Review Paper on Diffusion of Eco Innovation Products

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Abstract:

The paper conducts a review of the literature regarding the diffusion of eco-innovation products using Rogers,2003 theoretical framework. It tries to find the barriers to diffusion of eco-innovation products as well as analyse the government philosophies which ought to be followed to support the diffusion process.The paper highlights the need for more focus on R & D as well as on the advocacy groups who are likely to help in developing political influence and legitimacy for the eco innovation products.

Index Terms : *Eco- Innovation, Diffusion , Adoption , Government Policy*.

Introduction:

Climate change is a defying reality that stares at the face of human race . The effects are rampart which are visible in shifting weather patterns, catastrophic flooding, all of which threaten the food production. As we cross the 7 billion population mark, the level of green house gas emissions has been increasing at a rapid rate leading to steady rise in the mean global temperatures . The fifth assessment report of UN Intergovernemental Panel on Climate Change (IPCC) provided a comprehensive assessment of causes for the rapid rise of sea levels in the past few decades. The special report of IPCC issued in Oct 2018 , threw light on the impact of global warnings .The report clearly specified that limited global warming to 1.5^{o} C - 2^{o} C would ensure sustainable and equitable society. The report said that limiting global warming to 1.5^{o} C would require a rapid and far reaching "transition in land , energy , industry , building , transport and cities".

At the 21st Conference of Parties in Paris in 2015, parties to UNFCC agreed to accelerate & intensify the actions and investments needed for a sustainable low carbon future .The parties committed to enhance support and assist developing sustainable low carbon future. As per the special report on renewable energy sources and climate change mitigation published by IPCC , solar energy was considered one of the renewable energy sources and technologies as solution to low carbon footprint

As per the report ,direct solar energy technologies harness the energy of solar irradiance to produce electricity using photovoltaics (PV) and concentrating solar power (CSP), to produce thermal energy. Solar applications ranges from low maturity products such as fuels produced from solar energy to passive and active solar heating, and wafer-based silicon PV which are high on the product maturity cycle. Changes in market demand create opportunities for firms to invest in innovation to satisfy unmet needs i.e demand "steers "firms to work on certain problems (Nemet ,2007).Better implementation of basic technologies can also have greater impact in developing countries than the adoption of new technologies (Prahalad, 2012).

Objectives :

Review on the origins and evolution of the field of science policy and innovation studies, points out that innovation studies are a consolidated research field in the developed world (Fagerberg and Verspagen, 2009; Martin, 2012). The main purpose of this paper is to conduct literature review in the area of diffusion of eco-innovation while highlighting the dynamics that drive the diffusion . The paper aims to answer the following questions :

1) What are the barriers to diffusion of eco innovation?
2) What are the governmental philosophies to support the diffusion of eco innovation ?

Eco –innovation has been defined as the production , application or exploitation of a good , service , production process , organisation structure or management or business model that is novel to the firm or user and which results , throughout its life cycle , in a reduction of environment risk , pollution and the negative impacts of resource use (including energy use) compared to relevant alternatives(Kemp & Foxen ,2007).

The five categories of eco-innovations are as follows:

- Add-on innovations which include pollution handling technologies and services
- Integrated innovations (cleaner technological processes and cleaner products)
- Eco-efficient technological system innovations (new technological paths)
- Eco-efficient organizational system innovations (new organizational structures)
- General purpose eco-efficient innovations e.g. renewable energy technologies and ICT. (Andersen ,2005)

As per Kemp & Pearson (2007),the eco-industry (or environmental goods and services sectors as it is also called)may be measured on the basis of environmental protection measures or on the basis of sales, or a combination thereof. Bruce Tether in the UK and Anthony Arundel and Hugo Hollanders at UNU-MERIT said that eco-innovators could be classified in one and 9 only one category on the basis of how they introduce environmental innovations. For instance:

• **Strategic eco-innovators:**These people develop eco equipment & services for sale to other firms.

• **Strategic eco-adopters:** These people implement eco-innovations by either developing in-house or by acquiring from other firms, or both.

• **Passive eco-innovators:** Process, organisational, product innovations etc. that result in environmental benefits, but where there is no specific strategy to ecoinnovate.

• **Non eco innovators:** These people conduct no activities with environmental benefits.

Keeping in with the view that any innovation that offers environmental benefits compared to relevant alternatives is to be viewed an eco-innovation Kemp & Pearson (2007) developed the following classification for eco-innovation.

A. Environmental technologies –

i. Pollution control technologies including waste water treatment technologies.

ii. Cleaner process technologies: new manufacturing processes that are less polluting and/or more resource efficient than relevant alternatives;

iii. Waste management equipment;

iv. Environmental monitoring and instrumentation; -

v. Green energy technologies;

vi. Water supply; -

vii. Noise and vibration control.

