Dipartimento di Scienze Economiche, Matematiche e Statistiche

Università degli Studi di Foggia

INNOVATIONS AND SUSTAINABLE DEVELOPMENT: NEOCLASSICAL *VERSUS* EVOLUTIONARY APPROACH

Edgardo Sica

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Dipartimento di Scienze Economiche, Matematiche e Statistiche, Largo Papa Giovanni Paolo II, 1, 71121 Foggia (Italy), Phone +39 0881-75.37.30, Fax +39 0881-77.56.16

Innovations and sustainable development: neoclassical *versus* evolutionary approach

Edgardo Sica*

Abstract

In the last 20 years, the concept of 'Sustainable Development' (SD) has become very popular and widespread in the world. In particular, the environmental dimension of SD asks for new ways to accomplish enhanced quality of life with reduced environmental impact. As a consequence, innovations that contribute to sustainable pathways through an improved environmental quality (the so-called 'Sustainable Innovations' - SIs) are facing a growing interest. The present study aims at contributing to the debate about innovation and SD, by focusing on the analysis of SIs from, respectively, the neoclassical and the evolutionary perspective. Whereas neoclassical theorists neoclassical theorists focus on the 'double externality problem' of SIs, on the one hand, and on the factors that influence their implementation, on the other, evolutionary approach analyses mainly radical technological changes thus stressing the need for a consideration of additional aspects (in particular social and institutional ones) in the analysis of SIs.

Keywords: Innovations, Sustainable Development, Neoclassical Theory, Evolutionary Approach

* Department SEMS, University of Foggia, Largo Papa Giovanni Paolo II, 1, 71121, Foggia (ITALY).
E-mail: e.sica@unifg.it

1. Introduction

In the last 20 years, the concept of 'Sustainable Development' (henceforth SD) has become very popular and widespread in the world. SD can be viewed as an evolution of the traditional concepts of 'growth' and 'economic development' (Park, 2005; Hofkes, 1996) since it recognizes the long-run impact of the environmental constraints on the patterns of development and argues in favour of achieving both intra-generational and inter-generational equity (WCED, 1987). The continuous increase of world population leads to higher and higher levels of consumption and, as a consequence, to increased pollution, climatic change, and depletion of natural resources and biodiversity (Halila, 2007). As a consequence, the environmental dimension of SD asks for new ways to accomplish enhanced quality of life with reduced environmental impact. In other words, it asks for environmental-friendly products, greener technologies, resource efficiency, dematerialization, reduction of waste and emissions, etc. (Nuij (2001).

In this framework, innovations that may contribute to sustainable pathways through an improved environmental quality - the so-called 'Sustainable Innovations' or, alternatively, 'Eco-Innovations', 'Environmental innovations', 'Green Innovations', 'Less-polluting Innovations', etc.[1] - have gained increasing attention. Indeed nowadays the global market for environmentally-related technologies is one of the most growing market in the world. Recent data reveal that it has gone from approximately USD 450 billion in revenues in 1993 to USD 652 billion in 2005 and that - within a decade - it is projected to reach up to USD 167 billion (OECD, 2008). European environment technologies industries, for example, have enjoyed a growth of around 5% a year since the mid-1990s (OECD, 2008).

On account of this, some authors (see for example Hargroves and Smith, 2005) argue that we are facing the 6th innovation wave since the first industrial revolution, being the first (in the late 1700s) based on the diffusion of textiles, water-power, and mechanization; the second (at the end of 1800s) on steam power, trains, and steel; the third (in the first part of 1900s) on electricity, chemicals, and cars; the fourth (by

[1] See MEI, 2008; Mazzanti and Zoboli, 2007; Hellström, 2007; Bernauer, 2006; Mazzanti and Zoboli, 2005; Horbach, 2005; Beise and Rennings, 2003; Rennings and Zwick, 2002; Rennings, 2000; FIU, 1998

the middle of the twentieth century) on electronics; the fifth (in the 90s) on computers and IT; and finally the ongoing (sixth) innovation wave, based on the implementation of sustainable technologies.

