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Exaptation as source of creativity and innovation

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Abstract: *In this paper we investigate exaptation as source of creativity and innovation. This term addresses natural features that enhance fitness, but were not built up by natural selection for that purpose. In the management literature this term has been used to address the exploitation of an existing body of knowledge to enter an emerging technological trajectory and gain a competitive advantage in a relative industry. So far, however, little attention has been devoted to the evolutionary dynamics underling and generated by this process. Therefore, in this paper we deepen our understanding of those aspects. Our main contribution is to highlight the discontinuous nature of those changes. Exaptation, differently from adaptations, are not selected for their contribution to the optimization of an existing function, but for their availability to perform an emerging function. Therefore, exaptations are not selected, but select and contribute to build up the environment valorising their potential.*

Introduction

In this paper we investigate exaptation as source of creativity and innovation. This term is used in natural sciences to address features enhancing fitness, but were not build up by natural selection for that purpose (Gould & Vrba 1982; Vrba & Gould 1986). In the management literature the same term has been used to address the exploitation of an existing body of knowledge to a gain a competitive advantage in an emerging industry(Joel Mokyr 2000; J. Mokyr 2002; Cattani 2005; Cattani 2006; Dew et al. 2004; Furnari S.d.; Andriani & Cohen 2005; Villani et al. 2007; Villani et al. 2009). However, little attention, so far, have been devoted to the underling dynamics characterizing this process. Our contribution, therefore, is to show how exaptations are developed and evolved overtime, and which are the main implications for the strategic management of innovation.

In order to achieve this objective we review Gould and Vrba's most relevant contributions (Gould 1982; Gould & Vrba 1982; Vrba & Gould 1986). As consequence of this work of review three aspects are highlighted. First, not all exaptations have been shaped by natural selection before being co-opted to their present function. Therefore, selection is not the only driver of evolution. Second, exaptations are not selected for their contribution to the optimization of an existing function, but for their availability to perform a contingent function. Therefore, these features are not selected, but contribute actively to the construction of a niche in which the role of those features is valorised. Third, exaptations are source of discontinuous change. These features, changing the morphology and the boundaries of a context, are generative of other changes and innovations.

The complex nature of exaptation has led us to analyze some of the basic assumptions underlying the evolutionary theory of the firm. We focus on three major issues. The first is whether we understand evolution as adaptive. The second is whether we understand evolution as gradual. The third how we understand exaptation. We suggest that in the management

literature evolution is perceived as adaptive. However, evolution is not understood as gradual, but punctuated by relative short period of radical change. There is less agreement on the reason underlying the emergence of these changes. Contributions can be roughly separated into two categories. On the one hand, there are contributions in which radical change is seen as consequence of scientific breakthroughs(e.g. Tushman & Anderson 1986; Tushman & Romanelli 1985). Therefore, it is treated as an exogenous variable. In other contributions radical change is seen as the emergent outcome of the interaction between science-institution and market (e.g. Dosi 1982). Therefore, it is treated as an endogenous variable.

Finally, we analyze the concept of exaptation. There are not yet many contributions focusing specifically on this issue. However, it has already emerged the controversy between who defines these competencies as pre-adaptations and who define them as exaptations(Dew 2007; Cattani 2008). This is an old controversy in evolutionary biology, which hides a different way of seeing evolution. These positions, according to our perspective, are reflected into a different way of looking at technological radical change. On the one hand, who prefers the term pre-adaptation tends to see evolution as mainly adaptive and driven by selection. Therefore, radical change is seen as mainly consequence of scientific breakthroughs. Differently, who uses the term exaptation tends to endogenize the source of radical change and focus more on the internal source of variation.

