1. Defining eco-innovations: characteristics, typologies and socio-economic approaches

INTRODUCTION

Economic theory considers innovation a process aimed to improve the competitiveness of companies, with their potential to contribute to economic growth. Indeed, innovative competences of companies represent a key driver of profitability and business success for enterprises other than a way to increase the employment opportunities of a country (Stosic et al., 2016). A definition of innovation commonly referred to is that of Schumpeter, according to which innovations represent ‘the commercial or industrial application of something new – a new product, process or method of production; a new market or source of supply; a new form of commercial, business or financial organisation’ (Schumpeter, 1912, 1934). Innovations are thus first-time applications of newly acquired know-how, methods, or products, new to the market or to the business itself, and can include non-technological aspects, such as changes in a company’s organisation or in product design. In this framework, the ongoing debate about the importance of sustainable pathways of economic development has moved the interest of many economists towards a particular type of innovation that is able to preserve environmental resources. Such innovations, generally labelled in the literature as ‘eco-innovations’ can be considered as innovations inclined toward environmental preservation (Braungardt et al., 2016; Hojnik and Ruzzier, 2016; Klewitz and Hansen, 2014). Thus, whereas the definition of innovation is somewhat neutral concerning the content of change, the concept of ‘Eco-Innovations’ (henceforth EIs) emphasises the direction and content of progress. In this framework, the distinctive characteristic of EIs is to reduce the environmental burden and to deal with specific problematic areas, such as greenhouse effects, loss of biodiversity, sustainable use of natural resources and so on (Bossle et al., 2016). However, despite the importance of EIs in the economic debate on environmental sustainability, the way they may contribute to sustainable pathways of development seems to still be unclear. In particular, the
analysis of EIs has recently found space in the framework of different economic approaches, ranging from the more traditional neoclassical studies on innovations to the new evolutionary literature on the techno-economic paradigm shifts. Although both approaches acknowledge the significant role played by EIs in fostering environmental sustainability, they dramatically disagree on the way EIs may drive economies toward sustainability. Based on this background, the present chapter explores and contextualizes roles and functions of EIs for sustainability in the framework of the neoclassical and the evolutionary schools of thought.

CONCEPTUALISING ECO-INNOVATIONS

The concept of ‘EIs’ can be considered as a response developed to address environmental impacts. Such a response includes changes in technologies and ways of thinking in order to improve the environmental performance of products, services and the way they are created. Literature has so far proposed many different definitions of EIs although they can be broadly classified into two main groups. The first group considers EIs as a sub-class of innovations that improve both the economic and the environmental performance of society. For instance, Lee and Min (2015) and Triguero et al. (2013) considered EIs as the generation of new products and processes that provide customer and business value but significantly decrease environmental impacts. Similarly, Kemp and Pearson (2008) defined EIs as the whole of new or modified products, processes, techniques and systems that avoid or reduce environmental damage and that allow the same use value at a lower environmental cost. Within this group, it is possible to include also definitions that focus on some specific characteristics of EIs, as in the case of Norberg-Bohm (1999) who argued that EIs are innovations that reduce environmental impacts through waste minimisation. The second group seems to broaden the concept of EIs, which are not considered just as a sub-class of innovations, but rather, in more general terms, as the introduction of environmental dimensions in economic strategies. For instance, Ghisetti and Pontoni (2015) and Hellström (2007) argued that, along with process, product and organisational changes in the management of companies, EIs include also changes at social and political levels as well as changes in environmentally counterproductive regulations and legislature, consumer behaviour and lifestyle in general. Similarly, in the ‘Innovation Impacts of Environmental Policy Instruments’ project (FIU, 1998), EIs are defined as all measures undertaken by relevant actors (companies, politicians, unions, associations, churches, private households) which (1) develop new ideas, behaviour, products and processes, apply or introduce
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them, and (2) contribute to a reduction of environmental burdens or to ecologically specified sustainability targets. Also, Huber (2005) has defined EIs as techno-organisational, social and institutional changes leading to improvement in the quality of the environment.

Although the above discussion highlights the lack of a distinct and universally recognised definition of EIs in the literature, at least two key elements seem to characterise EIs (see also Díaz-García et al., 2015):

1. The importance of their environmental performance rather than the environmental motivation of the innovator.
2. The existence of ‘technological’, ‘non-technological’, ‘incremental’ and ‘radical’ EIs.

Companies’ Strategies, Environmental Motivation and Environmental Performance

EIs may depend on the corporate strategic attitude of companies, that is, on the extent to which company’s managers react to stakeholders’ pressures, market characteristics and innovation potentials. Specifically, EIs can result from three different environmental company strategies:

● A follower strategy, when a company just complies with legal and regulation requirements.
● A market-oriented strategy, when the environment is subordinate to the business strategy of a company and single environmental actions are the consequence of specific market and competitive choices.
● An environment-oriented strategy, when the environment is seen as a key factor for companies to succeed, becoming thus integrated into the corporate strategy.

