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Commercializing clean technology innovations – the emergence of new business in an agency-structure perspective

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ABSTRACT

Clean technology is seen as indispensable to solve or at least abate an environmental/energy crisis without abandoning possibilities for progress and economic growth. This, however, does not imply that sustainable development can be readily achieved through a 'technical fix'. Innovation and commercial introduction of new technology are inherently uncertain processes that fail more often than that they succeed. Studies on the commercialization of new technology in entrepreneurship literature have often failed to explain why some new technologies reach markets while others don't, as well as why some technological solutions ultimately become industry standards while others quickly disappear from the market. Technology commercialization models are often linear, based on a technology-push logic and focus rather exclusively on micro-level issues such as characteristics of technology and product, entrepreneurial experience and access to resources. This chapter takes stock with a linear perspective to cleantech commercialization processes and, instead, suggests an alternative approach to analyze the entrepreneurial process of commercializing cleantech. In particular, this approach underlines the duality concerning structure and agency that entrepreneurs tend to encounter in the commercialization of cleantech. The objective of this chapter is to identify how agency and structure interplay in the process of commercializing cleantech. To do so, the chapter compares two literatures that each depart from different starting points. Whereas the institutional entrepreneurship literature often departs from the micro-level of individual or organizational action, the socio-technical transitions literature departs from a systems perspective on technological change. The contribution of the chapter lies in making explicit the agency-structure discussion in the different approaches in order to add to our understanding of cleantech as an emergent technological field and the role of entrepreneurs and/or entrepreneurship in shaping this field. By reviewing the recent knowledge development in the area, we also identify two possible ways how these literature streams can enrich each other; namely by incorporating the transition process in institutional entrepreneurship and by incorporating entrepreneurial strategies in socio-technical transitions.

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Keywords: cleantech, technology entrepreneurship, sustainability transitions, institutional entrepreneurship

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Abstract:

Clean technology is seen as indispensable to solve or at least abate an environmental/energy crisis without abandoning possibilities for progress and economic growth. This, however, does not imply that sustainable development can be readily achieved through a 'technical fix'. Innovation and commercial introduction of new technology are inherently uncertain processes that fail more often than that they succeed. Studies on the commercialization of new technology in entrepreneurship literature have often failed to explain why some new technologies reach markets while others don't, as well as why some technological solutions ultimately become industry standards while others quickly disappear from the market. Technology commercialization models are often linear, based on a technology-push logic and focus rather exclusively on micro-level issues such as characteristics of technology and product, entrepreneurial experience and access to resources. This chapter takes stock with a linear perspective to cleantech commercialization processes and, instead, suggests an alternative approach to analyze the entrepreneurial process of commercializing cleantech. In particular, this approach underlines the duality concerning structure and agency that entrepreneurs tend to encounter in the commercialization of cleantech. The objective of this chapter is to identify how agency and structure interplay in

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Introduction

Since the 1970s, environment and energy related problems have moved to centre stage on many political, business and research agendas. The notion of sustainable development has emerged as the dominant global discourse to adapt societies and economies to novel modes of production and consumption in areas such as transport, energy, housing, agriculture and food. For such shifts, new technology and technological change is considered of critical importance. In other words, clean technology (cleantech) is seen as indispensable to solve or at least abate an environmental/energy crisis without abandoning possibilities for progress and economic growth. This, however, does not imply that sustainable development can be readily achieved through a 'technical fix'. Innovation and commercial introduction of new technology are inherently uncertain processes that fail more often than that they succeed.

Following information technology and biotechnology, clean technology is often heralded in policy and investment circles as the new general purpose or platform technology to give rise to growing market opportunities for firms, regions and nations. Similar to its predecessors, initial enthusiasm may have outpaced a more fundamental understanding of the nature and characteristics of this emerging field. It is probably fair to say that a common definition of the cleantech concept is yet to be agreed upon. In a comprehensive literature review carried out in 2008 by the The Swedish National Board for Industrial and Technical Development NUTEK (since 2009 merged into the Swedish Agency for Economic and Regional Growth), it was concluded that cleantech indicates a broader notion than environmental technology. While environmental technologies are primarily defined in relation to environmental regulatory pressures, cleantech is supposed to be more market oriented. Moreover, it is acknowledged that the concept, in principle, stretches across all industries (including services). What makes the concept peculiar is that it concerns a relative notion. It is defined in relation to other alternatives by offering a better solution from an environmental point of view. By way of summarizing NUTEK (2008) defines cleantech as embracing a diverse range of products, services, and processes across industries that are inherently designed to (1) provide superior performance at lower costs, (2) greatly reduce or eliminate negative ecological impact and (3) improve the productive and responsible use of natural resources. This resonates with a more academic definition, where cleantech is defined as products and services that use technology to compete favorably on

price and performance while reducing pollution, waste, and use of natural resources (Burtis et al., 2006; Cooke, 2008).