This work, according to our perspective, offers two main contributions. The first is to extend our understanding of the concept of exaptation. The major argument here is that the role of exaptation cannot be understood outside of a specific way of looking at evolution. That is a way that explain evolution as emerging from the interaction between multiple Darwinian evolutionary entities. The second contribution is a first attempt to link the elements of a theory of evolutionary change based on the concept of exaptations. From this perspective, we highlight two major aspects that have received little attention, but the concept of exaptation

emphasizes. The first is the issue of selection. The way the production of knowledge is stimulated is relevant for the variety of the knowledge available and indeed the extension of the exaptable pool. This is relevant both at the level of innovation system and firm. The second is the issue of knowledge organization and availability. The production of an exaptation requires linking an existing body of knowledge to a possible new application. The emergence of this link requires a close interaction between producer and user of that knowledge. The current model of knowledge protection reduce the intensity of this cooperation. The case of open source software is indeed suggested as possible solution to enhance the probability of exaptation.

Exaptation: What does it mean?

The term exaptation has been coined by Gould and Vrba to indicate features that enhance fitness, but were not built by natural selection for that purpose(Gould & Vrba 1982). This term has been proposed as an alternative to the concept of pre-adaptation. This term has been originally proposed by Darwin to explain how nature builds up complex structures. The problem with this type of structures is that are made of interacting parts. According to Darwin, nature select features for their contribution to fitness. However, none of these parts contributes directly to fitness, but indirectly by the means of the others. Therefore, how did it come these parts have been selected and developed? According to Darwin, there have been pre-adapted by a previous function and successively co-opted to their present one.

Explaining the evolution of complex structure is a critical issue in the theory of evolution. According to Creationist, in fact, these structures proofs the existence of a predetermined design within which natural selection works. Selection is the mean through which nature discover its final destiny. However, Gould and Vrba's argument is different. Their objective is not to proof the existence of God. Their objective is to show that adaptation

is not the only mechanism through which nature evolves and to show how its role is complemented by the one of exaptation.

The term pre-adaptation, according to Gould and Vrba, has two major limits. First, it assumes that all exaptations are adaptations to a previous function. However, there are strong evidences showing that not all exaptation are adaptive. Therefore, there are features that contribute to enhance fitness, but were not originally shaped by natural selection. The existence of these features is commonly accepted even by Darwinist. However, according to their perspective, these events/features are rare and their role is of little significance to explain evolution.

Second and most important, the use of the term pre-adaptation, according to Gould and Vrba, hides the discontinuous nature of these features. Their development, independently from their origin, has not been always shaped by the same set of forces, but punctuated by one or more shift/s in the function performed. Therefore, there was a time when these features were not selected for their improvement to an exiting function, but for their availability to perform a novel and emerging function. Thus, the function did not pre-exist to the feature that is selected, but, conversely, the existence of that feature has shed light and made possible to take/select an opportunity. The term exaptation emphasize this difference by pointing out that exaptations were fit (*aptus*) by reason of (*ex*) their form and not their function.

The introduction of the term exaptation has encountered much resistance not so much for its meaning, but for its implications. The introduction of this term, in fact, questions the gradual nature of change and the role of selection. Evolution, according to Darwin, is driven by the accumulation of relative small changes that are positively selected for their contribution to fitness. Conversely, according to Gould (e.g. Gould 1982), evolution is characterized by the coexistence of long period of stability and adaptive change and relative short period of instability and radical change.

Gradualism, in Darwin's theory of evolution, is a postulate of the thesis according which selection rather than variation drives evolution (Gould 1982). This is not anymore true if the magnitude of a variation is enough for being responsible for a change in the evolution proces. However, this requirement, according to Gould, is consequence of a specific way of understanding and conceptualizing evolution. That is selection and indeed evolution is driven by the struggle for life. Therefore, it is selected the genetic code of those individuals that are better fitted to survive in a given environment.