However, despite the fact that many firms are devoting significant resources to developing new methods of reducing or treating air or water emissions, recycling or reusing waste, finding cleaner energy sources and other methods of environmental protection, and despite the hundreds of new patents granted every year in these sectors, the concept of 'Sustainable Innovations' (henceforth 'SIs') remains still vague and with unclear outlines.

The present study aims at contributing to the debate about SIs, by focusing on the role this kind of innovations play in the context of different theoretical approaches, specifically the neoclassical *versus* the evolutionary one.

The paper is organised as follows: section 2 defines exactly what SIs are; sections 3 and 4 move on to the analysis of SIs in the framework of the neoclassical theory (section 3) and in the context of the evolutionary perspective (section 4); section 5, finally, ends with some concluding remarks.

2. What are exactly 'SIs'?

Generally speaking, the term 'innovation' may be interpreted, in a broader sense, as the first-time application of newly acquired know-how, new methods, or new products. But it can also include non-technological innovation, such as changes in firm organization or the design of a product. Indeed, a definition 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). Thus, the general definition of 'innovation' is neutral concerning the content of change.

On the opposite, talking about SIs means putting emphasis on the direction and content of progress, i.e. towards a kind of innovations that takes into account the environmental problems. At this regard, one of the most known definition of SIs proposed in the literature can be found in the interdisciplinary project 'Innovation Impacts of Environmental Policy Instruments' (FIU, 1998), which defines SIs as all measures of relevant actors (firms, politicians, unions, associations, churches, private households) which:

1. develop new ideas, behavior, products and processes, apply or introduce them; and
2. contribute to a reduction of environmental burdens or to ecologically specified sustainability targets.

It is worth noting that literature proposes many other different definitions of Sis. Huber (2005, 2004), for example, defines SIs as techno-organisational, social and institutional changes leading to an improved quality of the environment. Norberg-Bohm (1999) argues that SIs are simply a kind of innovations that reduce environmental impacts through waste minimization. Kemp, Arundel and Smith (2001) consider SIs as the whole of new or modified processes, techniques, systems and products to avoid or reduce environmental damage. At this regard, Rennings (2000) and Klemmer et al. (1999) underline that SIs may include process and product innovations, organisational changes in the management of firms and on the social and political level, changes in environmentally counter-productive regulation and legislature, consumer behaviour, or lifestyle in general.

However, despite the lack of an universally recognized definition, SIs can certainly be conceived on the following four broad levels[2]:

1) ***technological***;
2) ***organizational***;
3) ***social***; and
4) ***institutional***.

Technological Sustainable Innovations (TSIs) are generally developed by firms, and include *curative* and *preventive* measures. The firsts aim to repair environmental damages (*ex-post*) while the seconds to avoid them (*ex-ante*)[3]. *Preventive*

[2] See also Hellström, 2007; Hertwich and Katzmayr, 2003; Ottoman, 1998; Hemmelskamp, 1997; Fussler and James, 1996)

[3] It is worth noting that, over time, there has been a shift from a curative to a preventive approach. In particular, by the mid-eighties, curative measures were seen insufficient as well as too expensive to solve massive environmental problems. Thus, in contrast to the 1970s and 1980s when the emphasis was

technologies may be on turn distinguished into *additive* and *integrated*. *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 subdivided into product and process 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 process are transformed into outputs (Chappin, 2008). *Product* innovations comprise changes in the composition, *design*, operation, quality or function(s) of products (including services): the more these factors are combined and overcome existing relationships, the higher the chance for larger *eco-efficient* improvements and for potential reduction of environmental burdens (see Rubik, 2001)[4].

