WHY TACIT KNOWLEDGE PROTECTS THE FIRM'S EVOLUTIONARY POTENTIAL (AND WHY CODIFICATION DOESN'T)*

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Abstract

The present article introduces the theory of cultural evolution as a possible basis for further development of a micro-evolutionary economic theory. Cultural evolution is Lamarckian and involves social transmission of explicit knowledge by choice or imposition. A possible complementary Darwinian principle operating in the social realm is defined in terms of social transmission of tacit knowledge. According to this principle, termed Local Emulative Selection, some forms of tacit knowledge are not adapted (those which cannot be reached by consciousness) by their carrier. I then identify a problem of adaptation that plagues any form of Lamarckian selection. This base-line problem implies that the evolutionary potential decreases as the possibility of adaptation increases. In consequence, the social transmission of tacit knowledge, which cannot be reached by consciousness, protects the evolutionary potential associated with any form of social evolution. By contrast, it is suggested that a systematic codification of tacit knowledge can potentially corrupt the evolutionary potential of any organisation.

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Although problematic from an evolutionary viewpoint, the "as if" assumption has been a very successful simplification for rationalising the emergence of equilibrium behaviour in economic models. The assumption seems a good approximation to a number of real-world phenomena involving large number of agents and non-strategic behaviour (Samuelson, 1997) but a number of situations defy its general validity (March, 1994). To further the development of theory, this motivates that we should take a more careful look at those important real world phenomena that exhibit imperfections assumed away in the construction of equilibrium models (Samuelson, 1997). Thus, the evolutionary approach can be distinguished from the classical by insisting that the emergence of equilibrium (if this is what happens) must be understood in dynamic terms that include additional imperfections (Young, 1998). As Young (1998) notes, neoclassical economics pictures the world as it should look after all the dust has settled whereas the evolutionary approach describes how the dust settles. But since the dust actually never settles, the two descriptions may differ considerably over the long run (Young, 1998). Evolutionary game theory has quite successfully adopted a set of useful techniques from biology to analyse a number of interesting economic problems involving learning and strategic interaction in terms of a stylised representation of the corresponding micro-evolutionary adjustment process (see e.g. Samuelson, 1997; Weibull, 1995).

Like evolutionary game theory, the present article introduces techniques developed in biology in order to study micro-evolutionary processes. The difference in emphasis lies in the kind of (out-of-equilibrium) imperfections that the present article focuses on. Rather than being interested in describing the dynamic interaction of a bounded set of well-specified strategies (as in the use of replicator models in ecological studies of genetic interaction), the focus is on the underlying process responsible for the emergence of the strategies themselves. The approach is distinctly micro-evolutionary and the idea is to understand the past as it has evolved, clearly an important criterion for a useful scientific theory (Aumann, 2000). In order to do this, we need a general model of evolution that can help us track the process itself and thus discipline how we interpret the empirical evidence. Nelson & Winter (1982) provided the outline of a Lamarckian micro-evolutionary model of economic organisation. Since then, most models of economic evolution have focussed on macro-evolutionary processes or included micro-features to rationalise macro-outcomes, e.g. in terms of competitive selection (Metcalfe, 1998) or price formation (Day, 1994; Day, 1999). To help fill the gap in our understanding of micro-evolutionary processes within business organisations, the present article introduces the theory of cultural evolution as a possible conceptual pillar. Thus, the present article considers in some detail how the two known selection processes Lamarckian- and neo-Darwinian selection may operate in the social realm. Although most agree that economic evolution is Lamarckian in some sense, the possibility of frequent adaptations creates a difficulty regarding the evolutionary potential of Lamarckism. Unless the agent's capacity for adaptive experiments is severely constrained, Lamarckian evolution may not work. This viewpoint is based on the conception that an underlying cultural code creates and sustains the potential for the semiautomatic execution of learned sequences of behaviour. Here it is assumed that the code tracks changes in the environment and that behaviour patterns change in response to changes in the code. Roughly, unless changes in the code are less frequent than changes in the environment, there will be no evolution because there is no way that the code can help to establish systematic improvement in behaviour.

This gene-centred view suggests that there is a crucial problem in constraining adaptive experimentation in order to establish the necessary base-line against which the next experiment can be evaluated. I refer to this problem as the base-line problem. Since a neo-Darwinian explanation permits no adaptation of the genetic code, it has solved the base-line problem by design. By contrast, a Lamarckian explanation remains saddled with the possibility that the base-line problem rules out any form of evolution, a problem which tends to be neglected in evolutionary economics. Since there is widespread agreement that social and economic evolution is Lamarckian, it is clearly important to point out how the base-line problem can be solved in order to identify the situations where a system's evolutionary potential is threatened.

In the following, I will focus on the base-line problem and the possibility of solving it in theories of economic evolution. The argument is based on the assumption that tacit and unconscious knowledge limits adaptation of routines. If this assumption is correct, the evolutionary potential of any social organisation, such as the modern corporation, should increase as the importance of tacit knowledge increases. And, should the organisation succeed in systematically converting tacit knowledge to explicit codifiable knowledge, its evolutionary potential should decrease or may even be lost. Not only is the difficulty in sustaining the evolutionary potential associated with any Lamarckian explanation overlooked in economics and organisation theory. Recently, it has been argued that firms may even benefit from systematic codification of tacit knowledge (Nonaka & Takeuchi, 1995; von Hippel, 1999; Zollo & Winter, 1999). In view of the role of tacit knowledge in sustaining evolutionary potential, I reach a slightly different conclusion. The idea that systematic codification of tacit knowledge is beneficial is problematic for the firm's evolutionary future. If possible, a successful systematic elimination of tacit knowledge will decrease and might even eliminate the firm's evolutionary potential. Since any discovery involves some codification of knowledge that was previously tacit and since diffusion increases in demand-side codification, it is not argued that all codification is bad. It is the idea of systematic elimination of tacit knowledge, which is found problematic.

The paper is organised as follows. First, I provide the necessary background by briefly outlining the structure of the Lamarckian and neo-Darwinian explanation. Second, the modern idea of cultural selection is described. It involves explicit transmission of knowledge contained in a cultural code. An alternative selection mechanism referred to as Local Emulative selection, which involves implicit transmission of unconscious tacit knowledge, is identified. It is backed up by a rapidly growing subfield of experimental psychology and consistent with the principle of natural selection according to neo-Darwinian standards. Third, I identify the base-line problem and point out one possible solution. The base-line problem refers to the problem of evolutionary potential associated with any version of Lamarckian selection. This problem is caused by the need to constrain adaptive experimentation in order to establish a base-line against which the value of the next experiment can be judged. I argue that the principle of Local Emulative Selection offers a possible solution of the base-line problem. In consequence, other forms of Lamarckian selection, including cultural selection, increase in evolutionary potential if they are nested within a neo-Darwinian explanation. The concluding section outlines some implications for the evolutionary theory of the firm.

Lamarckian and neo-Darwinian Explanations

Two premises underlie the present article's exclusive focus on the Lamarckian and neo-Darwinian explanations. The first premise is that we have no serious alternative contenders for explanation of evolution in terms of post-hoc reconstruction of spells involving the emergence of novel phenomena (Cronin, 1991; Dawkins, 1996; Maynard

Smith, 1989). As argued in previous work, the available alternative explanations leave too much of the process of evolution unexplained (Knudsen, 2000). The second premise is that any general theory of evolution in the social realm will necessarily resemble biological evolution to some degree, a point argued by Campbell (1969), Durham (1991), Plotkin (1994), Witt (1996) and others. This is so, since any evolving system must have replicating units, selective retention of some variants on the expense of others and sustained recreation of variation on part of the replicating units (Durham, 1991). In other words, there must be analogy between any model of evolutionary change at some level. This viewpoint is summarised in what Durham (1991) has termed Campbell's rule: the analogy between cultural accumulations is not in biology *per se* but rather in the general model of evolution for which organic evolution is but one instance (Campbell, 1969). Therefore, economic and social evolution must, at some level of abstraction, share the structural properties of the general model associated with biological evolution (Witt, 1996). That is, economic or social evolution must be either Lamarckian or Darwinian in some sense. In the following, the structural properties of these two versions of the general model of evolution, common to both social and organic evolution, are identified.