However, many authors (for example, Ryszko, 2016; Przychodzen and Przychodzen, 2015) argue that companies can no longer rely on defensive or reactive environmental strategies, but they should incorporate decisions concerning the introduction of EIs into the process of strategy formation. Despite this, the environmental motivation of innovating companies, that is, their intentions behind implementing EIs, is neither a necessary nor a sufficient condition for classifying the output of their innovative effort as an ‘EI’. However, to correctly define EIs, it is crucial to take into account the environmental performance of innovations, by considering whether they cause a ‘net environmental improvement’, that is, whether the environmental situation (in general or in certain aspects) has been preserved or even improved thanks to the innovation or not.
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The reason why environmental motivation is not necessary to define EIs is because companies can achieve environmental preservation without pursuing any environmental strategy. Although the eco-innovative process should generally be founded upon an environmental motivation, other situations may exist where environmental preservation is produced indirectly as an inseparable element of the innovation generated, making some innovations that are beneficial to the environment not readily recognisable as EIs (Machiba, 2010). An example might be the increased fuel efficiency of cars arising from the incremental improvement of the motor: although the prime motivation for such an innovation is most likely performance or price considerations, the effects on the environment may in any case be positive. Thus, EIs may not occur exclusively in the ‘eco-industries’ (which specifically produce goods and services that measure, prevent, limit, minimise and correct environmental damage), but may occur in any productive sector, since they can be an integral part of the innovative efforts of companies across industries (Urbaniec, 2015).

The reason why environmental motivation is insufficient for defining ‘EIs’ is because intentional EIs can also produce negative environmental effects, such as in the case of crops for biogas that can lead to the destruction of forest, releasing considerable quantities of greenhouse gases. Thus, more significant than the aim of innovations, is whether there are positive and recognised environmental effects related to their use.

The environmental performance of innovations can be assessed by referring to the use of relevant alternatives, for instance the technology used by a company or the normal technology in a sector (see Chassagnon and Haned, 2015). Thus, some possible evaluation criteria are: the reduction in the material intensity of goods or services, the reduced dispersion of toxic materials, the improved recyclability, the maximum use of renewable resources, the greater durability of products, the increased service intensity of goods and services and so on. However, such assessment requires extensive knowledge and understanding of the innovation and its contextual relationships, since environmental consequences may occur because of an unexpected interaction with other factors. Consider, for example, the provision of wireless internet connections in trains: although such adjustment consumes additional energy, thus leading to a decline in environmental performance, the overall environmental impact could more than offset such negative effect if the new facility attracts travellers who otherwise would travel by air or cars. EIs may, to a large extent, be systemic and complex in that they involve many areas of knowledge and many different industrial sectors. Two studies, one for the European Commission and one for the OECD, elaborated that the percentage of innovative companies that do not implement EIs either intentionally or unintentionally is
only between 20 per cent and 30 per cent and that more than half of all technological innovations in general have been estimated to have beneficial effects on the environment (Kanerva et al., 2009). Another OECD study (2008) shows that many companies take environmental considerations into account even when environmental improvements are not the main objective of their research and innovation efforts, and that they often do not see any difference between ‘general innovations’ and ‘EIs’.

**Technological and Non-technical EIs**

In general terms, innovations can be classified in different ways according to their objective, drivers, intensity and so on (Norman and Verganti, 2014). In the case of EIs, the most relevant classification concerns the distinction between ‘technological’ and ‘non-technological’ EIs and between ‘incremental’ and ‘radical’ EIs. According to the literature (Rashid et al., 2015; Chappin, 2008) technological EIs consist of process and product innovations while non-technological EIs consist of organisational innovations. This classification broadly reflects the definition of innovation reported in the Oslo Manual, according to which an innovation is ‘the implementation of a new or significantly improved product – good or service – or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations’ (Oslo Manual, 2005: 46, italics in original). It is worth noting that the classification between product, process and organisational EIs can be indistinct: for instance, product EIs in machinery in one company may represent process EIs for another company; moreover, although organisational EIs are a specific type of EI, they can be complementary to the implementation of technological EIs and so on.

**Technological EIs**

Include both curative and preventive measures. The first aims at repairing environmental damages (ex post) while the second at avoiding them (ex ante). Preventive technologies may be distinguished in additive and integrated (see Figure 1.1).

Additive measures are end-of-pipe technologies that occur after a production process has taken place and before the stream is disposed of or delivered. They are used to remove already formed contaminants from a stream of air, water, waste, product or similar. Integrated measures can be split into process and product technologies: they prevent environmental damages during the production process and at the product level.