Studies on the commercialization of new technology in entrepreneurship literature have often failed to explain why some new technologies reach markets while others don't, as well as why some technological solutions ultimately become industry standards while others quickly disappear from the market (Garud and Karnøe, 2003). Technology commercialization models are often linear, based on technology-push logic and focus rather exclusively on micro-level issues such as characteristics of technology and product, entrepreneurial experience and access to resources. The original idea of the process of commercializing a new technology (Bush, 1945) is that innovation starts with basic research, followed by applied research and development and ends with production and diffusion. This model has been very influential within the research community and, despite it being criticized for providing a simplistic and linear view of getting new technologies on the market, subsequent studies of technology commercialization have been largely building upon the same model (e.g. Utterback, 1974; Roger, 1983; Jolly, 1997). This relates also to the observation that the main part of entrepreneurship literature today continues to treat entrepreneurs as operating within a certain (stable) system of actors and institutions (Shane and Venkataraman, 2003; Johannisson and Wigren, 2006), despite the historical foundations of the entrepreneurship research field, which emphasized entrepreneurs as a source of structural change and renewal in the economy.

This chapter takes stock with a linear approach to cleantech commercialization processes and, instead, suggests an alternative approach to analyze the entrepreneurial process of commercializing cleantech. In particular, this approach underlines the duality concerning structure and agency that entrepreneurs tend to encounter in the commercialization of cleantech. Counter to the seemingly appealing simplicity of linear commercialization models, this framework seeks to acknowledge the complexity and uncertainty involved in bringing new technology to the market. First, there is the risk of technological spillover that may prevent the entrepreneur from capturing the full value of an innovation (Wustenhagen et al., 2008). Second, there is often a lack of internalization of environmental cost benefits that accrue from cleantech and eco-innovation (Rennings, 2000). Thirdly, there is a fundamental uncertainty about the complex and multi-dimensional shifts considered necessary

to adapt societies and economies to sustainable modes of production and consumption in areas such as transport, energy, housing, agriculture and food. The latter two are of particular significance for entrepreneurs' possibilities to capitalize on innovations in cleantech and makes the commercialization process fundamentally different from that of other types of technological innovations. In particular it reveals the importance to acknowledge the influence of prevailing social and economic systems on entrepreneurial action and strategies, and perhaps more importantly, the ability of entrepreneurs to adapt to and/or influence such social and economic systems and, through that agency, overcome barriers to commercialize cleantech (Dean and McMullen, 2007).

Given its particularities, clean technology provides a potentially insightful context to study the intersection between the agency that is enacted by entrepreneurs to shape their own paths and the structures that influence these actions. This resonates with the more general arguments by Low and MacMillan (1988) and Davidsson and Wiklund (2001) who argue that entrepreneurship research needs to increasingly adopt a multi level perspective, due to the embeddedness of entrepreneurs in multiple fields and systems. To deal with the seemingly paradoxical notion of embedded agency, the chapter compares two literatures that address the structure-agency duality in the context of innovation and technological change, namely, socio-technical transitions and institutional entrepreneurship.

The *objective* of this chapter is to identify how agency and structure interplay in the process of commercializing cleantech. To do so, the chapter compares two literatures that each depart from different starting points. Whereas the institutional entrepreneurship literature often departs from the micro-level of individual or organizational action, the socio-technical transitions literature departs from a systems perspective on technological change. The contribution of the chapter lies in making explicit the agency-structure discussion in the different approaches in order to add to our understanding of cleantech as an emergent technological field and the role of entrepreneurs and/or entrepreneurship in shaping this field. By reviewing the recent knowledge development in the area, we also identify two possible ways how these literature streams can enrich each other; namely by incorporating the transition *process* in the institutional entrepreneurship literature-based analytical models and by incorporating entrepreneur (and incumbent) *strategies* in socio-technical transition literature-

based analytical models.

Following this introduction, sections two and three will introduce and review the main literatures, i.e. sustainability transitions and institutional entrepreneurship literature respectively. The fourth section provides a reflexive discussion on the review carried out in the chapter, followed by conclusions and suggestions for further research.

Socio-technical systems and sustainability transitions

In the past decade, the literature on sustainability transitions has made a considerable contribution in understanding the complex and multi-dimensional shifts considered necessary to prepare and adapt societies for sustainable development. Transition is here understood as shifts or 'system innovations' between distinctive socio-technical configurations encompassing not only new technologies but also corresponding changes in markets, user practices, policy and cultural discourses and governing institutions (Geels, et al., 2008). Geels and Schot (2010) characterise transitions according to the following characteristics: (1) co-evolution and multiple changes in socio-technical systems or configurations, (2) multi-actor interactions between social groups including entrepreneurs, firms, user groups, scientific communities, policy makers, social movements and special interest groups, (3) 'radical' change in terms of scope of change (not speed), and (4) long-term processes over 40-50 year periods. One of transition analysis' strengths has been its capacity to deal with structure-agency duality via co-evolutionary long-term trajectories of socio-technical change, illustrating how systemic contexts can act both as barriers and enablers for technological change.