B. Organisational innovation for the environment: The usage of organisational methods and management systems for dealing with environmental issues in manufacuring.This includes:

i. 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);

ii. Environmental management and auditing systems: formal systems of environmental management involving measurement, reporting and responsibilities for dealing with issues of material use, energy, water and waste (EMAS and ISO 14001 are examples);

iii. Chain management: cooperation between companies so as to close material loops and to avoid environmental damage across the value chain (from cradle to grave).

C. Innovative product and service which offer environmental benefits such as :

i. New or environmentally improved material products (goods) including ecohouses and buildings;

ii. Green financial products (such as eco-leases or climate mortgages);

iii. Environmental services: solid and hazardous waste management, water and waste water management, environmental consulting, testing and engineering, other testing and analytical services; -

iv. Services that are less pollution and resource intensive (car sharing is an example).

D. Green system innovations –

i. Alternative systems of production and consumption that are more environmentally benign than existing systems: biological agriculture and a renewables-based energy system are examples.

Rennings et.al , 2004 notes that environmental regulation can be good for business and is consistent with economic growth –a concept sometimes known as ecological modernisation. Kemp & Foxen , 2007 sees the direct benefits for the eco –innovating firm as being :

- Operational advantages such as cost savings from greater resource productivity & better logistics
- Sales from commercialisation

Indirect benefits for the eco-innovator include :

- Better Image
- Better relations with suppliers , customers & authorities
- Capability for innovation is enhanced due to interaction and discussion with knowledge holders
- Health & safety benefits
- Greater worker satisfaction

Own & others experiences (about net benefits from eco-efficiency) are therefore instrumental in changing the mindset (Kemp & Foxen , 2007)

Theoretical Framework:

Rogers,2003,defined innovations are ideas , practices or objects that adopters (people, groups ,companies or other social agents) perceive to be novel.The adopters were classified as innovators, early adopters, early majority, late majority, and laggards. The individuals in are similar in terms of their innovativeness: “Innovativeness has been defined as the degree to which an individual is relatively earlier in adopting new ideas .

Adopter Categories (Rogers,2003) :

1) Innovators: Innovators are willing to experience new ideas. Innovators act as the gatekeepers to bringing the innovation in from outside of the system. Innovators are required to have complex technical knowledge.
2) Early Adopters: Early adopters are more likely to hold leadership roles in the social system, other members come to them to get advice or information about the innovation. Early adopters’ help in decreasing uncertainty about the innovation in the diffusion process.
3) Early Majority :The early majority have a good interaction with other members of the social system, they do not have the leadership role that early adopters have. Their interpersonal networks plays a critical role in the diffusion process. They take more time in taking decision than the previous categories .
4) Late Majority: Similar to the early majority, the late majority includes one-third of all members of the social system who wait until most of their peers adopt the innovation. Economic necessity and peer pressure drives them to the adoption of the innovation.
5) Laggards:They have the traditional view and they are more skeptical about innovations and change agents than the late majority. They do not have a leadership role. Because of the limited resources and the lack of awareness-knowledge of innovations, they first want to make sure that an innovation works before they adopt. On account of these characteristics, the time taken by the laggards is the longest amongst all the adopter categories.

The rate of adoption has been defined as "the relative speed with which an innovation is adopted by members of a social system" (Rogers (2003 p. 221). Rogers reported that the type of innovation-decision type (optional, collective, or authority), communication channels (mass media or interpersonal channels), social system (norms or network interconnectedness), and change agents may increase the predictability of the rate of adoption of innovations. Rogers considered relative advantage as the strongest predictor of the rate of adoption of an innovation.

1) Relative Advantage: The degree to which an innovation is perceived as being better than the idea it supersedes" (p. 229). The cost and social status motivation aspects of innovations are elements of relative advantage.
2) Compatibility: The degree to which an innovation is perceived as consistent with the existing values, experiences, and needs of adopters defines the compatibility of the innovation. (p. 15).
3) Complexity:The degree to which an innovation is perceived as relatively difficult to understand and use defines the complexity of the innovation (p. 15). Excessive complexity has been considered as an obstacle to adoption of the innovation
4) Trialability:The extent to which an innovation is susceptible to be experimented on a limited basis"defines its trialiability (p. 16). The more the innovation is susceptible to trial , the greater will be the rate of its adoption.
5) Observability:The extent to which the results of an innovation are visible to others"defines its observability. (p. 16).

In summary, Rogers (2003) argued that innovations offering more relative advantage, compatibility, simplicity, trialability, and observability will be adopted faster than other innovations. Diffusion results from reducing uncertainty about the innovation through conversations with people to gain insights into reasons for adoption , such as desirable attributes of innovation and social pressures to adopt it (Rogers,2003).