In biology, we speak of genes and organisms. Genes contain a code, which is replicated in a high fidelity copying process. The new genetic code provides the instructions which, dependent upon environmental triggers, unfold into the properties which constitute the mature organism. The mature organism, in turn, comes with a potential to interact with the environment as a cohesive whole in such a way that replication is differential. In biology, this layered theoretical structure corresponds to empirical reality, the replicating code to genes, and the interacting entity to the organism. It is further important to emphasise that the relation between the code and its carrier is not deterministic. The code contains a wide range of potentials, which are gradually triggered by environmental cues through the organism's unfolding in maturation. According to Jacob (1985), the code provides any normal child with the potential to grow up in any community, to talk any language, to accept any religion and any set of social conventions. The code installs the conditions that allow the child to react to environmental stimuli, to seek and find regularities, to memorise regularities and to recombine regularities (Jacob, 1985). In this sense, it works very much like a recipe for a mince pie. Although all mince pies have shared features they are also unique and none are quite like my grandmother's. In short, any organism is programmed by the genetic code, however, it is programmed to learn (Jacob, 1985).

In biology, the code is contained in the genes in terms of a specific sequence of nucleotide bases, which make up the DNA molecule. In economics, matters are less settled but there seems to be wide agreement that Nelson and Winter's (1982) idea of routines as the economic analogy to genes is useful. In both instances an underlying code acts as a recipe for the development of an entity (organism or agent) and its capacities. Evolution, then, can be explained in terms of two general subprocesses: (1) changes in the code due to replication, and (2) changes in the code due to interaction. In biology replication involves recombination and mutation (genetic response), whereas interaction involves imitation, competition, migration, death and differential reproductive success (phenotypic selection). Given enough time, the ongoing replication and interaction processes can be associated with the accumulated changes in the code to account for the evolution of very complex entities such as the human eye.

Normally the evolutionary process is explained in terms of the tripartite mechanisms of variation, selection and retention. In view of the difficulties in development of an adequate description of the entities involved in economic evolution, the term replicator and interactor are particularly attractive as supplementary criteria since they help identify the entities that evolve. Since the identification of an appropriate replicator and interactor demands detailed consideration of the implied selection process this exercise may provide further progress towards a tight evolutionary explanation. *If* the use of the term replicator and interactor can be justified, the adoption of the replicator-interactor concepts potentially allows a translation of the explanatory structure of neo-Darwinian or Lamarckian selection into economics. Assuming that a meaningful economic equivalent of replicators and interactors can be found, economic evolution by natural selection may be defined as a two-step process. Step one involves (direct) *replication* of a notional code, and step two involves that the entity of interest (directly) *interacts* with the environment in a way the results in differential replication. Evolution, then, is defined in terms of variation accumulated over time because of the independent but, causally linked, subprocesses of replication and interaction. Having provided the necessary background, the difference between neo-Darwinian and Lamarckian selection can now be described in more detail.

FIGURE 1 HERE

The important difference between the two forms of selection lies in the information flow between genes and somatic cells. In neo-Darwinian selection, it is strictly one-way from genes to somatic cells, from replicators to interactors[i]. Figure 1 above, illustrates both neo-Darwinian and Lamarckian selection. The neo-Darwinian understanding of natural selection refers to the one-period change that happens in replicators and interactors. Evolution can happen because the successes and unsuccesses of multiple generations of interactors cumulate as changes in the frequency of replicators. As Cronin (1991) notes, natural selection will seize on every advantageous characteristic, of whatever kind, however small and insignificant, however deeply buried, however rarely exercised, however indirect. It can only do so because there is a built in correspondence between what is of advantage and what evolves. And this correspondence is secured since there is no possibility that the underlying replicating code may be changed too frequently. The neo-Darwinian explanation effectively rules out this possibility since the replicating code cannot be changed at all by its carrier. In other words, replicators can be viewed as entities that take part in an experiment. They provide interactors with a limiting set of potential behaviours. Since the replicator itself is not changed in response to the requirements put on interactors, the expected number of offspring produced in the lifetime of a particular interactor in a particular environment will determine the frequency of the replicators around in the next period. And through recombination of a very large pool of replicators, there would always be recreated the new variation necessary to feed an unending process of evolution.

As shown in Figure 1 above, there is no difference between the structure of neo-Darwinian and Lamarckian selection. *The only thing which differs from Darwinian selection is that replicators alter their state due to information received from their carriers, the interactors.* Subsequently, this altered state is passed on to the successors. As indicated in Figure 1, a Lamarckian interactor can adapt its replicating code many times during its lifetime. In biology, there are no Lamarckian interactors and this traffic is prevented. In socio-economic systems, structural adaptations are ubiquitous, social entities can, and do continuously, change the underlying codes that provide guidance for behaviours. In consequence, the possibility remains that a social or economic system's evolutionary potential is lost.

Before addressing this problem, the next section describes the theory of cultural selection, which provides the, arguably, most detailed understanding of micro-evolutionary processes in the social realm. By focusing on the role of tacit knowledge in transmission of cultural traits among members of face-to-face groups, I then develop an alternative to supplement cultural selection. Whereas cultural selection is Lamarckian, this alternative, which I refer to as Local Emulative Selection, is neo-Darwinian. Armed with this detailed understanding, I then discuss the base-line problem associated with Lamarckian explanations and how it may be solved.

Cultural Selection versus Local Emulative Selection

The motivation for the present article's focus on the theory of cultural evolution is that this theory offers a general heuristic model of evolution superior to those found in economics, both in terms of micro-evolutionary foundation and empirical track record (see e.g. Durham, 1991 for an example). Since economic evolution can be viewed as a special case of cultural evolution, there is good reason to start here in order to provide theories of economic evolution with a solid basis in terms of a well-defined micro-evolutionary model. In the following I, therefore, use Durham's (1991) Lamarckian model of cultural evolution to define cultural selection. I then add the idea that also tacit knowledge may be culturally transmitted. This leads to the definition of Local Emulative Selection, a principle of selection in the social realm consistent with the general neo-Darwinian model of evolution. Thus Local Emulative Selection is a specific form of social transmission that operates through a cultural inheritance system and yet differs from cultural evolution. Where cultural evolution is Lamarckian, Local Emulative Selection is consistent with the neo-Darwinian understanding of natural selection. As pointed out in the following section, this is a great attraction since it solves the base-line problem associated with Lamarckian evolution.

The following brief account of the key features of cultural selection is based on Durham's (1991) work on the dynamics of cultural evolution and the nature of the relationships between cultural dynamics and genetic evolution. The attraction of Durham's (1991) model of cultural evolution, shared with other related work (e.g. Cavalli-Sforza & Feldman 1981; Boyd & Richerson 1985), is that it obeys Campbell's (1969) rule mentioned above. All these models of cultural evolution are consistent with the structural properties of the general Lamarckian and Darwinian model of evolution. In comparison, most models of economic evolution neglect the structural requirements of the general evolutionary model, a problem associated with the rather loose use of metaphors in evolutionary economics (Witt, 1996). As a result, the detail of micro-evolutionary processes and their connection to macro-evolutionary outcomes are ignored and the theory looses its explanatory bite. Nelson & Winter's (1982) model is the notable exception that carefully considers micro-evolutionary processes in terms of a Lamarckian transmission of routines. There remains, however, a problem of connecting Nelson & Winter's (1982) micro-evolutionary theory to macro-evolutionary outcomes associated with differential profits and competition (see Knudsen, 2000b). Since the theory of cultural evolution obeys Campbell's rule, it is an attractive basis from which the missing micro-evolutionary detail in models of economic evolution may be developed. Due to the genetic determinism associated with previous sociobiological models, their domain was restricted to a limited range of social phenomena. Economists, therefore, concluded they were too simplistic to be of any use as explanation for complex economic phenomena (see Nelson, 1995). When the next generation of cultural evolution models emerged, however, they came with a dual inheritance system. That is, the organic and the cultural inheritance system were seen as completely distinct and yet interacting. Whereas early sociobiological models seem too simple to be of much use in economics, there is much to learn from the dual inheritance models. In the following, Durham's (1991) sophisticated model of cultural evolution is used as example.