Organizational Sustainable Innovations (OSIs) comprise all measures aiming at incorporate some environmental perspectives into an organisation's operations and to develop an environmental-respectful awareness and new priorities in policies and practices. OEIs include the introduction of organisational methods and management systems for dealing with environmental issues in production and products. Examples of OEIs are (MEI, 2008, p.10):

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mainly on downstream technologies (for example filter systems to keep air and water clean), nowadays TSIs generally refer to the entire life-cycle of a product (manufacture, use, recycling). Following this approach, natural resources are to be used efficiently, and harmful effects on the environment minimised, throughout a product's entire lifecycle. Thus, despite the fact that downstream end-of-pipe technologies still represent a large part of TSIs, the future resides in integrated technologies, which can transform waste products into reusable materials (Bullinger, 2009), although some authors (see, for example, Frondel et al., 2004) argue that a certain amount of end-of-pipe technologies will be anyhow necessary to control specific emissions which cannot easily be reduced with cleaner production.

[4] At this regards, it is crucial clarifying the linkages between TSIs and two related but different concepts, i.e. *eco-design* and *eco-efficiency* (see Halila, 2007, pp. 11-14, for a complete review on this topic).
E*co-design* focuses on how to integrate environmental considerations in the development of products, services and systems. It addresses all environmental impacts of a product throughout its complete life cycle, without compromising other criteria like function, quality, cost and appearance.
Eco-efficiency is a dynamic concept that 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, firm, sector, region or the entire economy.
In this framework, TSIs are one step beyond eco-design since they aim at developing new products and services that:
1. provide the consumers with the function they require in a more eco-efficient way;
but
2. are not necessarily based exclusively on the re-design of an existing product.

- pollution prevention schemes, aimed at prevention of pollution through input substitution, more efficient operation of processes and small changes to production plants (avoiding or stopping leakages and the like);
- environmental management and auditing systems, i.e. formal systems of environmental management involving measurement, reporting and responsibilities for dealing with issues of material use, energy, water and waste (e.g. the EU Eco-Management and Audit Scheme (EMAS), and the ISO 14000 series);
- chain management: cooperation between companies so as to close material loops and to avoid environmental damage across the value chain (from cradle to grave).

Social Sustainable Innovations (SSIs) consist of changes in lifestyle and consumer behaviour as a consequence of an increased awareness about the environmental problems. They include mobility (public transport use instead of private cars, car sharing), nutrition (not-packed, seasonal and organic food consumption), housing (energy saving for heating, cooling and warm water, eco-houses), clothing (wash-machine use only with a full load, clothes recycling), services (eco-leases) and, generally, all those measure that make consumption more sustainable.

Finally, ***Institutional Sustainable Innovations (ISIs)*** consist mainly in the creation of new regimes of environmental governance, such as local network agencies, international environmental organizations, etc.

It is worth noting that despite the fact that TSIs and OSIs are generally implemented by companies, SSIs by consumers, and ISI by governments and policy makers, the classification exposed above is not sharp since, for example, product innovations in machinery in one firm are often process innovations in another company; collective actions of consumers concerning sustainable consumption may represent ISIs; an increased environmental awareness in firms can be considered as a SSI, etc. Moreover, even though OSIs are a separate category of SIs, they are often complementary to the implementation of TSIs.

3. The neoclassical analysis of SIs

In the neoclassical framework, the analysis of SIs can generally be placed across *environmental economics* and *innovation economics*.

On the one hand, *environmental economics* focuses its attention on the public good nature of the environment and on the 'double externality problem' of SIs, by developing methods and strategies to assess environmental policy instruments aiming at correcting the market failure that arises from it. Indeed, SIs combine a benefit for the company or user, and an environmental benefit, depending on the characteristics of the SI (Hemmelskamp, 1997)[5]. Such a characteristic of SIs justifies the importance of the regulatory framework as a driver of SIs, since the addition of two externalities may lead to suboptimal investments in SIs, supposed to be appropriable with difficulty[6]. In other words, environmental policy measures are needed to 'internalize' externalities through the use of different policy instruments.