Following the tradition of ecological modernization it has been explicit in pointing to technology and innovation as crucial instruments to adapt capitalist, industrial societies to fit within the earth's ecological carrying capacity (Langhelle, 2000). On the one hand, it acknowledges the difficulties that purposeful structural change to ecological sustainability faces because of lock-in and path dependence (Geels, 2010). For example, Unruh (2000) argues that lock-ins in fossil fuel-based energy systems have created persistent market and policy failures that can inhibit the diffusion of carbon-saving technologies despite their apparent environmental and economic advantages. On the other hand, sustainability transitions literature acknowledges the importance of radical,

path-breaking innovations that lead to cracks, tensions and windows of opportunities vis-a-vis such lock-ins. On an overall level, this literature investigates and emphasizes mechanisms that both induce change as well as inertia in technology-driven sustainable development.

Proponents of socio-technical systems have argued for more explicit attention to the adoption and use of innovations and new technologies (see also Rekers, 2010) and the (potentially transformative) impacts on society in a broader sense (Geels, 2004). Instead of limiting the user side merely to a selection environment, the socio-technical systems approach places (new) technology in a context of societal functions (e.g. transport, communication, nutrition). Socio-technical systems are thus understood as the elements necessary to fulfill societal functions in relation to the production, distribution and use of technology. A strength of the socio-technical system framework lies with its ability to reconcile the structure-agency duality in transformative technological change. Long periods of relative stability and technology optimization are followed by relatively short periods of structural change and technological upheaval (Andersen and Tushman, 1990). In this process a paradigm shift takes place where existing structures are broken down and new ones emerge. Within the literature on socio-technical systems, the so-called *multi-level perspective* helps explain this dynamic process of change in a way that does justice not only to the structural inertia or sluggishness of technological change but also to the sudden discontinuities when radical novelty emerges. In offering a perspective that allows for 'small' activities to matter a lot in the face of 'large' challenges, such as climate change and resource scarcity, the approach embraces a tone of (technology-based) optimism and pragmatism.

Multi-level perspective to socio-technical systems: regime, niche and landscape

The multi-level perspective differentiates between landscapes, regimes and niches as three different levels through which transitions evolve. A central tenet in the framework concerns the stabilizing influence of a socio-technical regime on innovation dynamics and technological change. Here, a regime is defined as `the coherent complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, established user needs, regulatory requirements, institutions and infrastructures'' (Rip and Kemp, 1998, p. 338). The multi-level perspective conceptualizes sustainability transitions as regime shifts from existing unsustainable regimes (in e.g. energy, transport, housing, etc) to sustainable ones. Arguably the best-

known example of such a regime shift concerns the decarbonization of energy and transport systems in light of climate change (Verbong et al., 2008). By its very nature a regime seeks to retain its configuration, allowing only for incremental, path-following innovation that 'resists' the broad, transformative and structural change implied by a transition. Regime pressure or selection provides an explanatory framework for technological lock-in (Unruh, 2000) or the prevalence of sustaining innovation. Conversely it can be used to identify barriers to disruptive innovation (Christensen, 1997).

In contrast, the second level in the multi-level perspective, i.e. 'niches', acts as 'incubation spaces' for radical path-breaking innovation yet immersed in uncertainty and experimental disorder. These are "protected spaces in which actors learn about novel technologies and their uses" (Geels, 2002, p. 365) and that nurture novelty creation and protect radical innovations against mainstream market selection. Finally the landscape level represents the exogenous environment that influences both regimes and niches. In the literature, the landscape has been defined as a ". . . set of heterogeneous factors, such as oil prices, economic growth, wars, emigration, broad political coalitions, cultural and normative values, environmental problems." (Geels, 2002; p. 1260). The multi-level perspective has been criticized for some ambiguity in empirical studies with regard to the delineations of the three levels (Smith et al., 2005; Markard and Truffer, 2008; Genus and Coles, 2008) and for conflating the respective levels with alternative models of aggregation and geographical scales (Coenen et al., 2012). Nonetheless, its strength is that sustainability transitions can be explained by the interplay of stabilizing mechanisms at the regime level combined with the emergence of radical innovations at the niche level.

This particular feature fits very well with the challenges and opportunities for commercialization of clean technology in a combined micro (agency) and macro (structure) framework. In the following we will first review studies focused on the regime level to unpack specific barriers for the commercialization of cleantech. This is followed by an overview of insights following from studies on niche dynamics to identify drivers for breakthrough innovation in cleantech. These insights are subsequently merged into a framework that specifies barriers and drivers to commercialization of cleantech against the backdrop of an evolving sustainability transition over time. The rationale for doing so is that we argue that commercialization strategies need to take account of the particular stage of a transition pathway and the particular opportunities and challenges that follow from this for

an entrepreneur involved in commercializing cleantech.

Regime based barriers to commercializing clean technology innovations

For the purpose of identifying a number of potential regime-based barriers to commercializing cleantech, we identify the following factors (based on Kemp et al., 1998): (1) technology and infrastructure factors, (2) government policy and regulatory framework, (3) demand factors, (4) production factors, (5) undesirable societal and environmental effects of new technology. One of the hallmarks of the regime notion is that it emphasizes how different factors are interrelated and mutually reinforcing, thus strengthening its stabilization effects. But for explanatory purposes it makes sense to first disentangle the different factors and discuss their effects respectively.