A key distinguishing feature of Durham's (1991) model of cultural evolution compared to the more narrow early sociobiological models which emerged in the 1970s (e.g. Bischof, 1972; Wilson, 1978) is that culture is viewed as a separate inheritance system. Where early sociobiological models had genetic selection as a primary cause, Durham (1991), Cavalli-Sforza & Feldman (1981), Lumsden & Wilson (1981) and Boyd & Richerson (1985) insisted that culture should be seen as a separate cause interecting with but not dominated by genetic selection. Through social transmission, culture provides informational guides to behaviour that are shared among individuals in social groups (Durham, 1991).

According to one version of this model, culture is a separate nongenetic inheritance system even if the cultural units are conceptualised as traits, which are part of the phenotype (Durham, 1991). Notably, the units of the cultural inheritance system are associated with a distinct measure of cultural fitness. To this Durham (1991) adds the insight from cognitive anthropological theories that culture can be conceptualised in terms of ideational units. As a result, cultural inheritance is completely separated from genetic inheritance. This conceptualisation implies that culture evolves due to informational inheritance associated with the differential transmission of ideas, values, and beliefs in a population (Durham, 1991). Accordingly, economic evolution can be seen as a specific instance of the differential transmission of ideas, values, and beliefs with economic significance in populations of economic actors. Obvious parallels in economics are Nelson & Winter's (1982) Lamarckian theory of routine transmission, the related conceptualisation of the technological progress function as an abstract flow of ideas (e.g. Kaldor, 1957), various different models of imitation and diffusion (e.g. Rogers & Shoemaker, 1971) and the transmission of rules, norms and practices implied by institutional theory (e.g. Hodgson, 1988; North, 1990, Scott, 1995). Having broadly defined cultural evolution in terms of an informational inheritance system, the ideational units, which operate in such a system, need more precise definition.

Based on an extensive literature search, Durham (1991) identified a large number of possible terms, which fitted the bill as an ideational replicating unit. To avoid being drowned in terminological soup, Durham (1991) identified the following three major properties such a unit must have. It must: "(1) consist of information that actually or potentially guides behavior, (2) accommodate highly variable kinds, quantities, and way of organising information (that is, with variable amounts of hierarchy and integration), and (3) demarcate bodies of information that are, in fact, differentially transmitted as coherent, functional units." (Durham, 1991: 188). Here, one could add that condition three implies the ideational unit must have a certain degree of immutability. Durham (1991) chose to use the term meme (devised by Dawkins, 1982) to represent the culturally transmitted units of information regardless of their form, size or internal organisation. He further subdivided memes into the two categories, holomeme and allomeme. Holomemes were defined to represent the entire cultural repertory of variation for a given meme (including any latent unexpressed form). Allomemes were then defined as the subset of holomemes that "are actually used as guides for behavior by at least some members of a population in at least some circumstances." (Durham, 1991: 189). Durham's (1991) examples of allomemes include:

> *…the alternative marriage principles used by the thongpa…; differing techniques or strategies for procuring subsistence resources; alternative schools or sects of religious thought coexistent within a population; differing conceptions about the length of a postpartum sex taboo; or variable definitions of a word or label such as variations in the wavelengths of light described by a given color term. (Durham, 1991: 189-90).*

It is easy to think of parallel examples with relevance for economics and strategy such as, (1) different schools of training coexistent within a population of economists (Shackle, 1967; Reder, 1999) or strategists (Mintzberg, 1994), (2) different conceptions of the role of managers, employees and customers among a population of business organisations, and (3) differing techniques for handling process equipment among a population of steel-workers, IT-experts or musicians. The theory of cultural evolution assumes that these ideational units replicate among members of a cultural population and that they inform or instruct behavioural traits. That is, the potential of an allomeme is expressed as a "behavioural trait," i.e. a specific regularity in behaviour. Cultural evolution follows the scheme shown in figure 1. It is thus assumed that patterns of historical change in the distribution of behavioural traits are completely or partially caused by the sequential transformation through time in the replicating code, the allomeme. To understand cultural evolution, then, requires an understanding of the sources of differential replication responsible for the sequential change in the frequency of allomemes. Such frequency change may happen without social transmission of allomemes (e.g. due to innovation, migration or drift) or because of social transmission involving choice or imposition (Durham, 1991).

Cultural evolution is a distinct social phenomenon associated with changes in the cultural system. Durham (1991) points to three important differences between cultural evolution and biological reproduction. First, cultural evolution differs from genetic evolution because the causal mechanism involves differential social transmission of allomemes due to choice and imposition as well as biological reproduction. When people adopt, sustain and transmit ideational variants this will influence and possibly change the distribution of allomemes and the associated behavioural traits (Durham, 1991). Second, since allomemes are socially transmitted, they can be adopted and rejected due to collective decisions. A business organisation can, for example through a board meeting, choose to adopt the ideational unit "scientific management," "quality control," "best practice" or "customer orientation." (see e.g. Szulanski, 1995; Winter, 1994 for an example). In consequence, differential replication is not necessarily decided at the individual level in cultural evolution. Third, since the units of social transmission, the allomemes in Durham's (1991) terminology, have enormous variation in information content, cultural evolution need not be slow and gradual but may be fast and episodic.

The next step is to define cultural selection, or meme selection. Durham (1991) defines meme selection as the gradual and slow change in the distribution of allomemes caused by their differential social transmission. Given the assumption that culture can be subdivided into allomemes influencing their carrier's behavioural traits, evolution can happen due to meme selection or because of a rapid but large allomeme change. In the latter case, there will be some evolution but it is likely to be an autocatalytic process, which dies out fast (see e.g. Maynard Smith & Szathmáry, 1999). Therefore, the gradual but slow meme selection which is consistent with Darwinian selection will have a larger evolutionary potential than the adjustment associated with a large and fast change in allomemes. Finally, a measure for cultural fitness can be defined on basis of the relative transmission success implied by Durham's (1991) definition of meme selection. Thus, Durham (1991) defines cultural fitness as:

> *…an allomeme's expected relative rate of social transmission and use within a subpopulation, where the "expected rate" can be defined, following Philip Kitcher (1985: 51), as "the probabilistically weighted average of all possible values."*

So far, I have described Durham's (1991) theory of cultural evolution including its key concepts (meme, allomeme) and principles (meme selection). As indicated in the above, these concepts and principles are grounded in social theory and can therefore easily be adopted as a basis for developing a theory of micro-evolution in economics. In this connection, Durham's (1991) measure of cultural fitness has great attraction for empirical work. Note here, that cultural fitness can be translated to economic fitness in terms of the expected relative rate of social transmission of allomemes with economic significance. This implies that we attach an economic weight to each specific allomeme. There is one problem, however, with Durham's (1991) theory and any other Lamarckian theory. Due to the possibility that the carrier of the cultural code (allomeme) can change it, the evolutionary potential may be severely compromised. In the next section, I give this problem more detailed consideration. Before doing so, I define an alternative selection mechanism that may supplement and help cultural selection overcome its problem with evolutionary potential. The following section, then, discusses the evolutionary advantage of this selection principle, termed Local Emulative Selection.

