge refers to know-how, and more generally, it reflects how information is collected, classified and finally transferred/diffused in any economic system. Such knowledge may be *formal* when there is a standardized form of expressing it and transferring it from one entity to another. But it may also take a more *implicit*, informal form which a process of on-the-job learning can only reveal. For example, the production of a vaccine may require researchers to use formal knowledge regarding human anatomy and epidemiology. Still, its success will also involve a certain amount of tacit knowledge regarding the conduct of successful trials, knowledge of government regulations work, marketing or sales experience and so on, many of which are built on past experiences that researchers or organizations may have accumulated with their time on the job.

Knowledge and technology are closely related. The term, technology, has been used popularly to refer to new products or solutions, but in reality, it refers to a specific kind of knowledge that governs production. It refers to all the technical know-how that determines how products are created from their inputs. While the term technology and innovation are often used interchangeably, they are conceptually very different. Innovation refers to net value addition due to new technologies, new business models, new organizational approaches and new designs. Put differently, innovation refers to the final stage of commercialization of tacit and formal knowledge. Innovation ultimately depends on knowledge, but it needs to be differentiated from these concepts formally and conceptually. Knowledge stocks accumulated over time combined with knowledge flows received from others allow organizations, countries, firms and other entities to expand their skill set, which adds to their innovative capacity. However, the generation of knowledge, its ultimate diffusion across an economic system and its conversion into innovative outcomes is not an automatic linkage. Thus conceptually, it is worthwhile to break down the innovation system into sub-parts and underscore how successful innovation requires an entire supportive eco-system to promote and encourage it.

To take an example, it is well known by now that China had already developed the necessary wherewithal of steam power well before Britain. Yet, in Britain, this knowledge took off in the form of the steam engine in the 19th century that was crucial to its Industrial Revolution. The fact that Britain surged ahead in this front was therefore not merely a matter of availability of knowledge but the fact that its level of commercialization, its access to colonial markets and resources, its mastery of international trade and the ready availability of coal deposits in areas close to its industrial centres all added together and incentivized the wide-scale deployment of steam-based innovations in its case. One, of course, does not have to go back so far into history to understand these distinctions. Examples of the importance of knowledge flows and their relationship to innovative outcomes abound. Closer to home, it has been widely noted that both Brazil and India had started developing IT capabilities in the 1970s and 80s yet. At the same time, Brazilian firms never really took off and were all but overshadowed by foreign MNCs. The Indian strategy of protecting domestic firms and providing them with immense state support allowed the economy to develop strong IT capabilities that ultimately helped it manoeuvre successfully in the emerging global economy. Box 1 provides another exciting example of how network effects can combine and produce uncertain outcomes for innovations.

In this context, we can outline three essential determinants of innovation:

- The state can play an essential role in enhancing the knowledge base of an economy by investing in R&D in the public sector, subsidizing R&D in private organizations, by establishing labs and specialized educational institutions. The state can also establish regulatory institutions, laws and policies to protect innovative firms from domestic and foreign competition at the early stages of their development. State subsidies, tax incentives and patent protection are essential examples of the tools that the state has at its disposal to protect and encourage infant firms to encourage innovativeness in them.

- Firm-level characteristics are another critical determinant of innovation. Acquisition of knowledge by entities requires them to build on already existing knowledge stocks, and this can be done purely internally, but it can also be done by acquiring knowledge from outside. Knowledge flows refer to the transfer of knowledge from one entity to another, and in fact, this process has been crucial for the development of firms. The successful transfer of knowledge from one entity to another -or knowledge flows- in turn, are crucially dependent on the absorptive capacities, which are determined by level of technical training, organizational forms along with a variety of cultural and institutional factors. More generally, the ability to gain from external knowledge flows requires the existence of knowledge and requisite ability to accept and make use of such knowledge, none of which can be presumed to exist *apriori*. Firms can strengthen their absorptive capacities by imparting skills and training to their workforce, by spending on R&D, by reorganizing their business model to make them more flexible to meet diverse technological challenges diverse and thus become receptive to new knowledge.