Process innovation concerns changes in the way inputs in a production
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Product innovations comprise changes in the composition, design, operation, quality or function(s) of goods and services: the way these factors are combined determines the level of eco-efficiency of a product (Jang et al., 2015). Examples of traditional end-of-pipe technologies are air purification technologies (for example, filters for industrial facilities, filters for indoor rooms), waste treatment technologies regarding collection and transport, and material recovery facilities and environmental biotechnology (the development, use and regulation of biological systems to remediate contaminated environments). Examples of integrated measures are environmental monitoring technologies that help the ascertainment, observation and surveillance of natural processes (for example, satellite observation, measurement of fine particulates in inner cities), technologies for reuse or recycling, technologies for saving resources or to conserve both materials and energy when producing and

Source: Own elaboration based on the main literature.

Figure 1.1 Schematic classification of technological EIs
operating products (for example, the minimisation of friction in movable engine parts to save fuel), regenerative, fuelless energy (for example, photovoltaic, wind, hydro, tidal, wave, solar and geothermal energy), replacing hazardous chemicals by more benign low-impact substances, biofeedstocks partially replacing fossils as a raw material, new ultra-light, ultra-strong materials – which reduce energy and volumes compared to conventional materials – and nanotechnology and micromachines, which cause less environmental impact compared to larger conventional machines and chemical production (see Huber, 2008, p. 361). Despite the fact that downstream end-of-pipe technologies still represent a large amount of technological EIs (and, according to some authors, they will continue to be necessary anyway to control specific emissions in the near future, see, for instance, Frondel et al., 2004), from the 1970s to the present day policymakers, companies and public opinion have exhibited a growing interest towards the preventive rather than the curative measures, which they increasingly consider insufficient and too expensive to solve massive environmental problems (Durán-Romero and Urraca-Ruiz, 2015).6

Non-technological EIs

Non-technological EIs are essentially organisational innovations that comprise all measures aiming at incorporating environmental perspectives into companies’ operations and at developing an environmentally respectful awareness and new priorities in policies and practices. They include the introduction of organisational methods and management systems for dealing with environmental issues in production and products. Examples of non-technological EIs are: pollution prevention schemes aimed at preventing pollution through input substitution, more efficient operation of processes and small changes to production plants (avoiding or stopping leakages); environmental management and auditing systems that involve measurement, reporting and responsibilities for dealing with issues of material use, energy, water and waste (for example, the EU Eco-Management and Audit Scheme – EMAS – and the ISO 14000 series); chain management, that is, cooperation between companies so as to close material loops and to avoid environmental damage across the value chain (from cradle to grave) (MEI, 2008, p. 10).

A number of authors (see, for instance, Hellström, 2007) have broadened the group of non-technological EIs to also include:

- ‘Social EIs’, that is, changes in lifestyle and consumer behaviour as a consequence of increased awareness about environmental problems. They comprise mobility (public transport use instead of private cars,
car sharing), nutrition (non-packed, seasonal and organic food consumption), housing (energy saving for heating, cooling and warm water, eco-houses), clothing (washing machine use only with a full load, clothes recycling), services (eco-leases) and generally all those measures that make consumption more sustainable.

- ‘Institutional EIs’, that is, the creation of new regimes of environmental governance, such as local network agencies, international environmental organisations and so on.

However, according to the Schumpeterian definition of innovation, both ‘social’ and ‘institutional’ EIs should not be considered as a type of innovation, since they are not company-centred innovations (refer also to the Oslo Manual, 2005). However, their importance for sustainable pathways of development is nowadays largely recognised in the evolutionary analysis of EIs. Indeed, as will be discussed later in this chapter, the transition towards a more sustainable regime can happen only because of the co-evolution of technological and social elements: in this framework, technological EIs coexist and co-evolve with organisational EIs as well as with changes at the social and institutional levels.

The other relevant classification can be made according to the intensity of innovation between ‘incremental’ and ‘radical’ EIs. Incremental EIs take place more or less continuously in companies, although at dissimilar rates in different industries and over time periods. They occur mainly as the result of inventions and improvements suggested by customers and suppliers and/or by workers directly engaged in the production process. Moreover, incremental EIs are generally, but not always, curative measures that repair environmental damages instead of preventing them. By contrast, radical EIs are discontinuous events that are unevenly distributed over sectors and time and are the result of deliberate research and development processes in companies (Freeman et al., 1982). Radical EIs are generally preventive measures which are initially small and localised, unless they emerge in a new industry.

Technological, non-technological, incremental and radical EIs as a whole play a significant role towards creating more sustainable pathways of development. However, the way they contribute to sustainability changes according to the economic approach considered, in particular whether neoclassical or evolutionary.

**THE NEOCLASSICAL ANALYSIS OF EIS**

The neoclassical analysis of EIs – developed within the framework of ‘Environmental Economics’ – is centred on two issues. The first is the
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capacity of EIs to contribute towards sustainable development pathways through technological progress, that is, by offsetting the negative effects of the exhaustion of natural resources and pollution generation. This can happen through (1) the substitution of scarce natural resources with manufactured capital, and (2) improvement in factor productivity. The second is in regards to the importance of the regulatory framework as a driver of EIs. The next two sections explore the above two issues separately.