Descriptive Statistics:

Sample Selection

The sampling process in September 2019 using the Dimensions Web of Knowledge . After screening the titles and abstracts,a total of 29 studies were considered for analysis after a comprehensive screening of full text to assess the validity, reliability and applicability of each study .Most of the rejected studies were either short conference papers/abstracts or studies not focusing on eco – innovation or they did not match the dimensions of this study.

Findings:

The findings from systematic review are as follows:

Barriers to Diffusion of Eco-Innovation:

Fossil-fuel based energy systems have undergone a process of co-evolution, leading to the current dominance of high carbon technologies and the accumulated knowledge, capital outlays, infrastructure, available skills, production routines, social norms, regulations and life styles which support these (Unruh, 2000). Foxon (2003) further argues that electricity generation is contextualised by institutional factors - for example, the desire to satisfy increasing electricity demand and a regulatory framework based on reducing unit price – which feed back into expansion of the technological system.Thus, persistent market and policy failures inhibit the diffusion of carbon-saving technologies despite their environmental and possibly economic advantages.The evidence for what Unruh terms carbon lock-in is compelling says Schmidt and Marschinski (2009).

Rehfeld et al. (2004) found that a perception of expense amongst consumers of environmental products was a much more significant factor than attitudes towards reliability or quality. Economic rather than „soft" factors appear to be the major obstacles to the commercial exploitation of environmental products and therefore also to environmental product innovations (Rennings and Ziegler, 2006).

Jacobsson and Johnson (2000) summarizes the factors that represent potential barriers to eco-innovation:

1. Actors and markets
    a) Poorly articulated demand
    b) Established technology supported by increasing returns
    c) Market control by incumbents
2. Networks
    a) Poor connectivity
    b) Wrong guidance with respect to future markets
3. Institutions
    a) Legislative failures
    b) Failures in the educational system
    c) Skewed capital markets
    d) Underdeveloped organisational and political power of new entrants.

Vincent (2006) suggested that there are various ways in which, and stages at which, the innovation and commercialisation of new and emerging low carbon technologies can fail including:

(i) funding inadequacies at the demonstration and pre-commercial stages;

(ii) failures at the planning stage for commercial developments;

(iii) insufficient attention to setting industry standards and test regimes for new and emerging products;

(iv) a focus on grant support schemes to address the initial capital cost premium from the consumer's perspective whilst paying insufficient attention to working with manufacturers on ways to move their new and emerging products faster

Factors outside the firms may prevent or promote mechanisms of innovation creation and diffusion which,in turn, determine the speed and pattern of diffusion among firms within a country (Cohen and Levinthal, 1989; Keller, 2004). Nguyen and Jaramillo (2014) found that lower institutional quality (specifically, rule of law, regulatory quality, property and patent right protection) lower the return to innovation. Allard *et al.* (2012) found evidence that national systems of innovation were most likely to flourish in developed, politically stable countries and less likely to prosper in historically unstable countries.Almeida and Fernandes (2008) found a strong positive correlation between openness and technology adoption amongst 43 developing countries.

Government Policy & Regulatons:

The solar photovoltaic industry in China and India was analysed by Fu and Zhang (2011), who found that the national innovation systems was a critical success factor in developing and supporting the industry`s capacity to mix and sequence different technology transfer and indigenous innovation mechanisms.Watson (2008) argues that government technology eco-innovation policies have to do more than fund basic R&D and internalise the social costs of carbon emissions. There is a need for government to support other stages of the innovation process such as the so-called valley of death as technologies move from demonstration or prototype phase to commercialization.Major areas of uncertainty within the low carbon arena include the long run relative costs or feasibility of emerging technologies (Anderson et al., 2001); the emergence of entirely new technologies; consumer behaviour and preferences; and geopolitical uncertainty, which may affect fuel prices or the political acceptability of some technologies or fuels such as nuclear power or natural gas. The implications of climate change are of themselves uncertain and will affect the scale of emissions reductions expected in future (Gross, 2008).The magnitude of FDI and trade depends on host-country policies which highlights the importance of local governance to nurture innovation in local firms attracting foreign knowledge and technologies (Dollar *et al.*, 2005; Franco *et al.*, 2011).

Philosophy of Government Interventions:

Governments should avoid providing targeted support to particular technologies Watson (2008). Policy needs to create the conditions that allow a variety of low carbon options to emerge and prosper. But, perhaps paradoxically, policies will also need to ensure that the most promising low carbon options can themselves benefit from increasing returns to adoption. The same processes that created lock-in to a high carbon energy system can be harnessed to reduce the costs and improve the performance of low carbon technologies (Gross ,2008).