On the other hand, *innovation economics* analyses the factors influencing the implementation of SIs, by giving prominence to environmental policies as a key determinant for the environmental innovative behaviour of firms, households and other institutions. At this regard, Porter and van der Linde (1995 a, b) argue that environmental regulations can stimulate firms to find more efficient ways to produce, and that such innovations may partially or even more then fully offset the static private adaption costs, thus boosting the competitiveness of regulated firms through improved technical efficiency (see section 3.1).

In the neoclassical framework, SIs play a crucial role for achieving sustainable targets. Generally speaking, neoclassical models of SD extend the models of growth and capital accumulation to include the natural capital. Such models generally conclude that a non-diminishing per capita consumption path can be maintained indefinitely, insofar as *technical progress* is able to offset the negative effects of the

[5] For example, biological food creates benefits for both the user (taste, health) and the environment (less pesticides) compared to the conventional products, while the benefits of other TSIs - such as electricity from renewable energy - have no additional private benefits compared to the use of fossil or nuclear energy.

[6] This is particularly relevant for the initial phase of an innovation since, in later phases, the early developed innovations may promote further SIs thanks to the specialisation of human capital and the establishment of adequate institutions (see Horbach, 2005).

exhaustion of natural resources and pollution through the substitution of scarce natural resources with man-made capital and through improved factor productivity. Neoclassical theories have in fact great confidence in technological innovations as tools to enable the capacity of the economy-environmental system to satisfy the human needs (Common and Stagl, 2005). Moreover, economic growth may involve a set of changes in education and economic structure of a country which may act in favour of the environmental preservation. Such an idea is at the basis of the well-known '*Environmental Kuznets Curve*' hypothesis (see section 3.2), as well as it represents the underpinning thought of the so called '*Ecological Modernisation*' approach (see section 3.3).

Summing up, neoclassical theorists are very confident of the role played by SIs (particularly by the technological ones) for the environmental preservation: their analysis focus above all on the 'double externality problem' of SIs as well as on the factors that influence their implementation.

3.1 SIs and the Porter Hypothesis

As argued earlier, neoclassical theories puts a lot of effort into developing methods and strategies to assess environmental policy instruments aiming at correcting the market failure that arise from the 'double externality' problem of SIs. At this regard, Porter and van der Linde (1995 a, b) suggests that, by pushing firms to develop and adopt SIs, environmental regulation may improve the natural environment, on the one hand, and the firms' competitiveness, on the other (so-called Porter Hypothesis', henceforth PH). In other words, the PH suggests a win-win situation as a consequence of environmental policies, in the sense that the environmental regulation may lead to a situation in which both *social welfare* and *private net benefits* of firms can increase.

On the one hand, the reason why stringent environmental regulation may increase the *social welfare* is well recognised among the environmental economists: in presence of negative externalities, the marginal social cost is higher than the marginal private cost, being the difference the marginal external cost. As a consequence, the efficient output is lower than the output actually produced in the industry: in other words, when there are negative externalities, firms produce too much output. In this framework, environmental regulations (taxes, emission permits, standards) represent a very useful tool to correct this inefficiency, i.e. to correct the market failure resulting from an externality.

On the other hand, the reason why environmental regulation may increase the *private welfare* is less obvious. At this regard, the PH suggest that environmental regulations can stimulate firms to develop SIs that may partially or even more then fully offset the static private adaption costs. As a consequence stringent environmental regulation may boost the competitiveness of regulated firms through improved technical efficiency. According to Porter and van der Linde: '*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 can lead to SIs and these innovations may generate profits (Mohr and Saha, 2008). Porter argues that firms have not realised all profitable opportunities since they have not yet been discovered due to not perfect management systems. Thus, well designed legislation may inform firms about their drawbacks, pushing companies to consider opportunity costs (for example by substituting unwanted materials) (Cerin, 2006).