EIs and Technological Progress

From the neoclassical perspective, EIs play a crucial role in achieving targets of environmental sustainability. However, the neoclassical analysis seems to be focused essentially upon technological rather than on non-technological EIs, without taking into account any possible distinction between incremental and radical innovations. Within the Ricardian relative scarcity framework, neoclassical economists are optimistic that technological EIs can reduce the potential constraint on economic growth imposed by the resource scarcity (Venkatachalam, 2007). From a methodological point of view, neoclassicists extend the models of growth and capital accumulation to include natural capital. For example, Solow (1974) shows that it is possible to include the environment in growth models without altering their tractability (see, for instance, Sica, 2007). Similarly, the ‘individual rationality’ based macromodels developed by Hotelling (1931) and Hartwick (1977) explore the sustainability of resource use. Such models conclude that a non-diminishing per capita consumption path can be maintained indefinitely insofar as technological progress is able to (1) substitute scarce natural resources with manufactured capital, and to (2) improve the factor productivity. Indeed, neoclassicists are confident that technology, as a tool, can enable the capacity of the economy-environment system to satisfy human needs (Common and Stagl, 2005). In this framework, EIs contribute positively to environmentally sustainable pathways of development by executing tasks (1) and (2), providing employment increases as well.

The importance of technological progress to achieve targets of environmental sustainability can be easily identified by observing the ‘Environmental Kuznets Curve’ (EKC); the well-known inverted U-shaped (empirical) relationship between the level of economic activity and air pollution emissions in advanced industrial nations (Dasgupta et al., 2002). The EKC is founded upon the idea that, as income grows, the level of pollution in a country rises since the main purpose of the first stages of development is to increase production, with a consequent use of great volumes of natural resources and a general depletion of the environment.
However, in the following phases of growth, the level of pollution declines after reaching a ‘turning point’: as a wealthy nation can then afford to spend more on Research and Development (R&D), innovations and technological progress, which occur concurrently with economic growth, with the obsolete technologies being replaced by the cleaner ones. In this process, technological EIs therefore play a crucial role in achieving environmental sustainability targets, by encouraging the efficient use of natural resources, so that a given amount of goods may be produced by employing a reduced quantity of natural resources or energy (Weina et al., 2016).

Moreover, when individuals enjoy greater incomes, they become more inclined to care for the quality of natural resources and to show an increased willingness to invest in the environment in which they live. This pushes companies to be more eco-innovative (Bousquet and Favard, 2000). Not all agree with this analysis. From a global perspective, the EKC in one country can result from the shifting of polluting industries towards the poorest countries, which thus represent ‘pollution havens’ (Kearsley and Riddel, 2010). In other words, rich countries may simply export their polluting industries to jurisdictions with less stringent environmental regulations where pressures for a clean environment are secondary to growth.

Similarly, the ‘Ecological modernisation’ (EM) approach, which has an underlying political economy founded upon neoclassical environmental economics, argues that any environmental problem may be solved through further advancements of technology and industrialisation, without any need to stop the process of industrialisation to deal with ecological crises (Foster, 1992). Indeed, supporters of EM believe in ‘super-industrialisation’ (that is, the transformation of industrial production based on the development of advanced technologies) as a means to address environmental problems (Fisher and Freudenburg, 2001). In this framework, the diffusion of systematic EIs must be encouraged to reduce the environmental burden. In particular, the nexus between EIs and the environment founds upon the key concepts of:

- **Efficiency**: since policies useful to promote EIs may simultaneously result in both economic and environmental benefits EIs may reduce the consumption of raw materials and the emissions of a number of pollutants and, at the same time, they may create competitive products (Murphy and Gouldson, 2000).
- **Precaution**: since damages to the environment should be avoided in advance, it is necessary to keep economic development separate from environmentally dangerous production processes. In this framework, EIs may contribute positively to the ‘precautionary principle’ (*Vorsorgeprinzip*, in German) since *precaution* means developing
innovations that reduce environmental burdens by taking time and effort to consider all possible alternatives and to gather deeper information in the eco-innovative process (Stirling, 2016).

- **Social market**: since through emission standards, environmental taxes and other preventive rather than curative or end-of-pipe regulatory mechanisms, regulation may drive the process of industrial innovation with environmental and economic gains realised as a result. In this framework, governments should provide financial support to EIs while the private sector should develop, test and market them. In other words, there is a preference for market-based solutions: the governments set the environmental targets and the market decides how to achieve them (Andersen and Massa, 2000).