Conversely, according to Gould, selection does not only select individuals, but species, ecosystems and so forth. These are all Darwinian individuals. They are born, die and reproduce themselves. Evolution is indeed the emergent result of the interaction between these individuals/dimensions. This way of looking at evolution, according to Gould, presents some advantage. It enable us to explain stability as consequence of the prevalence of negative feedback between dimensions. For instance, the large size of a population tends to inhibit the diffusion of changes. This is because it is very unlikely that holders of the same successful variation reproduce with each other. Therefore, the reproductive process converges toward a common average. But it enables us, for the same reason, to explain rapid and radical change. This is stimulated by the prevalence of positive feedback between dimensions. In a population of small size, for instance, parents' features have greater chance to determine children's. Furthermore, the consequences of random events play a more relevant role in determining the future structure of the population. It enables us to explain also hyper-specialization and rapid extinction as the effect of lock-in between levels. Individuals are too adapted to their environment to survive even to a small change. Therefore, according to this perspective, nature does not select the most adapted individuals, but the species and the populations that are more capable to change.

In this framework, exaptation and adaptation play a complementary role(Gould 1982). Exaptations define the trajectories along which selection and adaptation work. Therefore, selection selects the change that are compatible with a given evolutionary trajectory. Exaptations and indeed non adaptive changes set up the ground on which a trajectory is set up and developed. This way of looking at evolution calls for a rebalance between internal sources and external sources of evolution. Evolution is not anymore driven by the selection of features that are better adapted to perform a role, but also by a reserve of features, such as genetic drifts, that are available to perform novel role and functions to respond to emergent and rapid changes. Therefore, the concept of exaptation calls for the need to better understand how non adaptive changes are reproduced and accumulated.

Is our theory of evolution adaptive?

One of the main reason why Gould and Vrba introduced the notion of exaptation is to highlight the fact that adaptation is not the only mechanism through which nature evolves. Therefore, the first question we need to answer in order to understand the possible implication of this concept in the managerial literature is whether or not we conceptualize evolution as an adaptive process.

In order to answer to this question we need to retrace briefly the key elements of an evolutionary theory of the firm (R. R Nelson & Winter 2002; R.N. Nelson S.d.; D.A. Levinthal 2007). This perspective, as know, is in contraposition with a rationalistic perspective of the firm. According to this latest one firms are rational agents. Therefore, they are capable of fully forecasting the future and behave accordingly. Evolutionary theory, conversely, is grounded on the observation that firms are not as rational as it is hypothesized, but bounded in the capacity of evaluating the alternatives available and the consequences of their behaviour (e.g. Simon 1976). Therefore, the question is how do firms do what they do?

The answer to this question lies, according to evolutionists, in the concept of routines(R. R Nelson & Winter 1982).

Routines are institutionalized pattern of activities build up on the experience a firm has accumulated overtime. Therefore, according to this definition, routines are based on experience. This implies that a large part of the knowledge these routines are based on is tacit (NONAKA & TAKEUCHI 1995). Managers, therefore, are not fully conscious of the reasons why these routines work. Consequently, they do not hold full control on their functionality nor on the relative resources. Furthermore and most important, managers do not hold full control on how these routines may be changed in order to achieve an expected goal. The reasons are mainly two. First, these routines make managers blind to change. Second, even if change is perceived, managers may not hold the capacity and the power to change these routines accordingly.

The set of organizational routines is, therefore, the genetic code of a firm (R. R Nelson & Winter 1982). It defines the repertory of reproducible behaviors a firm can enact. It is a repository of successful solutions/variations to contingent problems arising from the failure of existing routines to provide satisfactory results. The search for a solution to these problems is local and path dependent (e.g. Levinthal & March 1993). It is conditioned by the past choices of this company. However, local searching and path dependency is only partially consequence of sunk costs. Mostly, these are the consequence of the incapacity of this firm to look for solutions outside of the cognitive space defined by the set of competencies a company already holds(Tripsas & Gavetti 2000). Consequently, this searching process is based on trials and errors. The process of searching a solution ends when a satisfactory solution is found. The solutions tried are indeed blind to their ultimate fate. It is market competition that selects the best solution/variation available.

Thus, returning back to the initial question, is the evolutionary theory of the firm adaptive? Our answer to this question is affirmative. Searching, in fact, is both blind and local. Furthermore, it is driven by contextual factors. Therefore, evolution is selection driven. It is the market that selects the variations better fitted to compete in a give environment. However, it is worth noticing that, despite of the great relevance placed on this issue, the concept of selection has received, with few exception, only little attention in the economic literature (D.A. Levinthal 2007).