In the proposed alternative, Local Emulative Selection, transmission is implicit in the sense that ideational units are unconsciously emulated during a period of exposure to a group of transmitters'. This idea has a history that goes back at least to Aristotle's conceptualisation of how habits were acquired in social settings. According to Aristotle, habits arise from emulation of social behaviour and as response to distinct states of nature:

> *…by doing the acts that we do in our transactions with other men we become just or unjust, and by doing the acts that we do in the presence of danger, and being habituated to feel fear or confidence, we become brave*

or cowardly. … Thus in one word, states [of character] arise out of like activities. This is why the activities we exhibit must be of a certain kind; it is because the states correspond to the differences between these. It makes no small difference, then, whether we form habits of one kind or of another from our very youth; it makes a very great difference, or rather all the difference. (Nichomachean Ethics II.I, 1103b14-25, cf Lear, 1988).

Note here that the original Greek term for habit implied a stable disposition to act, which is translated as a "state of character." This view derives from Aristotle's interpretation of the term ἕξις, which both means "having" in the sense of possession (of a garment, for example) and a "state" in the sense of being disposed towards expressing a particular kind of action, character or virtue (see Metaphysics, V.XIX-XXIII; Tredennick, 1996). It is the latter interpretation of the term ἕξις, which Aristotle uses to denote habits as a socially acquired disposition to engage in a specific behaviour. For Aristotle, distinct "states of character" then corresponds to distinct kinds of activity. In the terminology of cultural evolution, "state of character" is a distinct underlying cultural code (allomeme), which is expressed as a distinct type of behaviour. Thus, habits in Aristotle's view instil a disposition to engage in a specific behaviour. But Aristotle goes further. Habits are also cues for behaviour in the sense that they instil a sensitivity to what type of behaviour is appropriate in specific circumstances (Lear, 1988). According to Aristotle, the purpose of education was to instil habits, dispositions to act, rather than conveying explicit rules for action. And the reason why it is necessary to instil a disposition to act rather than relying on explicit rules for action is that, according to Aristotle, it is simply impossible to define a set of rules which describe how a virtuous person should act (Lear, 1988). Thus, for Aristotle, educating a person to virtue (a state of character) involved an implicit transmission of appropriate habits through emulation rather than merely getting the person to act virtuously through conveyance of an explicit list of rules for action.

Much later the idea of implicit transmission of cultural traits was associated with the idea of habit formation proposed by the American pragmatists (see Hodgson, 1988) and institutionalists (e.g. Veblen, 1899). More recently, Ryle (1971) and Polanyi (1966) described the process of implicit transmission of tacit knowledge in education and emphasised how tacit knowledge is a precondition for the emergence of the cognitive frames that enable any form of conception. During the last twenty years, the idea of implicit learning has since gained influence due to massive empirical support from rapidly growing research in experimental psychology (Kentridge & Heywood, 2000; Liebermann, 2000; Nisbett &

Wilson, 1977; Reber, 1993). Using increasingly sophisticated experimental design, it has consistently been shown that cognitive schema develop without awareness in a process referred to as implicit learning (Kentridge & Heywood, 2000; Reber, 1993). Implicit learning involves long term exposure to stimuli, does not necessarily involve meta-cognition and must be distinguished from transient activation (Bock & Griffin, 2000). It is also important to note that implicit learning can involve both improvement and detrimental outcomes (Woltz et al., 2000). Based on a number of empirical studies in the workplace, Eraut (2000) divides the tacit knowledge conveyed through implicit learning into three categories: (1) tacit understanding of people and situations, (2) routinised actions, and (3) tacit rules that underpin intuitive decision-making. A well-known example of the first category is provided by Ryle (1971), Nelson & Winter (1982) is the classic example of the second category and Schelling (1999) of the third. According to Eraut (2000), these three types of tacit knowledge come together when professional performance involves sequences of routinised action punctuated by rapid intuitive decisions based on a tacit understanding of the situation. This leads to an understanding of intuitive, analytic and deliberative cognition as separate and yet interdependent modes of cognition (Eraut, 2000), i.e., that analytic and deliberate cognition is supported by intuitive decision making based on tacit knowledge conveyed through implicit learning.

The parallel in economics is Nelson & Winter's (1982) influential proposal that routines are partly composed of tacit knowledge. Although Nelson & Winter (1982) do not describe how tacit knowledge is actually transmitted, the idea is implied by their emphasis on routinisation. A more explicit treatment of the social transmission of tacit knowledge is provided by von Hippel's (1988) idea that tacit knowledge may be transferred through the product in which it is embodied. However, in von Hippel (1988), the transmission of tacit knowledge is a result of an explicit choice (e.g. prototypes embodying tacit knowledge that are shuffled between sites) or imposition (reverse engineering). Thus, von Hippel's (1988) theory is a specific example of cultural selection. By contrast, in Local Emulative Selection the transmission of tacit knowledge is implicit and thus, at least temporarily, outside the reach of consciousness, an idea also found in Reber (1993), Polanyi (1966), Ryle (1971) and others who emphasise that implicit transmission happens in consequence of direct exposure to other individuals in a specific social setting. In consequence of the latter condition, the social transmission of tacit knowledge is predominantly local, a property that may explain the barriers to internal knowledge transfer identified in Szulanski's (1996) empirical study of internal 122 best practice transfers in eight companies.

Thus, I define Local Emulative Selection as the gradual and slow change in the distribution of allomemes caused by differential emulation (implicit social transmission) of tacit allomemes in face-to-face groups. The term tacit knowledge covers a continuum from knowledge not reachable by consciousness to completely conscious but inexpressible knowledge. Local Emulative Selection refers to tacit knowledge that cannot be reached by consciousness and thus involves implicit transmission of unconscious tacit knowledge components. By contrast, cultural selection involves explicit transmission of conscious knowledge components. In cultural selection, the transmission is explicit in the sense that ideational units are chosen, imposed, or, perhaps transmission more commonly involves a mixture of choice and imposition (Durham, 1991). Note further that the term allomeme refers to an ideational component expressed in a certain type of behaviour. The allomeme, can, therefore, be seen as a habit very much in the sense of Aristotle, an individually held ideational component acquired through emulation in a social setting which instils a disposition to act as well as a sensitivity to what type of behaviour is appropriate in specific circumstances. Recently, Hodgson (1997) has derived a similar point based on the term "habit" taken from instinct psychology and the American pragmatists.

A further conceptual clarification is needed in order to align the terms "allomeme" and "habit" with Nelson & Winter's (1982) "routine." One possibility is to define routines as the social level expression of habits. At least this seems to be what Nelson & Winter (1982) writes about, i.e., routines acquired through socialisation serve as organisation level targets for control, truce and memory, and so forth. A routine then, is an ideational component acquired in a social setting (business organisation), which is expressed as a disposition to act as well as a sensitivity to what type of behaviour is appropriate in specific circumstances. A set of routines containing productive knowledge (ideational components) is passed on to a newcomer entering a business organisation. As a result the newcomer will, over time, acquire a set of regular behaviour and thought patterns suitable for the task at hand.

In terms of evolutionary potential, the important difference between Local Emulative Selection and cultural selection is that the carrier of the ideational cultural code, the allomeme, cannot choose to change it. And since some forms of tacit knowledge not reachable by consciousness are thought to be immutable for relatively long periods of time (Reber, 1993), we have devised a perfect analogy to the general version of neo-Darwinian selection shown in Figure 1. As suggested in previous work (Knudsen, 2000), the idea of Local Emulative Selection helps settle the discussion of the unit of selection in theories of economic evolution since it necessarily involves face-to-face contact over a longer period. Also, the idea of profits as proxy for economic fitness seems to need revision, since it must be redefined in terms of the expected rate of social transmission and use of an allomeme characteristic of a specific teams or workgroups. The difficulty then lies in the economic weight that must be attached to the allomeme. Here, a possible and obvious solution is to define the contraction and expansion of alternative workgroups in the business organisation as an outcome of the manager's choice (for a useful modelling approach see Metcalfe, 1994; Metcalfe & Gibbons, 1995). This choice should depend upon the team's contribution to productivity and profits but in extreme cases it need not be so. These issues are clearly important and some were addressed in previous work (Knudsen, 2000). I will not give these issues further treatment in the present article but continue to consider Local Emulative Selection as a solution to the base-line problem according to which any form of Lamarckian evolution is threatened by loss of evolutionary potential. For reasons of expositional convenience, I will use routines associated with production in business organisations as an example of allomemes.