Overall, neoclassicists therefore seem to believe that technological EIs represent the main tool to achieve environmentally sustainable pathways of development. This view has been deeply criticised by an opposing line of thought that assumes that technological progress cannot avoid fundamental energy and resource constraints. In this framework, ecological economists argue that, along with the more efficient use of resources, technological EIs also involve new processes and products that cause additional pressure on the environment (Shmelev, 2012). Moreover, the final effects of technological change cannot be foreseeable, since an increase in efficiency in the use of natural resources may stimulate the demand for them, thus reducing or even deleting the mitigating effects of efficiency increase (Roca and Padilla, 2007).

**EIs and Regulatory Framework**

The neoclassical approach to EIs is also based upon the study of the regulatory framework necessary for their implementation. From this perspective, the analysis of EIs spans ‘environmental economics’ and ‘innovation economics’. On the one hand, environmental economics focuses on the public good nature of the environment and on the ‘double externality problem’ of EIs, by developing methods and strategies to assess environmental policy instruments aimed at correcting the market failure that arises from it. The starting point of the discussion is that EIs can combine a benefit for the company or user along with an environmental benefit depending on the characteristics of the innovation. The combination of these externalities, is likely to result in substantial underinvestments in eco-innovative projects and this justifies the importance of the regulatory framework as a driver of EIs (Hemmelskamp, 1997). That is to say, environmental policy measures are necessary to ‘internalise’ externalities using different
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policy instruments. On the other hand, innovation economics analyses the elements influencing the implementation of EIIs, by giving prominence to environmental policies as a key factor for companies' eco-innovativeness. Recognising the importance of the regulatory framework, neoclassicists emphasise methods and strategies to assess environmental policy instruments in an effort to correct the market failure arising from the double externality problem. Although such aspects are thoroughly analysed in Chapter 2, it is worth stressing here the argument proposed by Porter and van der Linde (1995a) who suggest that, by pushing enterprises to eco-innovate, environmental regulation may improve the natural environment, on the one hand, and the companies' competitiveness, on the other ('Porter Hypothesis' – PH). This means that well-designed environmental policies may lead to a win-win situation where both the social welfare and the private net benefits of companies increase. The reason why stringent environmental regulation may raise social welfare is well recognised among the neoclassical economists: since the marginal social cost is higher than the marginal private cost in the presence of negative externalities, and environmental regulation may correct such market failure.

How environmental regulation can increase private welfare is less obvious. In this regard, the PH argues that environmental regulations can drive companies to implement EIs that may partially or even completely, offset the static private adaption costs. Consequently, stringent environmental policies may boost the competitiveness of regulated companies through improved technological efficiency: 'properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them' (Porter and van der Linde, 1995b: 98). In other words, regulations drive the eco-innovative behaviour of companies that, in turn, contribute towards increasing their profits. More specifically, Porter and van der Linde argue that companies may not have realised all of the possible profitable opportunities due to their imperfect management systems. Thus, well-designed legislation may inform companies about their drawbacks, pushing them to consider opportunity costs of eco-innovating. Moreover, environmental regulations can represent an opportunity for firms to gain a competitive first mover advantage. It is worth noting that the win-win situation proposed by Porter and van der Linde may not always be the case. Some authors (Hottenrott and Rexhäuser, 2013; Roediger-Schluga, 2003) argue that environmental regulation can instigate a crowding out effect since companies are forced to devote considerable financial and human efforts to satisfying the given requirements and consequently they lack resources for other innovative projects at least in the short-term. In some cases, companies can also adopt expensive end-of-pipe technological EIs with the aim to (1) increase the
pollution control costs towards their current competitors, which are thus crowded out from the industry, and to (2) create entry barriers to their potential competitors (Keohane et al., 1998).

THE EVOLUTIONARY ANALYSIS OF EIS

The evolutionary approach extends the analysis of EIs by including social and institutional aspects along with technology. Evolutionists adopt an inductive approach founded upon observations of the complex reality that changes over time (Faucheux et al., 1996). Their holistic approach makes them more interested in the analysis of transitions and learning processes than in equilibrium states, and assumes bounded rationality of eco-innovative companies rather than optimisation criteria. Thus, whereas neoclassical theory deals with marginal conditions and economic equilibrium, evolutionists focus more on conflict aspects of economic processes and explain changes in terms of systems’ capacities to adapt to crises. By extending the analysis beyond the purely economic aspects, within the view of the evolutionary framework, EIs are developed and diffused not only based on the extent of their characteristics (cost, quality and so on), but also on the grounds of their compatibility with existing systems and structures (Kemp, 1993). Along with the technological intensity of the company’s operations and the nature of the knowledge they involve, evolutionists stress the relevance of coordination between actors and institutional frameworks that support it (Galliano and Nadel, 2015). Therefore, whereas neoclassicists tend to investigate specific aspects of EIs (double externality problem, environmental regulation, efficiency and so on), the evolutionary approach explores EIs in their dynamic and multidimensional nature, by considering them as dependent upon the interactions of technological, sociological and economic systems. In other words, the evolutionists analyse EIs in the broader context of their co-evolution with social and institutional systems, by placing emphasis on the necessity of their reorganisation within a broader ‘green paradigm’ (Rennings, 1998). Indeed, according to this perspective, environmental preservation may still be possible through ‘incremental’ EIs, but larger jumps towards environmental sustainability may only be possible through systemic EIs, which involve new technological artefacts, markets, user practices, regulations and infrastructures.