Is evolution conceptualized as gradual?

A second issue raised by the concept of exaptation is the nature of evolution. Darwinist see evolution as gradual. It is the emergent result of the long term accumulation of small changes. Gould, differently, see evolution as characterized by long-term period of stability and gradual change punctuated by relative short periods of instability and rapid change. The two perspectives, according to Gould, are not incompatible. The first, in fact, is based on a unidimensional view of selection and evolution. The second, differently, is based on a multidimensional view of evolution. In the second discontinuity emerges from the interplay between different evolutionary Darwinian individuals. The objective of this section indeed is to understand how economists understand evolution. Is it addressed as gradual or punctuated? If it is punctuated, how the emergence of a new trajectory is it explained ?

In the literature, according to our perspective, there is large agreement on the fact that evolution is punctuated by period of rapid change. Abernathy and Utterback (1975) characterize the evolution of an industry distinguishing between two phases. In a first phase competition takes place between alternative and incompatible designs. This phase is triggered off by a discontinuous change, which establish either a new cluster of activities or a completely new way of doing things in an existing cluster of activities. This phase last until a dominant design is selected. That is a common set of components and rules to integrate those

components (architecture) is selected. Once a common design is selected, competition shifts from product-based to process-based. Therefore, from the establishment of an architecture to the improvement of its performance.

Dosi(1982), in a similar vein, distinguishes between technological paradigms and technological trajectories. His theory is based Kuhn's (1962). Therefore, a paradigm is defined as a model/pattern of solution of selected (technological) problems, based on selected principles, methodologies and tools. A technological trajectory is indeed defined as the pattern of normal problem solving activities on the ground of a technological paradigm. Therefore, the main function of a technological paradigm is to define the direction of progress firms should follow.

There is less agreement, however, on the way the transition from a paradigm to another takes place. Dosi, for instance, suggests that theories of technical change can be broadly divided into two categories: demand-pull versus technology-push. In demand-pull theories innovation is explained as consequence of market forces. In technology-push theories, conversely, innovations is driven by scientific advancement. Both perspectives, according to Dosi, do not recognize the role played by the institutional context, such as sunk costs and public R&D policy, in mediating the interaction between these two functions. Market signals, according to Dosi, are efficient only once a trajectory is established. However, which trajectory is selected depend on the institutional context.

Others, differently, explains the rise of a new trajectory as consequence of be positioned a specific niche market niche. Christensen and Rosenbloom (1995) define a disruptive technology as one that is grown up in a specific value network and invades an incumbent industry. Consumers' expectations toward the performance of a technology grow with a much lower pace with respect to the technology itself. Therefore, companies that have invested on the development of the same technology, but focusing on specific needs, may

exploit that mismatch to enter the mass market and displace incumbents. Levinthal(1998), in a similar vain, show the evolution of a technology is punctuated by rapid period of radical change triggered off by the speciation of an existing body of knowledge. He draws on Eldredge and Gould's (1972) punctuated theory to suggest how rapid and radical change is triggered off by small changes. In this framework speciation is the process through which the development of a knowledge is leveraged by its being incubated into a separated and specific niche. The acceleration of the evolutionary process is drawn by the availability of more resources and the specificity of the selection function. However, both these theories do not explain how these specific niche are emerged. Therefore, both ends up by highlight the role market selection is promoting radical change.

How do we understand exaptation?

There are not yet many contributions addressing the issue of exaptation in the management literature. This term has been imported by Mokyr (Mokyr 2000) to highlight the fact that there are a large number of technologies that are selected for a trait, but owe their later success to a related, but different, one which, for some reason, they also happen to possess. Furthermore, all these contributions focus on exaptations as technological features. There are, however, three contributions in which the issue of exaptation has been investigated deeply. Those are Dew et.al (2004) and Cattani (2005; 2006). It is worth noticing that Cattani refers to these features in term of pre-adaptation rather than exaptation. This choice has motivated Dew (2007) to write a notice in which he criticizes Cattani for this choice. The terms of this controversy are going to be reviewed in the last part of the section in order to make emerge the limits of our way of understanding evolution.