Technological and infrastructure barriers concern the relatively sub-optimal performance of new technology in terms of user functionality as well as the need for facilitative, complementary technology or supporting infrastructure that perhaps is not available yet or expensive to use (Utterback, 1994). Often new technology does not diffuse into large scale application until a dominant design is established, allowing for economies of scale. A good example concerns the commercial introduction of electric vehicles (Cowan and Hulten, 1996) where ill-developed battery technology and uncertain and sceptical consumer behavior constitute critical bottlenecks in the competition with combustion-engine vehicles. A positive example how this barrier has been overcome is provided by the case of biofuels (bio-ethanol) in Sweden. An important disincentive for consumers to purchase more environmentally friendly flexi-fuel vehicles concerned the limited availability of biofuels at filling stations. Government regulation obliged filing stations over a certain size to include biofuel in their product portfolio after which the sales of flexi-fuel vehicles sharply increased (Hillman et al., 2008).

Also *government policy* may be a barrier in case it provides unclear or contradictory signals concerning the need for specific new technology. When there is no clear future vision that helps guide technology developers, entrepreneurs and investors this infringes on their innovation journey towards sustainable development (Negro et al., 2008). While the Dutch have had a rich tradition in windmill construction, the country belongs to one of the laggards in terms of wind power generation and industry development. Breukers and Wolsink (1997) point to

a highly volative public support for windpower as an important cause for this missed opportunity. Obviously, government policy can also facilitate the development of new technology when taking a future-oriented and more pro-active stance in terms of sustainable development (Porter and van der Linde, 1995) illustrated by the stringent recycling legislation in Germany, which has induced incumbent firms to develop less packaging-intensive products, which are both lower in cost and sought after in the marketplace.

In terms of *demand factors*, Kemp et al. (1998) refer to persistent values and attitudes among manufacturers and consumers that reinforce the familiar and eschew unfamiliar alternatives (e.g. resistance against car-sharing borne out of the value of individual freedom that supposedly comes with possession and use of a car). This relates also to *economic barriers on the demand side* vis-à-vis prospective users' preferences, risk aversion and willingness to pay for new technologies that have not proven what they are worth (Kemp et al., 1998).

Also on the *production* side, potential barriers exist. Sunk investments and existing competence in existing facilities may constitute an important impediment for firms to invest in setting up a technical and organizational production structure for a new technology from scratch. Industrial biotechnology is often mentioned as a promising technology to make chemical production processes more cost- and eco-efficient as it allows for use of green instead of fossil feedstock and direct production pathways of chemical substances instead of indirect, more polluting routes. However, most chemical firms remain wary of introducing this technology because of the formidable upfront costs involved in redesigning and re-engineering the production process.

Finally, it is possible that new, clean technology very well may solve certain environmental problems but at the same time give rise to new ones. Such backlash problems may frustrate the introduction of a new technology or in the worst case annihilate its chances for commercial success. The recent crops for food or fuel discussion serves as an example of this.

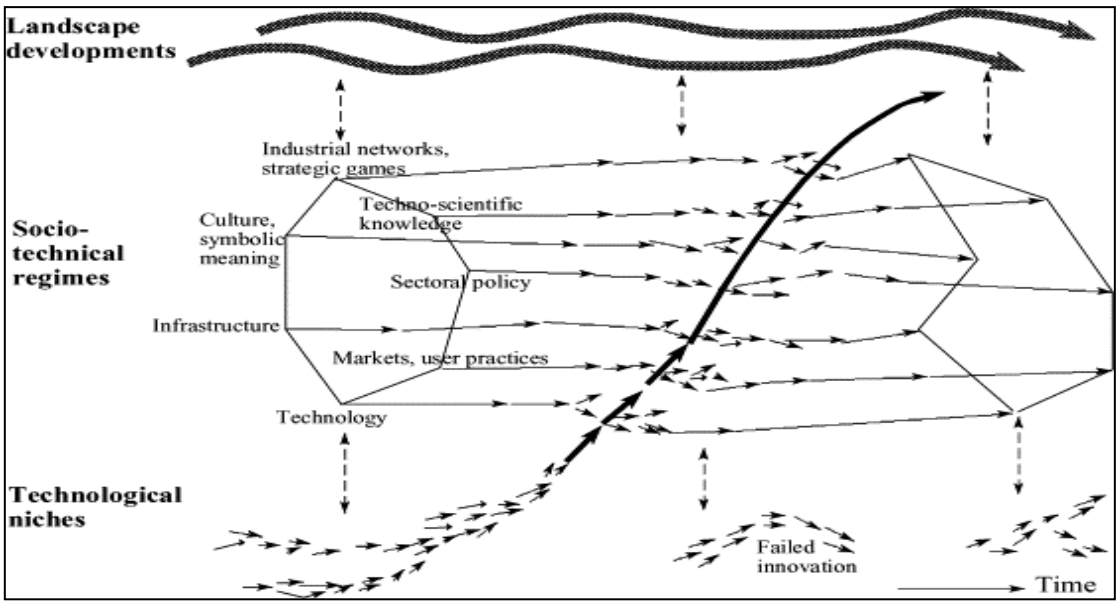
Role of niches to induce regime shift

Whereas regime level factors may be used to identify structural barriers to the commercialization of cleantech, the socio-technical transitions literature identifies niches as the key level where transformative change may take place. Raven (2005) makes a distinction between market and technological niches. Market niches can be seen as