EIs and ‘Socio-technical Regimes’

An interesting approach to analyse EIs in the framework of the evolutionary studies reflects upon the so-called ‘Socio-technical Regimes’. Such
issue stems from the ‘technological regime’ concept (Nelson and Winter, 1982), which represents shared cognitive routines in an engineering community that help to explain patterned development along technological trajectories (Geels and Schot, 2007). Since scientists, policymakers, users, special-interest groups and so on contribute to patterning of technological development, evolutionists have expanded the concept of ‘technological regime’ in order to also include a broader community of social groups. From this perspective, changes are based on mechanisms of co-evolution of society and technology (Kern, 2012). The socio-technical regime offers useful insights into the reasons why some EIs may fail, despite promising better environmental performance. The basic idea is that EIs are introduced into systems developed for older technologies and this may result in some resistance and inertia regarding their adoption because of the already existing routines, tasks, qualifications and user-producer relationships. Thus, many promising technological EIs are not adopted, since the existing system is ‘locked-in’ on many dimensions (economic, social, cultural, infrastructural, regulatory and so on), as are the consequent user practices, regulations and infrastructure (Elzen et al., 2004) that would have to change along with new technology.

The existing socio-technical regime receives destabilisation pressures from the socio-technical landscape, which is the wider context where activities carried out by the regime are situated. The landscape is an external structure or context for interactions of actors and includes elements at a macroeconomic level, such as material infrastructure, political culture and coalitions, social values, worldviews and paradigms, demography and natural environment (Geels, 2004). Consequently, technological changes can take place only within particular trajectories: due to the pressures of the selection environment, a certain technology becomes a dominant ‘technological paradigm’ that excludes other evolutionary options (Fallde and Eklund, 2015). In this framework, radical EIs driven by new scientific insights may emerge essentially through technological niches or niche markets that act as ‘incubation rooms’, where initially unstable socio-technical configurations are protected against mainstream market selection. Even if niches perform poorly in more conventional terms, such as price, convenience, speed and so on, in such protected spaces, EIs are given the opportunity to be appreciated, evaluated and to mature through gradual experimentation and learning of producers, users, researchers and others, as was the case with organic foods (Smith, 2006). As a result of destabilisation pressures on the existing regime from the socio-technical landscape, EIs in the niches have the opportunity to emerge and compete with the existing regime, going into the mainstream markets: this implies that EIs need to be fostered through strategic policies of niche management.
EIs and Green Innovation Systems

Innovation systems represent all the elements and their interrelations that exist in the production, diffusion and use of new and economically useful knowledge (Freeman, 1995). Within the evolutionary perspective, they provide an analytical framework to analyse how some technologies give rise to specific technological trajectories. In this context, EIs can be viewed as the market standard for ‘green innovation systems’ (GIS), that is, innovation systems where environmental issues are fully integrated into the economic process (Foxon et al., 2008; Jacobsson and Bergek, 2004). Following such a perspective, EIs are placed within the wider context of the knowledge economy and are analysed from a dynamic perspective. The greening of innovation systems requires addressing the environmental inconsistencies between different segments of the system, such as policy and research areas, technological and market standards, financial institutes and so on. Foxon and Andersen (2009) identify five different phases of this process, each one is characterised by significantly different levels of development and diffusion of EIs.

The first phase is the demand of environmental regulations for EIs. The second and the third are the beginning and the launch of green markets, respectively. The fourth is the consolidation of green economy. The fifth and final phase is the wide diffusion of EIs as a market standard for the economy. In particular, the rationale for environmental policies in the first phase addresses the necessity for governments to correct for multiple market failures: in this framework, reaching efficient market solutions (or even ‘second best’ solutions) is unreasonable and thus the role of public intervention becomes the identification and the possible solution of ‘system failures’ in infrastructure and investment provision, along with transition and lock-in failures (Grubb and Ulph, 2002). The first phase began in the 1950s when the environment was considered as a burden to business. The second phase started at the beginning of the 1990s, when integrated product policies and clean technologies support companies began to appear in the market. The critical shift towards the green market take-off (third phase) is currently happening and is still accelerating: it is surprisingly rapid compared to the long first phase and the rather slow second one. Nothing can be said about when (or if) the transition to the fourth and fifth phases will take place. Table 1.1 reports the main co-evolutionary processes taking place within an innovation system in the transition towards a green techno-economic paradigm, showing the most important implications in terms of EIs. While moving along the above co-evolutionary stages, green competitiveness becomes increasingly important and influences the selection of suppliers, customers, learning
### Table 1.1  Co-evolutionary processes towards a green innovation system