The contribution of Dew et.al. is mainly theoretical. It achieves three main results.

The first is to better define the concept of exaptation by pointing out what are not exaptations. Exaptations are not externalities. They do not involve any interdependence between activities in a given period of time. Exaptations are not creative combinations. A creative combination results from combining two existing bodies of knowledge/technologies. Exaptations, differently, are creative applications of an existing bodies of knowledge in a related, but different, field. Third, exaptations are not unintended consequences. Exaptations, differently from unintended consequences, requires someone leveraging on an existing body of knowledge in order to exploit its potential in a related application field. Therefore, it requires someone playing the entrepreneurial role of linking a given body of knowledge to a new field.

A second contribution is a categorization of the forms of exaptations. Those are two. The first are pre-adaptations to a precedent function. Therefore, these features were selected for their contribution to a precedent function and then co-opted to their present one. The second includes features that were selected in as part of a bundle. Therefore, their effect on the performance could be either null or negative. In this second case, however, these features have been included because the advantage of that knowledge are more than the disadvantages produced by that specific feature.

The third an most important contribution is to highlight exaptation as endogenous source of entrepreneurship. Entrepreneurship is often seen as an adaptive process. The competitive advantage of an entrepreneur is to perceive a potential market/application for a technology before then others. Therefore, it is that perception shaping the way a technological opportunity is exploited. Exaptation, according to Dew et. al., might be the base for an alternative theory of entrepreneurship. It is not anymore required an external force. Entrepreneurship may be a self-enforcing process driven by the attempt to exploit the

potential of an existing technology in new markets. Therefore, it is not anymore the market that pre-exits to an innovation, but the technology that pre-exists to the market.

Cattani, according to our perspective, makes two contributions. The first is to show how existing competencies may be exploited to entry and gain a competitive advantage in a emerging industry. Cattani distinguishes between two phases of an exaptation process. In a first phase – pre-adaptation – knowledge and skills are accumulated without any anticipation of their future use. In the second phase – that we could call exaptation - firms leverage on this existing body of knowledge to gain a technological advantage in the new industry. Cattani distinguishes between these two phase because he wants to clearly separate between the role of lack and the one foresight in the process of exapting a set of pre-existing competencies to a new use.

A second contribution is to link pre-adaptation and speciation. The theory of speciation, as we have already seen, highlights the role played by the specificity of an emerging field in leveraging the development of an existing body of competencies. However, in these studies it is not entirely clear to which extent it is the environment that selects those firms whose skills and knowledge randomly match the requirements of a new domain or, conversely, firms enter that domain because they anticipate which skills and knowledge will be needed. Cattani's analysis shows that firms are pre-adapted to see and build up that opportunity and are not selected by an existing opportunity.

Cattani's choice to use the term pre-adaptation rather than exaptation has been criticized by Dew for two reasons. The first is that pre-adaptation, as suggested by Gould and Vrba, suggests the existence of some foresight in the development and accumulation of that knowledge. It seems to imply that the exapted knowledge has been developed and accumulated in the anticipation of its future use. However, as also recognized by Dew, Cattani has been explicit in excluding this option. The second is that exaptation points to the

process of shifting in the function performed rather than the adaptive origin of that knowledge. It highlights the discontinuity that is implicit in this process. The fact that a piece of knowledge have not been selected for its efficiency, but for its availability. Therefore, as we shall argue later on, this choice is going to condition heavily the development trajectory selected. Furthermore, the use of the term pre-adaptation assumes that all exapted bodies of knowledge have been pre-adapted to their present function by a previous one. Therefore, it excludes all kinds of knowledge that have been produced for some reason, but have never been applied.