new application domains, understood as selection environments that employ different selection criteria or have substantially different resources to deploy compared to mainstream markets (Levinthal, 1998). These differences may in turn give rise to the development of a new technology trajectory. Raven (2005) remains critical of the dominant focus on the demand side and, instead, conceptualizes niches as being situated between variation and selection environments, thus stressing the interplay between technology generation(s) and its application(s).

Niches are often created and nurtured in a purposeful manner in order to induce regime shift, referred to as strategic niche management. Kemp et al. (1998, p. 186) define it as "the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation", with the aim of learning about the desirability of the new technology and enhancing the further development and the rate of application of the new technology.

Figure 1 illustrates how regime-niche interaction shifts over time in the context of a sustainability transition and how this matters for commercialization strategies for cleantech. According to Geels (2002), a successful regime shift (to sustainability) through niche substitution takes the shape of an S-curve (see figure 1)



<Predevelopment> < take-off > < acceleration > < stabilization >

Figure 1. A model of technological shift: adapted from Geels (2002)

Over time, niche stability increases and creates sufficient momentum to compete and challenge the existing regime until ultimately the niche has transformed (made a transition) into a dominant regime. Drawing on Deuten (2003) and Rotmans et al., (2001), this process of emerging stability can be divided into different phases. At the initial, *predevelopment* phase, niche actors are largely disconnected and acting independent of one another. During *take-off*, ad-hoc network formation takes place facilitating interaction and exchange of expectations. However, actors still very much act independent of one another guided by individual expectations. Learning processes are primarily focused on technical issues and user dimensions. At the *acceleration* phase, social networks have established a critical mass in terms of size and density which enables group-think. Collective action becomes prevalent and group-based rules (institutions) are established. At this point, learning processes are primarily geared to government policy and regulation, industrial development and societal and environmental impact. Finally, during *stabilization*, the niche has evolved into a regime that consists of established networks, shared expectations and collectively endorsed institutions.

To summarize, the socio-technical transitions literature suggests that the introduction of radically new and green technology involves the built-up of a supporting socio-technical system of production, diffusion and use for clean technologies in the face of resistance and competition from non-sustainable alternatives (i.e. a socio-technical system). While this literature highlights the role of entrepreneurs as system builders, it remains silent on the entrepreneurial strategies that could support such a system built-up (Markard and Truffer, 2008). Instead, analytical focus is directed to processes of niche formation for radical new technology. The following section will review the literature on institutional entrepreneurship to accommodate for a micro-level perspective.

Entrepreneurial action and institutional structures

Recently, we have seen an emerging academic interest in the role of entrepreneurs and entrepreneurship in

sustainable development (e.g. Schaper, 2005; Cohen and Winn, 2007; Dean and McMullen, 2007; Wustenhagen et al. 2008 and the Journal of Organizational Change Management Special Issue on Environmental Entrepreneurship in 2008), focusing on such issues as the nature, motivations and strategies of sustainability-oriented entrepreneurs, as well as the context and framework conditions for sustainability-oriented entrepreneurship. A variety of concepts have been introduced that aim to describe sustainability-driven entrepreneurship and individuals engaging in this activity, such as "environmental entrepreneurs", "green entrepreneurs" and "eco-entrepreneurs". The exact definition varies between authors, but the common denominator is that these entrepreneurs conduct commercial activities that have an overall positive effect on the natural environment and the move towards a more sustainable future (Schaper, 2005). More specifically, we know from the history of technological change that entrepreneurs, next to researchers and engineers, play a central role in turning inventions into commercially successful innovations (Hughes, 1983). Entrepreneurs are, following Schumpeter (1934) considered to be a driving force for realizing fundamental change in society through "the process of creative destruction" which involves the discovery and exploitation of new combinations of technologies, products, markets, processes and organizational forms that create (revolutionary) changes in the economy.

Entrepreneurial young firms also have some important advantages compared to larger and more established firms, especially in a changing technological environment. They are considered to be more alert to recognize business opportunities that arise from market failures, one of such being environmental degradation (Dean and McMullen, 2007). They are also viewed as more capable to act upon these business opportunities than larger more established firms that frequently exhibit resistance to change, often as a result of hierarchical organizational structures, inertia and vested financial interests in current ways of doing things (Aldrich and Auster, 1986; Garud et al. 2007). On a more general level, young and small firms can more easily adapt to a changing (technological, market, political, etc.) environment than larger established firms (Aldrich and Ruef, 2006) and thus are more likely to be successful in turbulent environments. At the same time, we know little about how such entrepreneurial actions interplay with institutional structures and how these influence institutional change. These are questions that during the last couple of decades have started receiving academic

attention, notably with the emergence of institutional entrepreneurship literature. In the following we discuss the theory development relating entrepreneurial action to institutional level change and its limitations and present the collective action model as a stepping stone towards understanding the process of new technology commercialization.