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<td>Obstructive and reactive strategies to regulation</td>
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<td>Knowledge Institutions</td>
<td>Attention to environmental issues only in traditional environmental research areas</td>
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<td>Routine green search and education</td>
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<td>Reactive</td>
<td>Few green users</td>
<td>Rising green consumerism</td>
<td>Widespread green demand</td>
<td>Well-functioning green markets</td>
</tr>
<tr>
<td>National/Regional/Global Innovation System</td>
<td>No green market</td>
<td>High friction to early EIs</td>
<td>Medium friction to EIs</td>
<td>Strong green knowledge base</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** Own elaboration based on Foxon and Andersen, 2009.
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partners, employees and financial institutes, to name a few. Once the Green Innovation System is achieved, EIs become the natural innovations that are then routinised and mainstreamed. It is worth noting that the greening of the innovation system also depends on the interaction between environmental and technology policies, other than on the interaction of the different actors in the innovation process, going beyond the purely technological EIs.

DISCUSSION AND IMPLICATIONS

Although the importance of innovations for the environmental preservation is well recognised in the literature, the concept of EIs remains vague and has unclear outlines. The lack of distinct definition of EIs along with the numerous ways EIs are referred to in the literature (environmental innovations, green innovations, less-polluting innovations, sustainable innovations and so on) contributes to generating further confusion. However, to correctly define EIs it is necessary to take into account: (1) the environmental performance of innovations (that is, whether they cause a net environmental improvement or not) rather than the environmental motivation of the innovators (the eventual intention of companies to implement an innovation that is beneficial to the environment), and (2) the existence of ‘technological’ along with ‘non-technological’ EIs.

Bear in mind, this chapter highlights how the analysis of EIs can find space in the framework of different approaches, ranging from the more traditional neoclassical literature on innovations to the new evolutionary studies on the techno-paradigm shifts. Certainly, the most important contribution of the neoclassical approach is the analysis of the specific characteristics of EIs, in terms of cost, quality and so on. However, one of the great merits of the evolutionary approach has been the introduction of social and institutional aspects in the analysis of EIs. Indeed, whereas neoclassicists put companies at the core of the eco-innovative effort, evolutionists also take into account the possible existence of environmentally friendly changes at both social and institutional levels, thus avoiding the risk of ‘technological bias’ in their analysis. It is interesting to observe that both approaches devote a large space to examining the reasons why some promising EIs with better environmental and economic performance are not developed or adopted. According to the neoclassicists, this is due to the market failure that arises from the double externality problem of EIs, focusing on the concepts of partial equilibrium and marginal conditions as typical of the neoclassical framework. However, the evolutionists believe that some EIs have not further developed because they are embedded in an
inappropriate existing complex system. Regulation is another overlapping topic in the analysis of EIs. Indeed, both neoclassicists and evolutionists provide a rationale for the necessity of eco-innovative policies. For neoclassicists, regulation represents probably the most important driver of EIs, given the market failure arising from the double externality problem, which implies suboptimal EI investments in the enterprises. In particular, governments and regulatory bodies may correct such market failure through specific and well-designed environmental policies and/or through innovation support activities, by providing eco-innovating companies with access to finance and by delivering them business support services. In both cases, the neoclassicists devote significant efforts towards analysing the effectiveness of regulations. In contrast, evolutionists provide a rationale for regulation in terms of management of the socio-economic elements of a complex system and specifically in terms of niche management and system failures. When the existing regime receives destabilising pressure from the socio-technical landscape, regulation is necessary to ensure that emerging EIs in specific niches have the possibility to be evaluated and appreciated. Similarly, system failures in innovation systems justify the intervention of some form of regulation in the market economy by providing public support for infrastructure, by helping companies to cope with technological changes, by generating incentives for EIs, and by overcoming barriers created by the prevalence of incumbent technology.

This chapter provides the foundation for subsequent analysis and, in particular, for the theoretical model that will be introduced in Chapter 3. In particular, the present book will investigate the financial constraints of eco-innovating companies by integrating the neoclassical and the evolutionary approaches. Specifically, the book accepts that technological (and organisational) EIs are a promising step towards attaining environmental sustainability targets, but disagrees with the neoclassical idea that technology itself is capable of accomplishing environmentally sustainable pathways of development. Indeed, despite a general focus on the company-level view, this book acknowledges the importance of co-evolutionary changes at both social and institutional levels that are required to achieve environmental sustainability. In particular, it recognises that a number of internal and external barriers to companies, including companies’ financial constraints, can hinder some promising EIs to succeed, thus contributing to them becoming locked-in within the existing regime. The acknowledgment of the importance of social and institutional changes along with technological ones should assist avoiding the possible risk of ‘technological bias’ in the book. Furthermore, the book recognises the role of regulatory action in driving the eco-innovativeness of companies. Well-designed policies may contribute towards limiting the
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barriers that hinder some EIs to succeed, thus increasing both the social welfare and the private benefits of companies. Therefore, the general view accepted in this book is that environmental sustainability may only be possible through a systemic shift, which involves technological and organisational EIs as well as changes at the social and institutional levels. However, within the broader context of such a multi-level perspective, the book exploits a neoclassical approach to investigate the specific elements that drive companies’ eco-innovativeness or that contribute to hinder EIs from succeeding.