- Apart from individual characteristics of firms, countries or regions, robust innovation systems depend upon durable linkages between entities. For example, it has been observed that geographical proximity to technological hubs encourage knowledge spillovers from one region to another and thus enable faster and newer forms of innovation. Geographical spillover can be localized in nature, but in an age of growing global integration, commercial links that are developed through international trade and participation in foreign direct investment activities, for example, may also help firms/regions acquire new knowledge through formal R&D collaborations by greater access to the intellectual property of foreign firms or simply through a learning-by-imitating process. Of course, geographical proximity is one of the many essential ways in which network effects play out. Innovating entities may be geographically spread out, but their linkages may be durable enough for innovation to spread from one link to another.

17.4 TECHNOLOGY AND DEVELOPMENT: WORK-HORSE MODELS

As the discussion above clarifies, the concepts of technological progress and innovation are complex. They cannot be analyzed without the adequate grounding of these processes in the larger national, regional and global contexts. At the level of modelling, there has been an immense amount of effort to understand how knowledge flows, how innovations are generated, and how these, in turn, impact economic growth and development. We will not dwell upon these efforts in detail, but for the sake of continuity, a couple of essential issues deserve to be mentioned,

The earliest and most influential efforts to model the interaction between growth and technological progress have come from economics which has sought to understand the channels through which these processes intertwine and entangle with each other. The work-horse models of Harrod-Domar and Solow developed in the 1950s and 60s were the earliest attempts at studying the relationships under question. They remain standard benchmarks in policymaking even today. While each of these attempts eschewed the nuances that we have noted above, they provided a snapshot view of how technological progress affects economic growth. Given their drastic simplifications, to describe these models, we shall, for the time being, suspend the crucial differences between knowledge, technology and innovation and compress them into one interchangeable category of "technology". Readers should be aware that such simplification while allowing us to understand the macroeconomic links, are also drastic because they leave out essential characteristics of how innovations are produced and how knowledge accumulates over time. Despite this caveat, the following approaches provide essential insights into the matter under investigation.

Developed independently by Roy Harrod and Evsey Domar, the celebrated Harrdo-Domar model was one of the earliest attempts to analyze the dynamics of growth, investment and technology. The two models sought to problematize Keynesian assumptions and show how investment in physical capital could affect growth by creating new income flows and directly expanding the productive base of economies. More precisely, the Harrod-Domar model suggested that the following equation could represent the growth in per capita income:

$$g = \frac{s}{\theta} - \delta$$

The expression above suggests that growth of output, g, is a function of the savings ratio, s, (total savings as a proportion of total output), the capital-output ratio θ (technology) and the depreciation of capital δ (costs of wear and tear of machinery). The expression, while rather simple, suggests that the primary constraints on growth are determined by the extent to which savings can be generated in any economy, which reflect potential funds for investment in physical capital. Moreover, the capital-output ratio reflects the technical condition of production, which, as the model indicates, is inversely proportional to growth. That is, as technology improves andθ declines, we expect an economy to grow at faster rates. While the model takes $\theta$to be exogenously determined, it nonetheless suggests an essential link between growth and technological progress.

There are several interesting features of the Harrod-Domar model, but for our purposes here, it is worth noting that the model treats technical conditions (θ) as being fixed. Robert Solow's model, by contrast, begins with the assumption that the capital-output ratios change and that the ratio necessarily increases as more and more output is produced (diminishing marginal returns to capital). Assuming that there are only two inputs that are used for the production of the output (capital and labour) and assuming that output produced at any time is a well-behaved function of these inputs, the fundamental expression of economic growth, in this case, is given by:

$$sy(t) = (k(t+1) - k(t)) - (n+\delta)\,k(t)$$

Here, s, as earlier is the rate of savings, y (t) refers to output per worker at time t, k (t) refers to physical capital per worker at time t, n refers to rate of growth of the workforce (which we assume is a constant)and δ as earlier is the depreciation rate. The above expression seems complicated but has a very intuitive explanation. It suggests that the dynamics of output growth can be broken down and decomposed as follows: As more and more capital is employed per worker, the economy can produce greater output per capita. The resultant savings ($sy(t)$) can either be channelled into *capital deepening* (the first term on the left-hand side of the equation) or *capital widening* (the second term on the left-hand side of the equation). To put it differently, as long as the economy generates sufficient savings, it will be able to enlarge the stock of capital per workers and equip the incoming labour force with at least existing amounts of capital.