Relating institutional change to entrepreneurial action – the institutional entrepreneurship literature

Our knowledge on the interaction between the individual/firm level on the one hand and the institutional/system level on the other hand has advanced significantly with the development of literature on institutional entrepreneurship. Literature on this topic has originated from institutional theory, which has mainly paid attention to the constraints imposed by institutions on the system in which actors operate. From the perspective of institutional theory, fixed institutions create stability and reduce uncertainty for actors in a system, which means that legitimacy is created by adhering to the institutional environment in terms of current practices, norms, standards, values etc. By using insights from stabilizing role of institutions, literature on institutional entrepreneurship aims to explain how organizations can take actions to shape, change or overthrow the institutions, despite pressure towards stasis. The so-called *institutional entrepreneurs* are seen as actors who can serve as catalysts for system change by taking the lead and giving direction for structural change in society. Thus, institutional entrepreneurs must both break the existing rules, practices and institutional logics and institutionalize the alternative rules, practices and logics they are championing (Garud and Karnoe, 2001). Institutional entrepreneurship framework has for example been applied to understanding the transformation of healthcare sector in the US during 1990s (Scott et al., 2000), global computer software industry in late 1990s (Garud et al., 2002) and professional business service market (Greenwood and Suddaby, 2006).

The usefulness of institutional entrepreneurship framework has however been limited by several important factors. Firstly, the applicability of concepts and theories originally used to explain the constraining influence of institutional structures on human behavior to explaining how individuals generate new institutions has in itself been questioned. At the heart of this criticism is what has been called the “paradox of embedded agency”. If, as institutional theory asserts, behavior is substantially shaped by taken-for-granted institutional prescriptions, how can actors envision and enact changes to the contexts in which they are embedded? A central weakness of

institutional theory for explaining institutional change driven by entrepreneurial action has therefore been its limited ability to adequately explain how and why actors shaped by (i.e., embedded within) institutional structures become motivated and enabled to promote change in those structures (Greenwood and Suddaby, 2006; Garud et al., 2007).

Secondly, institutional entrepreneurship framework is based on the assumption of entrepreneurs' ability to resist and neglect the pressure from current institutions in order to achieve institutional change, an action that requires a great extent of organizational power and legitimacy to be able to influence the system context and survive the negative influences. Young and small entrepreneurial firms are in this respect particularly disadvantaged, because of the liabilities of smallness and newness that they are facing. Entrepreneurs often lack financial resources, skills of owners and workers, organizational structure, legitimacy and established relationships with key stakeholders that they can leverage (Aldrich and Auster, 1986; Aldrich and Fiol, 1994). This means that entrepreneurs that challenge the status quo of the sector have to interact with extremely skeptical external resource holders (suppliers, creditors, customers, etc.), while competing with incumbent firms, that are committed to, invested in and advantaged by existing ways of doing things in a particular field (Landström, 2005; Garud et al., 2007). In other words, large companies or powerful networks of organizations will have a much better chance of achieving institutional change than smaller and younger companies. Not surprisingly, most of the empirical studies on institutional entrepreneurship to date have focused on large and established firms.

Additionally, studies that use institutional entrepreneurship as analytical framework tend to promote "heroic" models of actors that have been criticized as being "ahistorical, decontextualized and universalistic" (Garud et al. 2007:961). Moreover, by emphasizing the intentionality of action, these studies give little attention to unintended consequences of actions that are important components of institutional change. Increasingly, therefore, entrepreneurship scholars have argued that institutional change is not produced by an entrepreneur alone because they do not have the resources, power or legitimacy to produce industrial transformation and institutional change (Aldrich and Fiol, 1994; Van de Ven, 2005). Instead, entrepreneurs operate collectively in order to create the capacity to shape the system environment in a favorable form. Thus, the framework of collective action (e.g. Aldrich, 2006; Hargrave and Van de Ven, 2006), or what Van de Ven (2005) has referred to

as “running in packs” strategy, has become increasingly influential.

Collective action model of institutional change

The collective action perspective’s standpoint is that although entrepreneurial actions induce institutional level transformations, the latter are not a product of actions of a specific individual or organization. Rather it is a collective action by many people and organizations that jointly – in cooperation and competition – create conditions that transform institutions (Aldrich, 2010). In a similar vein, Van de Ven (2005) argues that entrepreneurs “run in packs”, which means that they simultaneously cooperate and compete, with others as they develop and commercialize their innovation. While entrepreneurs compete with their rivals for technological superiority, they at the same time cooperate with them to influence their institutional context and in standard setting activities.