The Base-line Problem

It is enlightening to consider what would happen if the firm's routines were adapted to the slightest shift in the business environment.

Adaptation can be considered as the accumulated wisdom that results from a series of experiments across agents across time. Unless these experiments use a base-line, it is impossible to provide estimates of the consequences of deviation from the last period's routines. Therefore, in the absence of a base-line, an additional experiment has no value. In Darwinian selection, immutable genes establish the base-line. By reference to the base-line contained in the gene pool, any new experiment provides the means of progress in existing knowledge. Thus, provided the environment does not change too abruptly, very complex structures, like the human eye, can be built in a series of experiments, each of which incrementally adds the possibility of improvement over the level defined by an established base-line. But in the absence of immutable genes, a base-line could not be established and in the absence of a base-line, knowledge could not progress cumulatively.

To bring out this point with more force, consider the extreme situation where all environmental changes were generated by some stationary random process. Let decision-maker i carry an allomeme a_i associated with a specific action x_i and let a_i track this process. Also let the allomeme be equipped to make statistical inference on the random variable X which measures the effect of the associated N realisations of a particular action. The mean of X is μ_x and the variance F_x. Assume that the allomeme adapts to a new action y_i if it is a significant improvement over the old one (x_i). The allomeme thus continues to sample an action until the estimation of the mean effect μ_x, associated with the effect of the action, is reliable enough to distinguish significant improvements. The number of sample points N associated with a particular action increases until the allomeme changes. If the allomeme is changed at every shift in the environment, the sample will include the effect of one action, i.e. N=1. By contrast, if the allomeme is never changed, the sample will, at the limit, include $N\rightarrow\infty$ actions. We are then looking for an answer to the question, when is it the right time to adapt the routine? The answer can be given in terms of optimal sample size.

From the law of large numbers, we know that, for independent and identically distributed variables with finite second moments, the sample mean will converge to μ in probability, i.e., as $N\rightarrow\infty$, the density of the sample mean becomes increasingly concentrated at μ. So, in the absence of further constraints, the optimal decision for the allomeme will be to wait for a sample of $N\rightarrow\infty$ actions so the sample mean converges to μ_x and thus allows detection of even very small improvements in a new action y_i. In other words, the more immutable the allomeme, the more reliable the estimate upon which the evaluation of a new action is based. This argument is obviously flawed in the sense that it implies that a particular allomeme should wait forever before it changes. Therefore the next step is to define the optimal sample size by allowing some error to slightly reduce the reliability of the estimate. In other words, we are looking for an estimate of μ_x, which is reliable enough to detect improvements above some magnitude. Therefore, we turn to statistical hypothesis testing.

Let the null hypothesis be that the new action makes no difference compared to the old, i.e., the new action does not differ from the sample mean associated with the old action. As we know, the probability of making a Type 1 error should be balanced with the probability of making a Type 2 error so both are reasonably small. Given our null hypothesis, a Type 1 error is the failure to recognise the absence of an effect and a Type 2 error is the failure to recognise the presence of an effect. The probability of making both forms of error decreases in sample size but unfortunately the two forms of error are also inversely related. The usual practice is therefore to define a reasonable level for the probability of making Type 1 errors, e.g. 0.05, and then increase sample size until the probability of making a Type 2 error is sufficiently small. Finally, we must take effect size into consideration, i.e., the order of magnitude associated with the effect (Cohen, 1977). Clearly, it is much more difficult to detect a 1% improvement in effect than a 10% improvement.

As an example consider a situation where the ratio between the true mean and the variance is 1. Set the probability for a Type 1 error to 0.05 and compute the required sample size to detect an improvement in the range of 1-10% (the relative tolerance). As can be seen in Figure 2 below, a reasonably small sample size (N=385) is required if we wish to detect a relative improvement of 10%. If we wish to detect a 1 % improvement, the required sample size is N=38.417.

FIGURE 2 HERE

The numbers in Figure 2 imply that if we wish to detect a relative improvement in the order of magnitude of 10%, it takes at least 385 repetitions of routine action to establish the required base-line. And should we wish to detect a relative improvement in the order of magnitude of 1%, 38.417 repetitions are required, and so forth. Note that if the routine is adapted before the necessary number of repetitions required to establish the base-line have been completed, it is unlikely that the allomeme can detect whether a new action is an improvement. This argument implies that any form of Lamarckian selection faces a formidable problem in a stochastic environment, which only presents the possibility of relatively small improvements. By contrast, any improvement in features that are highly correlated with survival, no matter how tiny will be seized upon by Darwinian selection. Given a sufficient number of generations, the consistent accumulation of slight improvements may eventually result in very complex and refined structures such as the eye (Dawkins, 1996).

Either Lamarckian selection is at sea in an environment that only presents the possibility of slight improvements or the carriers ability to change the allomeme (or genetic code) should somehow be restricted to the required degree of immutability. The first possibility completely excuses Lamarckian selection as a viable theory of evolution. The second possibility can be defended but it is an open question how the required degree of immutability has evolved. Ultimately, the only reasonable explanation seems to involve an underlying neo-Darwinian principle, which helps guiding Lamarckian evolution. In consequence, the possibility that cultural evolution may be guided by the underlying principle of Local Emulative Selection is a proposition that can explain why evolution is possible also in the social realm.

Heiner (1983) has previously presented the argument upon which this conclusion is based but in a slightly different form. Heiner (1983) posed the question, "when is the selection of a new action sufficiently reliable for an agent to benefit from allowing flexibility to select that action." The general answer was the "Reliability Condition" according to which flexibility is beneficial if the actual reliability in selecting the action exceeds the minimum required reliability necessary to improve performance (Heiner, 1983):

$$r(\mathbf{U})/\ w(\mathbf{U}) > l(\mathbf{e})/\ g(\mathbf{e}) * (1-p(\mathbf{e}))/\ p(\mathbf{e})$$

Here r(**U**) is the conditional probability of selecting the action when it is the right time to do so and **U** is the uncertainty about how to use information in selecting potential actions. As can be seen from this definition, r(**U**) corresponds to the probability of making a Type 1 error and the problem is similar to the one associated with the establishment of a base-line for evaluation of the effect of new actions. The gain in performance associated with a correct choice is g(**e**), where **e** is a vector of environmental variables. The complementary definitions are w(**U**), the conditional probability of selecting the action when it is the wrong time to do so and l(**g**), the associated loss. Finally, the probability that the right condition will occur is denoted p(**e**). Define the tolerance limit as $T(\mathbf{e}) = l(\mathbf{e})/\ g(\mathbf{e}) * (1-p(\mathbf{e}))/\ p(\mathbf{e})$. Then flexibility can only be chosen when $r/w > T$. It is straightforward to verify that as p(**e**) drops to zero, T quickly accelerates to infinity (Heiner, 1983). Therefore, it follows that an agent must ignore unusual situations and, conversely, that "an agent's repertoire must be limited to actions which are adapted only to relatively likely or 'recurrent' situations." (Heiner, 1983: 567). Heiner's (1983) argument is posed in terms of the presence or absence of an effect. If we instead interpret "unusual" as the degree to which an effect is present, we reach a conclusion similar to the one involved in determination of the required sample size to detect very small changes. That is, when the possibility of relative improvement goes to zero, at the limit, the agent's repertoire should not be adapted. In this version of Heiner's (1983) argument, some flexibility is appropriate in an environment in which large gains in relative performance are present. But the difficulty in accounting for the evolution of the right amount of flexibility remains unless we refer to an underlying neo-Darwinian process.