However, the point was that under conditions of diminishing returns, savings could not be expected to rise fast enough to cover both *capital deepening* and *widening*. Thus over time, as more and more capital gets pumped into the economy, the assumption of diminishing returns implies that the economy produces lesser and lesser savings for each unit injection of capital. In the long run, the growth of per capita output must converge to zero! The Solow model leaves us with the gloomy prediction that any economy that draws its sustenance solely from the accumulation of inputs is likely to stagnate in the long run. That is, of course unless there is some countervailing force that prevents growth from choking off. And indeed, Solow suggested that this is precisely why technological progress was so very crucial to the wealth of nations. Technological progress could ensure that the effects of diminishing returns are counteracted, thus allowing sustained economic growth to happen in the long run as well.

Check Your Progress Exercise 1

Note: i. Use this space given below to answer the question.

ii. Compare your answer with the one given at the end of this Unit.

1) Explain the difference between knowledge and innovation

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2) What is the role of technology in the Harrod-Domar model?

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17.5 GREEN TECHNOLOGY AND ECOLOGY

A few points are worth noting here regarding the traditional models of technology explained above. First, both work-horse models described above and the Solow growth model view technology as being exogenous to the model itself. Thus, the complex processes that give rise to technical progress and all the institutional scaffolds required for successful innovation remain under-theorized in these models. Related to this, the primary effect of technological change on growth in both models seems to affect the efficiency of production. The faster the technological progress, the more the output generated from a given amount of inputs. Such a view hides the complex nature of the innovation process and the multifaceted channels through which it affects the output.

Moreover, both models completely ignore environmental outcomes. This then brings us to our second observation: the models do not explicitly relate technological progress to ecological conditions. For example, our models tell us that faster rates of technological progress improve the efficiency of production and increases economy-wide output. Still, there is minimal discussion on how these changes interact with ecological constraints. Indeed, let's consider that a large number of the resources that go into production as inputs (like fossil fuels) are non-renewable and cause dangerous carbon emissions. The role of technology reveals itself to be a double-edged sword: it increases productivity in the short run. It lays seeds for long run ecological degradation, which may likely harm growth in the long run. It is, of course, true that one could be extended the models by incorporating the role of natural resources-both renewable and non-renewable- as an additional input and then study its dynamics, but as such the exact relation between technological progress and ecological constraints do not appear in the model. It is to these entanglements that we turn to in this section.

Ever since the Kyoto Protocol was put into practice in 1997, the role of technology in mitigating climate change and reducing environmental risks has been widely commented upon. One of the main concerns of policymakers worldwide has been growing global energy demand and consequent carbon emissions. Developed countries have historically accumulated massive per capita energy consumption levels, and with the rapid growth of developing economies, these countries are likely to catch up on this front. As a result, global energy consumption, which has been increasing rapidly, is only likely to skyrocket even more in the coming decades. Given that energy use is associated with carbon emissions, policymakers are scampering to find ways to meet the world's growing energy demand in a manner that does not vitiate sustainability goals.

In this regard, technological improvements in increasing energy efficiency have been deemed an important way to reduce energy use and control global carbon emissions. Thus Article 2 of the Kyoto Protocol places energy efficiency at the top of the agenda and states, as one of its goals, the "Research on, and promotion, development and increased use of, new and renewable forms of energy, of carbon dioxide sequestration technologies and advanced and innovative environmentally sound technologies". Even the Paris Climate Convention of 2015 has laid great stress on the role of technological development as a tool to fight against climate change.

Technology can be said to contribute to energy savings through many related channels at a theoretical level. For example, technological improvements may help increase production efficiency, i.e.in reducing energy input per unit of output produced. So if it took 500 units of energy to produce a unit of output, with new and effective technologies, the same unit of output may be produced by using only 250 units of energy; thus, the introduction of the new technology would have helped in conserving the energy inputs that go into production. This is, of course, the most apparent way that technologies can contribute to reducing carbon emissions, but there are others as well. For example, even if new technologies do not improve energy efficiency, they may enable the production of energy through clean, renewable and ecologically sustainable methods, which means that although energy efficiency may not have changed, the introduction of the said technology would nonetheless have reduced environmental risks by tapping into cleaner sources of energy- such as solar energy, wind power and biofuels-and thus mitigate environmental risks. Box 2 provides an interesting example of how automobile companies have experimented with hybrid cars to promote environmental goals.