Aldrich and Fiol (1994) describe the process of transforming of emerging technologies into new industries as a process of gaining *cognitive* and *socio-political legitimacy*. Cognitive legitimacy refers to the taken-for-granted assumption that an institutional change is desirable, proper and appropriate within a widely shared system of norms and values. Socio-political legitimacy consists of endorsements and the support of key constituents, such as financial investors, government officials, consumers and others who play key roles in developing and implementing an innovation (Hargarve and Van de Ven, 2006). This means that entrepreneurs have to strive to gain legitimacy with different groups of stakeholders to get access to resources, markets, etc. as well as to be perceived serious and trustworthy. For entrepreneurs within the cleantech sector this appears particularly important, because of the diverse set of involved stakeholders.

The primary concern of the collective action model of institutional innovation is how new institutional arrangements emerge from interactions among interdependent partisan agents. The collective action model “examines the construction of new institutions through the political behaviour of many actors who play diverse and partisan roles in the organizational field or network that emerges around a social movement or technological innovation” (Hargrave and Van de Ven, 2006:868). Collective action represents a dialectic model of change and focuses on how an established thesis (the established technology and the system around it) is confronted with an

anti-thesis (disruptive innovation) to lead to a synthesis, which becomes the thesis for the new dialectic cycle, i.e. the new status quo (Van de Ven and Poole, 1995).

As such, the collective action model has been very instrumental for our understanding of the complexity of institutional change, particularly by uncovering the multifaceted micro-level processes and bringing attention to the role of conflict, power and political behavior in institutional transformation processes. The collective action approach is today one of the dominant models for understanding technological change and new industry formation and has paved the way for further theoretical development within the field of innovation and science and technology studies (e.g. Bergek et al., 2008). At the same time, this perspective has been lacking some of the conceptual precision and concrete analytical tools, especially with regards to explaining the system-level dynamics (Hargarve and Van de Ven, 2006).

In a way of summarizing, we argue that these two literature streams can be integrated, or at least cross-fertilized, in order to shed more light on the process and outcomes of commercialization of clean technology innovations. Looking at the recent developments in the research field, two approaches seem to be particularly fruitful. One is incorporating the transition *process* perspective in the institutional entrepreneurship model in to enhance the understanding of the system-level shift. More specifically, this implies putting entrepreneurial action in the context of the specific phase of socio-technical transition that the technological field is in (cf. Alkemade et al., 2011). Another approach is to deepen understanding of micro-level processes and the outcomes that these subsequently generate by explicitly incorporating the *strategies* of entrepreneurs (and incumbents) into the sustainability transition model (Parrish and Foxon, 2009; Smink et al., 2011). The next section provides an example of technological change that illustrates the need for such knowledge development.

Discussion and conclusion

In this chapter we have argued that the commercialization process of cleantech needs to take account of an agency-structure duality. On the one hand, entrepreneurs are embedded in institutional and organizational contexts that enable and constrain their actions while, on the other hand, they need to mindfully diverge from certain rules and structures in order to create and realize the opportunities that cleantech may offer. We have

reviewed two streams of literature that both aim to conceptualize this process: (institutional) entrepreneurship/collective action literature and socio-technical sustainability transitions literature. It follows from both literatures that one-dimensional technology-based commercialization processes fails to account for the structural barriers that clean technology faces and runs the risk of creating heroic accounts of voluntaristic action. Moreover, such straightforward commercialization strategies often neglect the wider entrepreneurial strategies that are adopted by entrepreneurs to forge change in the area of clean technologies.

Adopting a top-down perspective, the transitions literature points to a structural 'resistence to change' that prevailing regimes in socio-technical systems create. Entrepreneurs involved in the commercialization of clean technology thus encounter an uneven playing field. The incumbents with whom they need to compete benefit from being embedded in a more matured and structurized socio-technical system. Incumbent technologies may thus profit from standardization, economies of scale, conducive regulatory frameworks, habitual consumer behaviour, sunk investment, accumulated skills and competences, etc. According to the transitions approach, these barriers act in a mutually reinforcing way, allowing for systemic lock-in and path-dependency in existing technological fields. This means that emerging clean technologies often face a number of these difficulties simultaneously, which in turn create considerable barriers to entry for newcomers and entrepreneurs. Similarly, the literature on institutional entrepreneurship emphasizes the resistance to (disruptive) change found in existing institutional structures when radical innovations are introduced. Here, a similar logic can be found in the sense that the individual entrepreneur struggles against systemic 'liability to newness'. While such liabilities may be unpacked into specific barriers such as lacking skills, inappropriate organizational structures or sceptical stakeholders, entrepreneurs often encounter these barriers as an ensemble rather than singularly.

This may explain why only few of the technological innovations that are taken to the market ultimately are adapted and achieve broad commercial success. Commercialization strategies need to take account of the particular stage of a transition pathway and the particular opportunities and challenges that follow from this for an entrepreneur involved in commercializing technology-based innovations. The appropriate commercialization strategies for the firms will differ depending on the stage of the transition that the system is at in terms of for instance the state of public awareness and attitudes, governmental regulations, consumer behavior, etc. When it

comes to the development of clean technology sector, this is especially relevant to consider because of the different stages of development that different parts of sector is in; while some have already started to consolidate, such as wind turbine manufacturing industry, many others are still characterized by a high degree of experimentation and new entries (Wüstenhagen et al., 2008).