Until now, it has been assumed that our allomeme samples from a single regime. Since the problem of multiple regimes has been suppressed, we have ignored the possibility that the obtained estimates of an action may belong to one regime but may be used for evaluation of an action after there has been a fundamental shift in regime. The obvious approach to this problem is to treat the shift in regime in terms of inference regarding the underlying process (Hamilton, 1994). Thus, the underlying process itself may be described by an unobserved random variable that indexes the possible regimes. Note that each regime or state is associated with a unique process. Given a sufficiently large number of observations as well as knowledge about the probabilities of transition between regimes and the conditional densities associated with each regime, it is then possible to test the conditional probability that the *n*th observation was generated by the *k*th process (Hamilton, 1994). On this basis it is further possible to form forecasts about the likelihood that the process is in a given regime and the probability that a particular observation was generated within that regime. So, it is possible in principle to detect a relative improvement in the manner described above but the number of observations required to do so is obviously much larger. Therefore, it should not be surprising that evolution can handle a limited number of regular shifts in regime but has problems with unusual and radical shifts in regime.

As shown in Table 1 below, we can systematise the possibility of a shift in the environmental regime, which generates the observed effect of an action associated with a particular allomeme in the following way. If there is no change in regime the allomeme can adapt or remain unaltered. In the latter case, it continues sampling realisations of a particular action until it can detect relative improvements of a certain order of magnitude, e.g. 10%.

TABLE 1 HERE

In the terminology of experimental design, we can refer to this possibility in terms of the treatment "do not adapt." This treatment will improve the reliability of the estimates in the manner described above. As an alternative, the allomeme can administer the treatment "adapt" (we assume it is free to do so when required). By doing so and sampling the required number of actions to form a reliable estimate, the two actions can be compared. Whether the new or the old action turned out to be preferred, the result will be an improvement in validity (assuming that the allomeme can switch back if required). By contrast, if there should be an undetected shift in regime, the treatment "adapt" will yield invalid estimates since the treatment effect will be confounded with the effect of the shift in regime. In this case, the treatment should be "do not adapt" with the purpose of gathering observations that can improve inference regarding the probability of a shift in regime as well as improving the reliability of the estimates within the new regime. From this discussion it should be clear that the possibility of shifting regimes poses a further requirement on part of the Lamarckian allomeme in order to form the baseline which may help it adapt to the right alternative at the right time.

The establishment of a base-line for the progress of knowledge through adaptation, then, provides a fundamental but ignored problem for the Lamarckian analogue of routines to genes. More generally, any Lamarckian explanation has to come up with a story that limits the genetic response to environmental change. The appeal to relative immutability is not enough since, in a Lamarckian explanation, there is no guarantee that the genes are not changed too fast. Put differently, when genes change against a background of stochastic environmental change, how do we explain the evolution of the right "amount" of immutability? The obvious explanation would be neo-Darwinian selection, which has no such difficulty since the level of immutability is absolute. Then, where does the base-line problem leave Lamarckian explanations of economic evolution?

Let us first note that a Lamarckian explanation has the allomemes associated with firm-specific routines as equivalents to replicating genes and the individuals' firm-specific behaviour patterns as equivalents to interacting organisms. While individuals carry routines, they are developed in a particular social setting, the business organisation. The explanation is Lamarckian because the individual managers and employees may change the routines. Whether they are changed, deliberately or not, does not change the fact that the explanation is Lamarckian[ii]. When the need for adaptation arises due to change in the business environment, some sluggishness may be appropriate to enable prediction (Richardson, 1960). But the base-line problem is deeper. Not only is some level of immutability or sluggishness in response appropriate, it is crucial in order to establish the base-line without which progress is absent. Then, how do we explain the evolution of the appropriate level of immutability of routines? Without the appeal to an underlying Darwinian explanation, the Lamarckian problem of discrimination crops up. In biology, discrimination on the part of the carrier of genes is necessary to explain why the useful developments, such as the blacksmith's strong arm, should change the genes whereas the harmful developments, such as burns or scars, are not inherited. In face of the demands on information processing capacity needed to discriminate between good and bad adaptations, Lamarckism, as a general explanation of evolution is problematic.

Clearly, as emphasised in recent developments in Austrian economics (see e.g. Loasby, 1991; 1998; Minkler, 1993), there is always a difference between *ex ante* and *ex post* managerial evaluation of various different alternatives. Therefore, we can excuse our manager as a general source of discriminatory power necessary to solve the base-line problem. In other words, it seems necessary to appeal to an underlying neo-Darwinian story to solve the base-line problem. Alternatively, we must appeal to divine intervention ensuring that the right level of immutability is always present, or assert that the evolution of institutions and business organisations is only apparent. Since the latter alternatives are unpalatable, it seems obvious to look for a possible economic or social explanation that abides with the structure of neo-Darwinian selection. Such an explanation, Local Emulative Selection, involving the social transmission of tacit knowledge was outlined above. In view of recent arguments to the advantage of codifying tacit knowledge, the base-line problem indicates that tacit knowledge may have a crucial role in limiting adaptation. Therefore, successful attempts of codifying tacit knowledge may ultimately threaten the evolutionary potential of a business organisation. This problem is discussed in more detail in the following section.

Evolutionary Potential and Codification of Tacit Knowledge

The above exposition of the base-line problem implies that any form of Lamarckian explanation has a difficulty in explaining how the "right" degree of immutability in routines or allomemes is somehow present. The difficulty in explaining the presence of the right degree of immutability can be solved by referring to an underlying neo-Darwinian process. As I have suggested in previous work, we can imagine social evolution as a Lamarckian process safely nested within an underlying process of Local Emulative Selection by which it is guided (Knudsen, 2000). This possibility seems very attractive as a solution to the base-line problem because it does not deny the Lamarckian aspect of social evolution. Rather, a neo-Darwinian track is added to support the Lamarckian track of evolution.

According to the base-line problem, the evolutionary potential decreases as the possibility of adaptation increases. The qualification for this statement is that the evolutionary potential increases as every slight possibility of improvement is seized upon by the allomeme. And as we have seen, this requires, at the limit, that individual adaptation must be prevented. In social and economic evolution, a solution to this problem is the principle of Local Emulative Selection according to which, some forms of relatively immutable tacit knowledge are socially transmitted by emulation in a process also known as implicit learning (Reber, 1993). The reason why some forms of tacit knowledge are relatively immutable is that they are outside the reach of consciousness. When knowledge is tacit in the sense that it cannot be reached by consciousness, the carrier of such knowledge is obviously prevented from even pondering a change in it. By contrast, if knowledge is tacit but known, it can more readily be adapted not to speak of the possibility of adapting explicit codified knowledge such as a grocery list. According to the principle of Local Emulative Selection some forms of tacit knowledge are not adapted and this constraint ensures that evolutionary potential is not reduced or lost due to the base-line problem.

The proposed link between tacit knowledge and evolutionary potential can now be summarised: (1) according to the base-line problem, the evolutionary potential decreases as the possibility of adaptation increases, (2) according to the principle of Local Emulative Selection some forms of tacit knowledge are not adapted (those which cannot be reached by consciousness), (3) in consequence, the social transmission of tacit knowledge which cannot be reached by consciousness protects the evolutionary potential associated with any form of social evolution, (4) the principles stated in 1-3 are general and are also present in the evolution of knowledge in business organisations.

To make the argument a bit tighter, it is necessary to give the term "evolutionary potential" more precise meaning. One way to do this is to define term "evolutionary potential" in terms of the potential for continued evolution (Maynard Smith & Szathmáry, 1999). Implicit in the principle of Local Emulative Selection is that the heredity mechanism is protected from untimely adaptation and, therefore, provides a necessary basis for continued evolution even when the possibility of improvement offered by the environment is very small. The protection of the hereditary mechanism is a necessary but not sufficient condition for continued evolution. According to Maynard Smith & Szathmáry (1999) continued evolution has two additional requirements. The first requirement is a system of unlimited heredity in which an indefinitely large number of structural variants of allomemes (or genes) are each capable of evolution (Maynard Smith & Szathmáry, 1999). The second requirement, associated with any system of unlimited heredity, is the principle of modular heredity according to which the replicating system can change one attribute without influencing the rest. I briefly consider how Local Emulative Selection fulfils each requirement.