Cattani, in a successive note, defends his choice by using two arguments. The first is that his study addresses a case of pre-adaptation. The body of knowledge that Corning has exapted to enhance the development of fiber optics cables had been pre-adapted by a precedent application in the filed of special glass manufacturing. The second is to question whether exaptation is a better term than pre-adaptation. The reasons are mainly two. The first is that exaptation encompasses both adaptations and non-adaptations. Therefore, one is left with the challenging task of defining which of the two situation are recurring. This task is defined as challenging because depending on when the cooption of a trait is situated in time that trait is an instance of exaptation with adaptive or non adaptive origin. However, according to our perspective, the term pre-adaptation, for the same reason, presumes the adaptive nature of knowledge. It assumes that any piece of knowledge available has been consciously build up for a reason. Therefore, there is not something as tacit knowledge. Knowledge becomes tacit, but is not born tacit. The second reason is that, according to Cattani, the term pre-adaptation better convey the idea that technologies and competencies cannot be clearly seen as the result of foresight. However, which term better than exaptation highlights the role of chance in giving shape to evolution.

This controversy, according to our perspective, highlights the limitation of importing a term from another filed of study without paying attention to the context in which that term makes sense. Goud and Vrba's objective is not to criticize a term, but a way of looking at evolution. A perspective that is based on the idea that evolution is a cumulative and adaptive process driven by selection. Exaptation, in this perspective, is a "tool" to show how creativity cannot be reduced to a single force. Exaptation is a complementary source of creativity. It establishes the ground for the development of new trajectories in which selection operates as optimizing force. Therefore, exaptations, differently from adaptations, play a creative role. These features are not simply selected to enhance effectiveness, but to establish new opportunities of development. However, exaptation makes sense if and only if we accept a multidimensional view of evolution. Therefore, if we accept that markets and institutions are evolutionary entities and do not pre-exists to a change.

Toward a theory of exaptation as source of creativity

The objective of this paper has been to investigate exaptation as source of creativity. This objective has led us to review Gould and Vrba's seminal contributions on this issue. This work of review has highlighted that is not sufficient to look at the concept of exaptation to understand its meaning. The concept of exaptation is part of a large theory that explains evolution as punctuated by relative short periods of radical change during which a new state of equilibrium emerges. These relative short periods of revolutionary changes are not triggered off by macro changes, which requires the existence of an external force capable to foresee the future. These revolutions are triggered off by relative small changes supported by the effect of positive externalities and increasing returns. Therefore, these small variations

have a disproportional relevance in the configuration of a new and emergent state of equilibrium.

Is this perspective of evolution compatible with ours? Our answer to this question is affirmative. Most of the elements of this theory are already in place. However, these are not yet integrated in a comprehensive complex theory of evolution.

First, the relevance of network externalities and increasing returns for the evolution of industries/markets and the dynamics of firms' competitive advantage has been largely recognized and analyzed in depth(Arthur 1994; P. A David 1985). These effects have been recognized as relevant for the emergence of standards, dominant designs and technological and institutional paradigms. Furthermore, it has been shown how the emergence of these platforms/contexts is often influenced by relative small events triggering off an enormous catalyst power in the network. Therefore, these network effects often prevent markets from selecting the best solutions available and are responsible for the emergence of lock-in situation. Finally, it also implies that evolution is both path-dependent and self-propelling. Therefore, what is selected in t_0 is relevant to establish what will be selected in t_1.

Second, it has been recognized the interdependence between science-institution and market in driving the emergence of technological paradigm and the direction of evolution (e.g. Dosi 1982). Therefore, according to this perspective, market selection works efficiently only within an established trajectory. However, the selection of a paradigm is a more complex matter. The reasons are mainly two. First, it is impossible, ex-ante, to establish which is the most efficient paradigm/solution. There is not a common standard to evaluate the contribution of each paradigm to growth and development. Each paradigm has its own advantages and disadvantages. It is impossible to forecast all the possible future states the selection of a specific paradigm will generate. Furthermore, this evaluation and the probability for a

solution to be selected is strongly conditioned by the initial state. That is from the sunk cost a society has accumulated over time.