Therefore, we may define green technology as consisting of both (a) technologies that enable lesser energy use or cause lesser waste and (b) technologies that generate energy from clean, renewable resources. Green technology is a far broader term than just these two because it may include several technologies that are not explicitly introduced to meet environmental goals but end up doing so. In the simplest sense, we may define green technologies as any piece of knowledge, product, design or method of production that can help significantly reduce energy use and mitigate adverse environmental risks. This definition which is based on environmental outcomes, is the most widely prevalent use of the term. Green technology from this perspective, is defined in terms of what it can achieve rather than why it was produced in the first place. For example, certain technologies may not have been motivated by environmental goals. Still, if their adoption leads to a reduction in environmental risks, they should be classified under green technologies.

Now, this definition makes clear how to measure and tangibly quantify what green technology is and what it isn't. However, the very broadness of the definition also leaves open several exciting problems that are still being debated by policymakers. To begin with, the idea that only those technologies can constitute green technologies, which have a large or significant effect on the environment, leaves open the question of how significant or how large a change must be in the first place for a technology to be called "green". All too often, technologies and innovations proceed gradually and incrementally but may nonetheless be important determinants of environmental outcomes.

Second, any technology may have multiple effects on the environment. If green technologies are classified thus based on their outcomes alone, this will require value judgements that may throw up complex ethical questions. For example, if new technology in a pharmaceutical firm reduces the energy used for boilers but at the same time leads to higher emittance of pollutants, then classifying this as a green technology would require a judgement about the relative weights placed on pollution and energy use.

Finally, another critical aspect of the definition of green technology above is that it pays no heed to the social or economic dimension. Indeed, it has been widely noted that environmental sustainability is inextricably linked to poverty, inequality, unemployment and other social and economic dimensions of development. The worst affected by climate change, GHG emissions and water pollution are the poorest and most socially vulnerable sections of society. Thus, policies that seek to transform the man-nature relationship have to be able to balance economic, societal, and environmental goals. The emphasis on the "triple bottom line" of social, economic, and environmental goals means that more than ever today, investments in green technology have to be supplemented by more substantial labour standards, investments in health care and education to create a synergy between these multiple goals.

Given these caveats, it is worth thinking about green technologies in a slightly more holistic manner by focusing on the nature of their impact on the environment. To begin with, small changes in design like the addition of some new component can help make technologies greener. In such cases, the overall production process remains essentially unchanged, the business model and marketing strategy do not need to be altered, and yet greener outcomes can be achieved. Such additions may make the existing production process greener. Still, to a large extent, these changes alone are unlikely to cause a significant, long-run shift in environmental outcomes because they are incremental.

A more radical impact would need more than just minor additions and deletions in the existing processes. To enact radical change, the entire production process itself may be targeted by utilizing green technologies at every stage of production and combining these with holistic strategies for reducing toxic pollutants, recycling waste produced in the production process, etc. These changes may be further strengthened by combining them with campaigns to increase consumer awareness about the environmental impact of their choices. Such changes could be made within a particular firm for a particular product, but when expanded to entire industries, such synergistic, complementary changes can have radical effects on environmental outcomes.

Check Your Progress Exercise 2

Note: i. Use this space given below to answer the question.

ii. Compare your answer with the one given at the end of this Unit

3) What is the Kyoto Protocol?

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4) What makes technologies "green"?

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5) What is the relationship between the concepts of "triple bottom line" and green technologies?

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17.6 GREEN TECHNOLOGY: ADOPTION, DIFFUSION AND REBOUND EFFECTS

The importance of integrating green technologies into a larger system-wide project aimed at environmental sustainability is worth dwelling upon. As we have discussed above, the focus of several international treaties and policy bodies has been on leveraging green technology to reduce energy use, control waste and reduce carbon emissions. But unless the development of green technologies is complemented by efforts to create a supportive eco-system, the kind of changes needed to meet environmental goals may not be possible to implement. For example, several studies have shown that the introduction of technologies aimed at increasing energy efficiency may paradoxically cause an increase in energy use. This is because energy efficiency improvements due to the introduction of green technology may reflect a lower price of the final product. If this price decline leads to higher demand for the said good, then in the long run, the feedback loop may push producers to produce on a larger scale than before and hence to use more energy. This is often termed the "Jevons paradox" or rebound effect. Originally theorized by William Stanley Jevons, an English economist and a crucial founder of mainstream economic theory, in the context of coal usage, the same phenomenon has been significantly observed even in contemporary examples. The prevalence of this phenomenon suggests that unless green technologies are complemented with other policies, they may not only fail to meet their stated goals but may worsen environmental degradation.