3.2 SIs and the EKC

The key-role played - according to the neoclassical theorists - by SIs for the environmental preservation can be easily identified in the case of the well-known *'Environmental Kuznets Curve'* (EKC henceforth), an inverted-U shaped relationship - empirically determined in the 1990s - between the level of economic activity and air pollution emissions in advanced industrial nations (see the works of Grossmann and Krueger, 1991; Shafik and Bandyopadhyay, 1992; and Panayotou, 1993).

Basically, the EKC states that as income grows, the level of pollution should rise, reach a 'turning point' and then decline in the following stages of development. SIs play a very important role in the theoretical justification for the existence of the

EKC, as often raised by both empirical and theoretical contributions (Mazzanti and Zoboli, 2007; Stagl, 1999).

In the first stages of economic growth, pollution raises since the main purpose is to increase production, with a consequent use of great volumes of natural resources and a general depletion of the environment (Dasgupta et al., 2002).

In the following phases of growth - when individuals enjoy greater incomes - people become more inclined to care for the quality of natural resources and show an increased willingness to pay for the environment they live in. Thus, they demand for environmental preservation, by (i) pushing governments into implementing adequate environmental policies; (ii) putting pressure on firms in order to develop and adopt SIs; (iii) implementing themselves some SSIs (Bousquet and Favard, 2000). Moreover, as a wealthy nation can afford to spend more on R&D, innovations and technological progress occur with economic growth, and the obsolete technologies are replaced by the cleaner ones, which can improve environmental quality (Dinda, 2004; Komen et al., 1997). In other words, the development of TSIs encourages the efficient use of natural resources, so that a given amount of goods may be produced employing a reduced quantity of natural resources or energy.

3.3 SIs and the Ecological Modernisation

The role of SIs for the environmental preservation is crucial also in the theory of '*Ecological modernisation*' (henceforth EM), whose the underlying political economy founds upon the neoclassical environmental economics. Generally speaking, EM argues that environmental problems may be addressed through further advancements of technology and industrialisation, without any need of stopping the process of industrialisation to deal with ecological crisis (Foster, 1992; O'Connor, 1991). Indeed, the EM approach - developed in the 1980s during the optimistic period of pollution control policies as a response to the failures of the former environmental policies in the 1960s and 1970s (see Huber, 1982; 1984, 1985; 1991; and Jänicke, 1984; 1998) - is centrally focused on the relationship between industrial development and the environment, and merges the concerns for ecology and employment into a powerful message about the assets of innovation, arguing for the possible harmonization of industry and ecology (Andersen and Massa, 2000).

In the EM framework, environmental problems can be solved through the so-called 'super-industrialisation', i.e. the transformation of industrial production based on the development of advanced technologies (Fisher and Freudenburg, 2001). Thus, SIs (particularly TSIs) need to be encouraged in order to address any environmental problem.

In particular, in the analysis of SIs, the nexus between innovations and the environment founds upon the key-concepts of (i) '*efficiency'*, (ii) '*precaution'*, and (iii) '*social market*':

- *Efficiency*, since at the hearth of EM there is the idea that, similarly to the PH, some forms of policy intervention may simultaneously result in both economic and environmental benefits. In particular, this is the case of policies useful to promote the development and application of TEIs (Murphy and Gouldson, 2000). These may reduce the consumption of raw materials and the emissions of various pollutants, while at the same time they may create competitive products;
- *Precaution*, since EM can be considered as the operational component of the 'precautionary principle' (Vorsorgeprinzip, in German), evolved out of the German socio-legal tradition in the 1930s and based on the concept of 'good household management' (Jänicke, 1988). This principle is founded on the idea that damages to the environment should be avoid in advance, keeping economic development away from production processes that are environmentally dangerous (Boehmer-Christiansen, 1994). In this framework, TSIs play a key-role since they allow for the creation of alternative paths of development (Andersen and Massa, 2000). In other words, precaution means developing innovations that reduce environmental burdens. Thus, SIs such as smart production systems, clean (or cleaner) technologies, innovations in sectors like renewable energy, biotechnology, etc. are a central aspect of EM (Barry, 2005);
- *social market*, since the principles of EM represent a kind of 'green Keynesianism', because they justify an active government intervention and state subsides for research and development (Boehmer-Christiansen, 1994). Through