Third, there are endogenous theory of radical change (Dosi 1982; Adner & D. A Levinthal 2002; D. A Levinthal 1998; Christensen & Rosenbloom 1995). The concepts of speciation and disruption explain that emerging trajectories are not consequence of scientific breakthroughs, but incubated in relative small and specific niches. The theory of exaptation, on the other hand, suggest that the emergence of these new trajectories is complemented by existing bodies of knowledge accumulated without any anticipation of their future applications. Furthermore, Mokyr (2002) in his recent book titled "The gifts of Athena: historical origins of the knowledge economy" shows that scientific breakthroughs have to be complemented by a network of small changes in order to emerge into a new paradigm.

However, all these concepts are not yet fully integrated into a larger and endogenous view of evolution.

What does the concept of exaptation adds to this picture? It highlights the role and the relevance of historical chances and contingencies in giving shape to the evolutionary process. However, according to our perspective, this has been already pointed out by concepts such as network externalities and path depends. We believe, differently, that the concept of exaptation is a useful to read the role and dynamics of historical chances and contingencies in those network. However, the objective is not to improve our ability to forecast these events or control their consequences, but enhance the probability with which they occur and the ability to canalize and exploit their effects. Therefore, according to our perspective, the concept of exaptations is useful if it enables us to improve our understanding on how building exaptive contexts. That is contexts that are capable to enhance their capacity to leverage and exploit existing knowledge for different purposes.

In this perspective, there are two aspects the concept of exaptation sheds light on: the relevance of the selection function and of knowledge availability. As far as the first issue is concerned there two most important aspects to be addressed.

The first is about the relationship between science and technology. The question, from this perspective, is how much scientific development should be driven by its immediate applicability(Foray David 1995). The system of incentives in place seems to push toward an immediate applicability of scientific principles. Therefore, toward a growing market influence in selecting development trajectories. This push toward a more integration between science and market if, on the one hand, it might guarantee a more rapid growth in the short time, on the other, it may reduce the number of future development alternatives available. A strong market orientation, in fact, may end up into a limited pool of exaptable knowledge. For instance, to which extent, in the current transition toward a green economy, an excessive market orientation is responsible for the lack of exaptable know-how on this matter and indeed the long time required to accomplish this transition.

The second issue is about the way development trajectories are selected within the firms. Cattani's work clearly show that being pre-adapted to a development trajectory may be a source of competitive advantage in the exploitation of that trajectory. However, Cattani focuses on the factors that define the capacity of a firm to exploit this potential advantage. He had devoted almost no attention to the factors enhancing the probability for a firm to enjoy a pre-adaptation advantage. In this perspective, therefore, it would be useful to understand if there are firms that are better than others in building this kind advantage and what kind of strategy these firms implement to leverage this capacity. We expect those firms' research strategy being less oriented toward short-terms returns, more diversified in order to enhance the probability of being pre-adapted to an emerging trajectory and more oriented toward the development of absorptive capacity. The transition toward an open innovation model, from

this perspective, may be reflect the firms' attempt to enhance their exapative capacity(Chesbrough 2003).

With regard to the issue of knowledge availability, the concept of exaptation highlight the relevance of being capable to exploit an existing set of knowledge for a new scope. However, the development of this know-how requires a close interaction between producer and user of that existing knowledge. This imposes re-thinking the way the knowledge-base is organized and shared. In this perspective much can be learned from analyzing cases such as the one of open source software(e.g. Hippel & Krogh 2003). In open source, in fact, knowledge is not protected by an exclusive copyright. Everybody is free to get access to a piece of source code and modify it according to their specific requirements. However, the modified version has to be released under the same terms of license. Therefore, it is made available for further requirements driven modifications. The lack of a strong form of property right protection has stimulated the formation of a learning community that enhance the capacity of a searching knowledge and exapting it into different field of application. For instance, it would be interesting to see how the Linux os source code has been exapted into different field of application, such as smart phone, and with what advantage for the Linux development as whole. The case of OS community is also interesting with respect to selection. The open nature of the source code, in fact, has stimulated the formation of a community-based system of peer review. Therefore, it would be interesting to analyze the efficiency of this system in balancing knowledge exploration and exploration.

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