Box 2: Toyota Prius

The Japanese automobile company, Toyota, was founded in 1937 and is now the most significant Japanese automobile company and a world leader in its field. Toyota is also known to be the first mass producer of the hybrid car Toyota Prius. The Prius was released in Japan in 1997 and has since been the bestselling hybrid car in Japan and the USA.

Hybrid cars began to appear as an alternative to conventional cars that ran on fossil fuels. Increasing fuel prices and carbon emissions were the reasons for the hybrid car segment of the automobile industry to take off since the early 2000s. Until recently, the Prius has been the most fuel-efficient car in the market, emitting as much as half the pollutants than a regular car over its lifetime.

The success of the Toyota experiment has several dimensions to it. To begin with, firms tend to innovate in green technologies if they face "higher tax-inclusive fuel prices". Tax credits and carbon pricing are ways to influence firms to move towards cleaner technologies. Recent research has also focused on breaking path dependence by discouraging investments in coal and instead incentivising research in cleaner technologies. As far as consumers are concerned, studies show that monetary calculations are essential. Thus the provision of tax incentives or increasing fuel prices often induces customers to adopt hybrid cars. Changing social preferences are also an important reason for increased sales of hybrid cars. Studies often show that people may be ready to buy costlier alternatives due to their environmental concerns.

Linked to this is the low adoption and diffusion of green technologies. Despite the widespread availability of new and effective green technologies, end users-whether residential consumers or producers- have been somewhat reluctant to adopt them. At times this is a result of their prohibitive initial costs. Still, more often than not, even when end users are likely to benefit substantially from lower energy bills in the long run, it has been found that they are often reluctant to purchase or adopt green technologies. The non-adoption of technologies even when they provide significant savings has often been termed the “energy-savings paradox”. It is said to occur because end users are often not aware of the importance of energy efficiency or lack the necessary cognitive skills to calculate benefits from new technologies.

All this suggests that the effectiveness of green technologies depends on the availability of a supportive ecosystem. Thus, meeting environmental goals can only be achieved via a systemic change that extends to social, behavioural, and economic dimensions.

17.7 LET US SUM UP

This chapter has introduced readers to the role of technology in economic development and, more importantly, about its role in ensuring environmental sustainability. Meeting ecological goals as set out by the Paris Climate Convention requires immediate and radical change. In this regard, green technologies have been identified as crucial in meeting ambitious goals set out by international and national policymakers. This chapter outlined the concept of green technology and discussed its limits and its potentials as a tool for environmental sustainability.

17.8 UNIT END QUESTIONS

1) Schumpeter summarized the effects of technology with the phrase "creative destruction"? What does this mean, and how can this conceptualization be extended to understanding the relationship between technology and ecology?

2) Define and explain the rebound effect. What implications does this have on the relationship between technology and ecology?

3) In both the Harrod-Domar model as well as the Solow model, technological progress is exogenous. Why is this assumption unrealistic?

17.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1) In popular terminology, knowledge and innovation are used interchangeably, but knowledge can be thought of as an intellectual asset theoretically. It can take a tangible form if it can be codified and symbolized in a manner that makes it readily transferrable. On the other hand, Tacit know-how is embedded in everyday practice and comes through long experience on the job. When knowledge is transformed into a final product/service, design, organizational modifications or even a new business model, we call this process innovation.

2) In the Harrod-Domar model, growth is determined by the savings rate and the capital-output ratio. The capital-output ratio can be taken as a proxy of technology. As technology improves, we expect fewer units of capital to be used per Unit of output. Hence we expect the capital-output ratio to decline. What is noteworthy here is that technological change is entirely exogenous to the model. In other words, it is a given datum and is not explained by the model itself.

Check Your Progress Exercises 2

3) Kyoto Protocol is an international treaty discussed in 1997 and finally put into force in 2005. It established limits of carbon emissions based on development levels. By 2012 it had 192 signatories.

4) Green technologies have several related definitions, but the most widely used definition conceptualizes it as consisting of all those technologies that reduce environmental risks.

5) The "triple bottom line" has come in vogue since the early 2000s to indicate the synergistic nature of economic, social and environmental goals. Green technologies are usually focused on improving environmental outcomes, but several observers have suggested that green technologies ought to be evaluated from a broader perspective of the "triple bottom line".

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