emissions standards, environmental taxes, and other regulatory mechanisms - all based on a preventive rather than a curative or end-of-pipe approach, according to the precautionary principle - regulation may drive the process of industrial innovation with environmental and economic gains realised as a result (Murphy and Gouldson, 2000). Some authors (see, for example, Christoff, 1996) argue that EM is a way for governments to manage ecological dissent and to relegitimise their social regulatory role. However, while the State should provide financial support to SIs, the private sector should develop, test and market them. In other words, there is a preference for the marked-based solutions: the State sets the environmental targets and the market decides how to achieve them.

It is worth noting that, similarly to the EKC, in the EM approach SIs are developed essentially by the private sector. The main difference between the two approaches is that, in the EKC, they are developed within an economic framework of complete *laissez faire* of governments (since the environment does not need any particular attention), whereas, in the EM, SIs are generally developed by the market thanks to the supportive action of the State that has the task of implementing policies to deal with environmental problems into the growth-oriented and globalised economy.

4. The evolutionary analysis of SIs

While deterministic neoclassical theories have the advantage of analysing incremental innovations, they are of limited value for exploring more radical changes of technological systems including the organizational and social context (Rennings, 1998). Moreover, the scale of SIs is particularly important, since small-scale SIs may have consequences only for a specific firm, industry, production process, or for a particular product or group of consumers, while, at the other extreme, large scale SIs may affect complete socio-technical systems (Oosterhuis and Kuik, 2008).

At this regard, the evolutionary theories can be particularly useful since they abandon the neoclassical attempt to find equilibrium for adopting inductive approaches based on the observation of the complex reality of change over time, using the concepts of disequilibrium, transition and non-linearity (Faucheux et al., 1996). Evolutionary approaches are in fact more interested in the analysis of transition and learning processes than in equilibrium states, and assume bounded rationality rather than optimization. Thus, whereas neoclassical approach emphasises marginal conditions and optimisation, evolutionary theorists focus more at conflict aspects of economic processes and explain changes in terms of a system' capacity to adapt to crises.

In the evolutionary framework, innovations are adopted not only on the extent of their characteristics (cost, quality, etc.) but also on the basis of their compatibility with existing systems and structures (Kemp, 1993). In other words, innovations must be introduced into systems developed for older technologies and this may result in some resistance and inertia regarding their adoption, because of the existing routines, tasks, qualifications, present user-producer relationships, etc. (Murphy and Gouldson, 2000). Therefore, whereas neoclassical theorists focus mainly on specific characteristics of SIs (such as efficiency, prevention, environmental regulation, etc.), the evolutionary approach considers them in their dynamic and multi-dimensional nature, being SIs dependent on interactions between technical, sociological, and economic systems. In other words, having in mind the risk of a 'technology-bias' (i.e. of conceiving progress simply as innovation in firms, as typical in neoclassical analysis), the evolutionary approach analyses SIs in the broader context of their co-evolution with social, ecological and institutional systems, and places emphasis on the necessity of their re-organization within a broader 'green paradigm' (see Rennings, 1998).

According to this perspective, substantial improvements in environmental efficiency may still be possible with innovations of an 'incremental' kind, but larger jumps in environmental efficiency may only be possible with system innovations that involve new technological artefacts, new markets, user practices, regulations, and infrastructures.

In the evolutionary context, technological changes take generally place within particular trajectories: due to the pressures of the selection environment a certain technology may become a dominant 'technological paradigm' which excludes other evolutionary options. This is also the case of SIs: in transport, energy and other systems there are promising new technologies with better environmental performance. But many of these new technologies are not taken up since existing systems are 'locked in' on many dimensions (economic, social, cultural, infrastructural, regulatory, etc.) (Elzen et al., 2004). Thus, the implementation of SIs may require other changes in user practices, regulation or infrastructure.