According to the principle of Local Emulative Selection, knowledge is socially transmitted over a relatively long period of time where newcomers emulate the seasoned member's allomemes. This could, for example, happen as a newcomer is socialised and trained in a religious order (Durkheim, 1995), in a military team (Dockery & Fawcett, 1998), in a unit of some police force (Van Maanen, 1973), in a team of nurses (Fox, 1997) or in any business organisation (Nelson & Winter, 1982). As a result, the existing members' allomemes are replicated. But in the process of replication, the allomeme is altered due the recombination of the transmitted allomeme with the new member's prior related knowledge. In addition, there is likely to be some error in replication. Since the principle of Local Emulative Selection ensures that the acquired variation is sustained, we have potentially an indefinitely large number of structural variants of allomemes each capable of evolution. That is, we have a system of unlimited heredity required for continued evolution according to Maynard Smith & Szathmáry (1999).

The second requirement of continued evolution, modular heredity, refers to the principle that changing any part of the heredity system and leaving the rest unaltered will only influence the replicating system in the module that was changed. For example, when any module of the genetic system (the nucleotide base) is changed and any other part left unaltered, the descendant molecules are just changed in that place (Maynard Smith & Szathmáry, 1999). Language is, according to Maynard Smith & Szathmáry (1999), the only other natural system of unlimited heredity and it has also the property of modular heredity:

> *[Language] is a system in which a small number of unit sounds (phonemes, roughly corresponding to the sounds indicated by the letters of the alphabet) can be strung together in different orders to express an indefinitely large number of different meanings. (Maynard Smith & Szathmáry, 1999: 9).*

Other examples provided by Maynard Smith & Szathmáry (1999) include so-called artificial systems of unlimited heredity such as the Morse code and the ASCII code. Since Maynard Smith & Szathmáry (1999) insist that all systems of unlimited heredity will turn out to be modular, it would be important to know whether the replicating machinery involved in Local Emulative Selection is modular. To do this one may consider that the allomeme is conceptualised as an ideational unit and then establish whether it is possible to change one ideational component without changing all the other. If we think of ideational components in terms of a system of cognitive categories (an idea backed up by cognitive psychology), it is conceivable that it is possible to alter a component of one category without influencing any other category.

Since Local Emulative Selection is a system of unlimited heredity and may, at least to some degree, have the property of modular heredity, it has the potential of continued evolution. And so has cultural evolution. The only difference in terms of evolutionary potential, according to Maynard Smith & Szathmáry's (1999) criteria is that the role of tacit knowledge in Local Emulative Selection is to protect the heredity mechanism from adaptation. And as we have seen, this protection is crucial in an environment that only offers small possibilities of improvement. A further reason why the protection of the heredity mechanism is required to preserve evolutionary potential is the possibility that variation may be destroyed by free adaptation when, for example, all members of a population would want to imitate some particularly attractive allomeme. According to these two reasons, a systematic reduction of the importance of tacit knowledge and thus Local Emulative Selection would threaten the evolutionary potential of any form of social evolution. In the hypothetical case where a systematic effort to codify tacit knowledge in, for example, a business organisation, should be met with success, the result would then be a loss of evolutionary potential. In consequence, the organisation would be threatened by degeneration as it lost the ability to distinguish between illusionary and possible improvements. Another possibility is that social systems would increasingly exhibit short-term evolutionary bursts (autocatalytic cycles) followed by degeneration.

In sum, the above argument implies that any form of cultural evolution will necessarily rely on a high degree of immutability in the underlying cultural code contained in the allomemes or routines. And whatever the exact selection mechanism, tacit knowledge will tend to provide the required immutability to protect evolutionary potential. This argument runs counter to a recent argument that the codification of tacit knowledge may be a source of competitive advantage for business organisations. On basis of the proposed link between tacit knowledge and evolutionary potential, I have pointed out why successful codification will erode the firm's evolutionary potential. In view of this conclusion, I will use three contributions by influential proponents of the idea of codification of tacit knowledge (variously referred to as unsticking tacit knowledge and externalising tacit knowledge) to discuss the efficacy of this idea in terms of evolutionary potential.

According to von Hippel (1999), an important aspect of sticky information (information that is costly to acquire, transfer and use) is tacit knowledge, which increases the costs of transferring information between technical problem solvers. Therefore, if information held at one locus for problem solving activities is sticky, problem solving activities will tend to be located at that site and if more loci with sticky information are present, problem solving activities will iterate between them (von Hippel, 1999). As the costs of iterating the locus of the problem-solving activity increases, there will be increasing incentives to “unstick” the information and sometimes efforts will be directed toward that end (von Hippel, 1991). In consequence, von Hippel (1999) suggests that the incentives to unstick information will increase in the number of potential future transfers. Since von Hippel (1999) focuses on the producer-user interface this conclusion seems reasonable in the sense that unsticking user-side information will increase user-friendliness and thus potentially increase demand. Von Hippel (1999) did not consider the associated problem of evolutionary potential, however. It is, for example, unclear if von Hippel (1999) implies a systematic reduction in tacit knowledge, which could threaten the organisation’s evolutionary potential? In view of the neglect of the potential problems in unsticking tacit knowledge, von Hippel’s (1999) view on the advantage associated with unsticking information seems too optimistic. Further important examples of this optimistic view of unsticking information, externalising knowledge or codifying tacit knowledge can be found in Nonaka & Takeuchi (1995) and Zollo & Winter (1999).

Nonaka & Takeuchi (1995) present a detailed discussion of the development of organisational knowledge. Their view that organisational knowledge creation is a continuous dynamic interaction between tacit and explicit knowledge is consistent with the present article’s view that the evolution of knowledge requires that a Lamarckian process of cultural evolution must be nested within a process of Local Emulative Selection. And so is Nonaka & Takeuchi’s (1995) view that individually held tacit knowledge is the basis for organisational knowledge creation. But due to the problem of sustaining evolutionary potential, Nonaka & Takeuchi’s idea of systematic externalisation of tacit knowledge seems too optimistic. It must be said, however, that Nonaka & Takeuchi’s (1995) model also involves creation of new tacit knowledge through internalisation. Still, if both the processes of internalisation and externalisation are speeded up, the organisation's evolutionary potential could be threatened because of the base-line problem. This suggests that the link between tacit knowledge and evolutionary potential must be considered in relation to Nonaka & Takeuchi's (1995) discussion of the creation of organisational knowledge. A possible solution to the implied problem of loss of evolutionary potential could be that some underlying process in Nonaka & Takeuchi's (1995) story was never "externalised." In this case, the idea that a process of cultural evolution is nested within an underlying process of Local Emulative Selection could be upheld. Moreover, this conceptualisation has some affinity with Zollo & Winter's (1999) recent model of co-evolution between tacit and explicit mechanisms of knowledge accumulation.

According to Zollo & Winter (1999), dynamic capabilities emerge from the co-evolution of tacit experience accumulation with explicit cognitive investments in knowledge articulation and codification. As a result of the mixture of these three processes, the organisation's existing routines are constantly reshaped and new are created. The basic idea is comparable to Nonaka & Takeuchi's (1995) learning model in the sense that ideas which exist in an embryonic and partly tacit form are subject to an internal pressure aimed at evaluating their potential (Zollo & Winter, 1999). In consequence, it is argued that the knowledge articulation and -codification process constitutes the internal selection pressure.