Instead of a simple technology commercialization strategy, the commercialization of clean technology needs to take account of the institutional work needed to re-write the rules of the game. In order to succeed in bringing a clean technology to the market, entrepreneurs need to work actively in changing the systemic context in which their technology is embedded. This may seem a paradoxical and daunting task, especially when entrepreneurship is seen as an activity carried out single-handedly by individuals. As such, it points to the need for collective action by and among entrepreneurs and in co-operation with other stakeholders. At this point, the reviewed literatures seem to take different positions with regard to how such collective action is conceptualized. While the transition literature primarily deals with the context conditions in which collective action takes place, the literature on institutional entrepreneurship is more geared to the processes by which entrepreneurs forge change. In doing so, the literatures hold potential to complement each other.

Transitions literature suggests that transformative change originates from niches that act as protective spaces for emergent technologies to mature up to a point when they are able to compete with incumbent technologies in a competitive market environment. In other words, the niche environment provides an alternative context, counter to that of a regime in a socio-technical system, which allows for stakeholders, including cleantech entrepreneurs, to engage in experimentation and learning processes that should ultimately facilitate the emergent technology to become competitive with incumbent technologies. In concrete terms this suggests that the commercialization of clean technologies can be seen as entrepreneurial experimentation carried out in heterogeneous learning networks of actors which have different knowledge, capabilities, resources and expectations. These networks include entrepreneurs, producers, users, regulators, societal groups, etc. Protection of experiments is however crucial in light of the immature / embryonic state of the socio-technical configuration. Such protection could be arranged through policy support (subsidies) or by cooperating with resourceful ‘user’ stakeholders. The field of clean technology provides many examples of this, e.g. the use of

alternative fuels and/or vehicles in municipal car fleets, the introduction of photovoltaic solar cells in space applications or living-lab, demonstration sites for sustainable urban development and housing.

Dependent on the level of maturity of the technology, the rationale to such experiments may be to discover of user preferences, to raise public, industrial and policy awareness and stimulate debate, promote the adoption of the technology in new markets, etc. The niche environment is conducive to such processes because the institutional and organizational environment is (still) loosely configured and articulated. Counter to the more hostile regime environment, it allows for immature technologies to exist and to evolve through social learning. Here, user-producer learning should be particularly emphasized. Users have to integrate new technologies in their practices, organizations and routines. This requires alignment and adjustment from both sides. As Geels (2004, p. 902) puts it, "new technologies need to be 'tamed' to fit in concrete routines and application contexts (including existing artefacts). Such domestication involves symbolic work, practical work, in which users integrate the artefact in their user practices, and cognitive work, which includes learning about the artefact". In sum, the niche and regime concepts help us to analyse how context matters for the commercialization of cleantech, avoiding heroic and voluntaristic accounts that studies of institutional entrepreneurship have been criticized of. At the same time, the behaviour of individuals and organizations often remains black-boxed in analyses of niche experiments. In other words, there is a lack of attention for the micro-foundations of transitions that yield agency to forge change (see also Farla et al, 2012). It is at the level of micro-foundations that institutional entrepreneurship may complement transitions literature.

To understand and explain commercialization processes in cleantech, the role of the actions and relationships of single individuals and organizations in a systemic context need to be more closely examined. So far, in transition studies entrepreneurs are seen as components of a system rather than purposive and mindful agents. How and why entrepreneurs become purposive, motivated and enabled to promote systemic change has remained largely unaddressed. Their presence, emergence but also disappearance has been assumed rather than explained. Instead of focusing on the individual attributes of entrepreneurs, the institutional entrepreneurship literature allows us to look at these processes as a two-way process between intention and emergence, or agency and structure. This reconceptualises entrepreneurs in cleantech as reflective change agents who push for change but

at the same time adapt to changes in their environment. This opens up for an appreciation and realization that entrepreneurship is not just about 'taking a technology to the market' but rather about generating and sustaining collective learning processes (Sotarauta and Pulkkinen, 2011). As such, considering institutional entrepreneurship in a context of niche experimentation provides a framework that allows us to analyse how agency and structure interplay in the process of commercializing cleantech.

This opens up a number of questions that could be of interest for future research. The first set of questions is about who the entrepreneurs in cleantech really are? Instead of preselecting the actors according to their formal position, our conceptualization would call for a search on the basis of process. It would allow identifying entrepreneurs not just in the private domain but also in the public sector or civil society. Moreover it would allow for the possibility to consider cleantech commercialization as a multi-actor phenomenon that unfolds like a relay where not a single actor is in charge from 'day one' to the end (Sotarauta and Pulkkinen, 2011). The second set of questions relates to the environments in which commercialization of cleantech takes place and how these environments may help but also hinder entrepreneurs to emerge, operate and learn their skills. Ultimately, to repeat and conclude, it is in the interplay between mindful agents and structuring contexts that commercialization processes take place, operating in between macro and micro issues.

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