4.1 SIs and 'sociotechnical regimes'

On the basis of the broader evolutionary approach to the 'environmental question', some recent studies on the role of SIs have extended beyond the analysis of the development and adoption of individual cleaner technologies, moving towards the investigation of the so called 'sociotechnical regimes' (henceforth STRs).

The issue of STRs stems from the concept of 'technological regime' (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, policy makers, users, special-interest groups, etc. may also contribute to patterning of technological development, sociologists of technology expanded the 'technological regimes' concept in order to include this broader community of social groups.

The issue of 'STRs' takes into account the role of these social groups in stabilising existing trajectories through adaption of lifestyles to technical systems, regulations and standards, sunk investments in machines and infrastructures, etc. (Unruh, 2000; Christensen, 1997). Thus, the STRs approach offers an insight into the reasons why new technologies may fail on, although they promise a better performance compared to incumbent technologies.

Following this approach, technologies are considered as embedded in a broad and complex system, which consists of interacting technological and social elements (users, policymakers, researchers, etc.). In this way, the STR becomes a dynamic unit of analysis, since it is the co-evolution of the technical and social elements that determines the way a regime operates.

Generally, STRs tend to hold processes for regime optimisation, making radical innovations difficult to prevail. These may emerge primarily through technological niches or niche markets that act as ‘incubation rooms’ where initially unstable sociotechnical configurations are protected against mainstream market selection (see Geels and Schot, 2007). Even if niches perform poorly in more conventional terms (price, convenience, speed), in these protected spaces new technologies are given the opportunity to be appreciated, evaluated, and matured through gradual experimentation and learning by producers, users, researchers, etc. (Smith, 2006).

In this framework, SIs are driven by new scientific insights which open up new technological opportunities, pressing technological needs, entrepreneurial activities and institutional support for radically original technologies (Kemp, 1997). They can be developed and successfully experimented only in niches where - as a consequence of destabilization pressures on the existing regime from the sociotechnical landscape - they have the opportunity of emerging and competing with the existing regime, going into the mainstream markets: this implies that SIs need to be fostered through strategic policies of niche management.

Thus, in the context of STRs theory, SIs need to be analysed in terms of transitions from one sociotechnical regime to another: the dominance of an existing technological regime helps to explain the reasons why many SIs fail although they promise a better environmental performance.

5. Conclusions

The concept of SD and, in particular, its environmental dimension asks for new ways to accomplish enhanced quality of life with reduced environmental impact. Innovations that contribute to sustainable pathways through an improved environmental quality (briefly the Sustainable Innovations – SIs) have consequently gained an increasing interest in the recent past.

The present papers contributes to the debate about innovations and SD by analysing SIs from both the neoclassical and the evolutionary perspective.

Following the neoclassical theorists SIs (in particular way the technological ones) seem to play a determinant role for the environmental preservation: their analysis focus above all on the 'double externality problem' of SIs as well as on the factors that influence their implementation. However, whereas deterministic neoclassical theories have the advantage of analysing incremental innovations, by focusing on specific characteristics of SIs (such as efficiency, prevention, environmental regulation, etc.), the evolutionary approach considers SIs in their dynamic and multi-dimensional nature, being SIs dependent on interactions between technical, sociological, and economic systems.

As a consequence, in the analysis of innovations for the SD both the neoclassical and the evolutionary approaches have their advantages and disadvantages. In particular, neoclassical perspective focuses on specific peculiarities of SI and is more appropriate to analyze the efficiency of incentive systems which are essential for driving SIs. On the opposite, evolutionary theories seems to be more suitable for analyzing radical technological changes and transition processes, other than to avoid the so-called 'technology bias', by stressing the need for a consideration of social and institutional aspect in the analysis of SIs.

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