NOTES


2. Or, alternatively, as ‘environmental innovations’, ‘green innovations’, ‘less-polluting innovations’, ‘sustainable innovations’ and so on. With regards to this, Angelo et al. (2012) and Schiederig et al. (2012) have reviewed the terms used so far in the literature to label eco-innovations, finding out that the term ‘environmental innovation’ has been employed in the majority of reviewed papers (65 per cent), although, since 2005, the notion ‘eco-innovation’ became increasingly used in scientific publications. Anyway, it is worth noting that such ‘labels’ are not perfect synonyms. For instance, ‘sustainable’ should refer to the social and economic dimensions of innovations rather than to the environmental one; ‘eco’ to the ecological dimension and so on.

3. On these grounds, the emergence of the Corporate Social Responsibility (CSR) – that is, the obligation for companies to manage their operations in such a way to maintain environmental protection and to promote social responsibility in their business operations and in their interaction with stakeholders on a voluntary basis – represents the managerial answer of companies to the global interests for sustainable development by integrating the environmental and social dimensions in their strategy. As will be discussed later in the book, a large strand of literature has proved that CSR initiatives can lead to reputational advantages, improvements in investors’ trust in the company, more efficient use of resources and new market opportunities.

4 Eco-industries refer generally to those sectors within which the main, or a substantial part of, activities are undertaken with the primary purpose of the development of technologies and the production of goods and services to measure, prevent, limit, minimise or correct environmental damage to water, air and soil, as well as problems related to waste, noise and ecosystems (Rademaekers et al., 2012). These include:

- **Pollution management activities**, such as air pollution control; wastewater management; solid waste management; remediation and clean-up of soil and water; noise and vibration abatement; environmental monitoring, analysis and assessment.
- **Cleaner technologies and products**, which improve, reduce or eliminate environmental impact of technologies, processes and products (for example, fuel-cell vehicles).
- **Resource management activities**, which focus on resource efficiency and development of new environmentally preferable resources (for example, energy saving, renewable energy plant).

5. It is worth explaining the linkages between product EIs and two related but different concepts, *eco-design* and *eco-efficiency*.
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- **Eco-design**, focuses on how to integrate environmental considerations in the development of products, by addressing all their environmental impacts without compromising other criteria like function, quality, cost and appearance.
- **Eco-efficiency**, measures the value of a product or service against its environmental impact and aims at obtaining more value with less environmental consequences. It represents a comprehensive notion that can be applied to various levels of analysis, such as product, company, sector, region or the entire economy.

On this ground, although product EIs should provide the consumers with the function they require in a more eco-efficient way, they are not necessarily based on the redesign of an existing product (see Halila, 2007: 11–14, for a complete review on this topic and Brezet and Van Hemel, 1997, for a classification of technological EIs based on different levels of eco-efficiency improvements).

6. It is possible to identify four main stages that have characterised the general development and diffusion of technological EIs since the early 1970s to the present day (see Markusson, 2001):

1. Early 1970s: technological EIs were primarily motivated by energy savings given the recent energy shock.
2. Mid 1970s–mid 1980s: end-of-pipe technologies were used as a passive response to the environmental policy developed by many Western governments.
3. Second half of the 1980s: technological EIs were usually timed with systems renovation as a defensive medium-term approach.
4. End 1980s–present: technological EIs have been included in the corporate strategy and are aimed at acquiring a competitive advantage.

7. It is worth noting that both in the EKC and in the EM approaches, EIs are developed essentially by the private sector. The main difference between the two viewpoints is that, in the EKC, EIs are developed within an economic framework of complete governmental laissez-faire, since the environment does not need any specific attention. However, in the EM approach, EIs are generally developed by the market thanks to the supportive action of governments that have the task of implementing policies to deal with environmental problems into the growth-oriented and globalised economy.

8. For instance, ‘organic’ food creates benefits for both the user (taste, health) and the environment (less pesticides) compared to conventional products; other EIs (such as electricity from renewable energy) most often lack additional private benefits compared to the use of fossil or nuclear energy.

9. In many cases, multiple system failures can lead to policy prescriptions similar to those suggested by the neoclassicists, such as the use of economic instruments to internalise negative environmental externalities. The key difference between the two approaches is that the innovation system perspective does not presume that public policy interventions can recreate economic efficiency: markets are based on a set of legal and institutional rules and the task of policymakers is to design such rules so that they are not excessively costly to companies and individuals.

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