As per Winskel and Moran (2008) policy lessons that can be drawn from international case studies of low carbon/renewable energy innovation:

- A significant period of R&D and building-up networks is necessary during the preparation phase ahead of industry take-off.

- During this period, policies must strike a balance between concentrating support on upscaling and progressing one or two leading prototypes, versus supporting a wide range of novel device designs.
- Some specific formal institutions and measures have proved important during the preparation phase:
- Dedicated R&D grants to support individual device development
- Technology-specific „feed-in" tariffs to stimulate market growth
- R&D networks linking industry, universities and research institutes
- Well-supported testing and accreditation centres to compare different designs and generate community-wide knowledge
- Powerful industry associations to disseminate knowledge
- Advocacy groups to build political influence and legitimacy for renewables
- Common backgrounds or shared understandings between technology developers, researchers, and suppliers (but building „trust" is an informal issue and difficult to transfer between regions/nations).

Winskel and Moran (2008), the most successful experiences have been associated with a gradual building-up of eco-innovation networks over time from the bottom-up.Negro and Hekkert (2008) found that the practical relevance of the technological innovation systems framework is that policy initiatives directed at stimulating sustainable change of the energy system, should focus on stimulating weak system functions to increase the chances of virtuous feedback taking place. Additionally, by identifying the underlying tendencies of the occurrence of flawed cycles, appropriate policy recommendations can be developed to prevent or resolve the occurrence of those cycles in the future.

Watson (2008) proposed five key implications for energy eco-innovation policy, relevant both to the UK and to other countries:

- First, government funding for sustainable energy technologies needs to be increased and rebalanced. Rebalancing means giving greater support to technologies facing, in particular, the „valley of death" between demonstration and commercial deployment.
- Second, the government funding for eco-innovation needs to be technology-specific. Generic incentives such as carbon emissions trading schemes are necessary but not sufficient. Research shows that technology-specific approaches work. However, policy makers will need to decide when to discontinue support.
- Third, the process of deciding which technologies to prioritise needs to be more transparent.
- Fourth, the energy eco-innovation policy needs to strengthen its evaluation capacity of technology support programmes.
- Finally, the energy eco-innovation policies need to address the locked in-nature of current energy systems. Whilst energy infrastructures, institutions and policies were developed to meet important social goals, radical change is likely to be required to tackle climate change effectively.

Some examples of Eco Innovation measures as per UNIDO , 2012

TABLE 15. EXAMPLES OF ECO-INNOVATION MEASURES

Type	Examples of measures	Policy fields
Market based instruments	Fiscal measures (e.g. energy tax, resource tax, carbon emissions tax, R&D tax incentives) Emissions trading schemes	Fiscal policy Trade policy
Regulatory and normative framework	Energy regulation standards and norms (including technology regulations, energy saving requirements) Permits and bans Land use regulations Environmental management systems, eco-labels and other soft standardization instruments	Environmental policy Industrial policy Energy policy Trade policy Local development policy
Direct support for innovation activity	Financial schemes (loans and credits) Subsidies (e.g. renewable energy subsidies) Venture capital funds Business incubation programmes Targeted R&D and technology transfer Business advisory services Eco-clusters (involved in development of eco-innovations and support for eco-innovative solutions in existing clusters)	Economic policy Energy policy Innovation policy Entrepreneurship policy Research policy Regional policy
Capacity building and demonstration measures	Professional training (eco-efficiency capacity building for enterprises) Changes in educational programmes	Education and training policy
Public procurement	Green public procurement	All policy fields with public procurement capacity (e.g. transport, construction and housing, national defence)
Strategic planning	Climate change foresight Strategic spatial planning	Foresight is relevant for all policy fields

Summary & Conclusion :

There has been an increasing concern for climate change around the world with an emphasis on reducing the carbon footprint.All the articles reviewed so far agree to the fact that co-evolution of fossil fuel energy system has been a major barrier towards diffusion of eco-innovation. As specified by Unruh (2000) this technology inertia has resulted in the form of lock in. Gross (2008) also agrees with Unruh as he cities that assets are long lived and capital intensive, incumbent technologies have benefited from decades of development, and the system has co-evolved into compatible networks of fuels, end use devices, vehicles, delivery infrastructure and institutions.

The papers reviewed highlighted the role played by national innovation systems in the diffusion of eco-innovation .Watson 2008 pointed to the fact that government policy needs to allow a variety of low carbon options to emerge and prosper. This would clearly rely on more focus on R & D as well as on the advocacy groups who are likely to help in developing political influence and legitimacy for eco –innovation products . However , paucity of literature with respect to supporting structures and influencers in adoption of eco-innovation pave the way for new studies in the field.

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