There is no doubt that articulation and codification plays an important role in development of dynamic capabilities in a turbulent environment as argued by Zollo & Winter (1999). And Zollo & Winter's (1999) hypotheses that the importance of explicit codified knowledge increases as the organisation must adapt to infrequent events, increasing task heterogeneity and causal ambiguity between actions and outcomes seem reasonable. By definition, experience accumulated over a high number of frequent and similar occurrences is ruled out in the two first cases. And the latter case, may completely undermine the efficacy of experience based learning. So far so good. It is an open question, however, if the form of knowledge codification considered by Zollo & Winter (1999) actually threatens an underlying evolutionary process of implicit learning in the sense of Local Emulative Selection? And related, will any form of articulation and codification of tacit knowledge not have to rely on a set of pre-existing cognitive frames previously generated through some process that works like Local Emulative Selection?

It appears that Zollo & Winter (1999) consider a trade-off between tacit and explicit articulated or codified knowledge. If so, a systematic codification of tacit knowledge will threaten the firm's evolutionary potential. But perhaps Zollo & Winter (1999) only describe the subset of tacit knowledge that can potentially be codified. In this case, an underlying process of Local Emulative Selection would still be possible. Such a process would also complement rather than negate the internal selection mechanism suggested by Zollo & Winter (1999). But what about the argument that codified knowledge is superior when the organisation is faced with infrequent events, a heterogeneous task environment and causal ambiguity? Perhaps, an underlying implicit learning process is disabled under these conditions but will a decision based on codified knowledge make a difference? One problem with this argument is that the internal selection of the subset of tacit knowledge to be converted is only possible if some selection criteria are in place. And since the provision of criteria for the internal selection of tacit knowledge requires that a set of cognitive categories already are in place, we may ask how these cognitive categories have evolved? Zollo & Winter (1999) leave the question open but one possible answer is Local Emulative Selection. A second problem is the empirical evidence related to the type of situations that according to Zollo & Winter (1999) should favour the use of codified knowledge. Thus, according to Reason (1990), studies of human error associated with infrequent events and causal ambiguity indicate that a cognitive mode does not necessarily reduce error but rather produces other less predictable error forms than a skill- or rule-based mode of operation.

In sum, the proposed link between tacit knowledge and evolutionary potential questions the optimism related to codification of tacit knowledge. In fact, should such an endeavour be met with success in the sense that the organisation's pool of tacit knowledge should somehow decrease, the firm's evolutionary fate seems less promising. One reason for the optimism associated with codification of tacit knowledge is undoubtedly that the base-line problem and its role in connecting tacit knowledge and evolutionary potential has been overlooked by previous authors. Another, is that articulation and codification of tacit knowledge is clearly a source of advantage in diffusion (Nonaka & Takeuchi, 1995) as well as a possible advantage in turbulent and complex circumstances (Zollo & Winter, 1999). Moreover, the successful codification of tacit knowledge seems inextricably connected with success in innovation. The problem is not so much that all these activities involve codification of tacit knowledge but rather the implied interference with an underlying process of implicit learning.

Conclusion

The present article has suggested that socially transmitted tacit knowledge may play a crucial role in protecting the firm's evolutionary potential and that successful attempts to systematically codify tacit knowledge may threaten the firm's evolutionary fate.

The present study used Durham's (1991) detailed Lamarckian model of cultural evolution as a basis to develop a complementary evolutionary model of socially transmitted tacit knowledge. This model differs from cultural evolution where explicit knowledge is conveyed through choice or imposition. By contrast, the proposed complementary model was based on the principle of Local Emulative Selection which is consistent with the neo-Darwinian understanding of natural selection since the carrier of (some forms of) tacit knowledge cannot choose to change it. Although this idea has not previously been fully developed, Nelson & Winter's (1982) emphasis of the role of tacit knowledge in routine behaviour is an important aspect of Local Emulative Selection. The added ingredient in Local Emulative Selection is the idea that tacit knowledge is directly transmitted among people in work groups.

This idea goes back at least to Aristotle and the associated empirical claim is supported by massive empirical evidence in the rapidly growing subfield of experimental psychology, which over the last 30 years has studied implicit learning (Kentridge & Heywood, 2000; Liebermann, 2000; Nisbett & Wilson, 1977; Reber, 1993). According to the literature on implicit learning, intuitive, analytic and deliberative cognition are best seen as separate and yet interdependent modes of cognition (see e.g. Eraut, 2000). In other words, analytic and deliberate cognition is always supported by intuitive decision-making based on tacit knowledge conveyed through implicit learning. One of the most important implications of these insights is that tacit and codified knowledge should be viewed as complements rather than opposites. In other words, deliberative choice is facilitated rather than debilitated by the tacit knowledge acquired through implicit learning. In economics, this point has not yet been taken fully on board (rare exceptions include Day, 1993, Loasby, 1999 and Witt, 1986) but the implications seem far-reaching. In the following, I will focus on a subset of these implications related to the role of the workgroup in the (evolutionary) theory of the firm. A more comprehensive treatment must be postponed to future work due to limitations of space.

First, the idea that there should be a trade-off between tacit and codified knowledge seems questionable. As suggested by Loasby (1999), by converting tacit knowledge into readily transferable codified knowledge, codification may be an investment that produces substantial benefits for the firm. The source of these benefits is the increased potential for diffusion among those who use the same explicit codes and procedures (Loasby, 1999). This viewpoint implies, as von Hippel (1999), Nonaka & Takeuchi (1995), Zollo & Winter (1999) and others have pointed out, that competitive advantage may come from differential capability in converting tacit into explicit knowledge as well as differential capability in continuous recreation of the required basis of tacit knowledge.

Although the amount of codified knowledge has undoubtedly increased rapidly over the last centuries and continues to do so because of printed media, electronic mass-media, the telegraph, the telephone, the IT-revolution and so forth, there is no reason to believe that the *proportion* that has been codified has also increased (Loasby, 1999). According to the literature on implicit learning, analytic and deliberate cognition is always supported by intuitive decision-making based on tacit knowledge. It is, therefore, questionable that increased codification will lead to a decrease in the amount of tacit knowledge. Rather, the evolution of tacit knowledge follows a separate track that supports the possibility of codification. Accordingly, codification may slightly reduce some fraction of tacit knowledge but perhaps the codification exercise actually produces an even larger basis of tacit knowledge to support the resulting elaboration of explicit cognitive categories. This argument is consistent with the characterisation of the role of tacit knowledge in the implicit learning literature and perhaps an underlying reason why, as indicated by Zollo & Winter (1999), organisational rigidity seems to increase in codification. If this is true, we need not worry about the loss in evolutionary potential caused by the conversion of tacit knowledge *per se*.

Nevertheless, codification may for a different reason threaten the evolution of tacit knowledge. It was argued above that the social transmission of tacit knowledge is predominantly direct and, therefore, takes place in face-to-face groups. This argument, in turn, implies that the team or the workgroup is the proper unit of selection, an important clarification in the evolutionary theory of the firm. A newcomer's relatively long period of exposure to seasoned team members will allow direct transmission of tacit knowledge through implicit learning. Once acquired, this tacit knowledge will form the basis of the group's deliberate decisions by providing the necessary shared cognitive categories enabling the team's intuitive understanding of various different work-related situations and rules and the smooth execution of routinised action sequences. In other words, the team's shared basis of tacit knowledge is maintained by use (Nelson & Winter, 1982) and should the team be disbanded for some time, it will be almost impossible to re-establish this shared basis of tacit knowledge. But since a tacit basis developed over a long time, and perhaps through extreme pressure, tends to be very deeply ingrained and to some extent will persist change, a retired member who return to a well-functioning team may almost instantly fall back into the familiar intuitive understanding etc. In consequence, the interesting empirical and managerial variable is employee turn over (and technology turn over)[iii]. The higher the turn over of employees, the more error in replication and, at the limit, the greater the threat to the team's evolutionary potential. According to this argument, one should never change a winning team. But some teams are loosing teams. Since evolution does not guarantee optimal outcomes, a team stuck on a degenerate evolutionary path may be set on a different (and perhaps better) path by increasing the rate of employee turn over.

Although the expression of this argument differs from March's (1991) model of exploration and exploitation, the underlying logic is identical. According to March (1991), the absolute level of organisational learning may be increased by reducing the speed of learning. Similarly, the present argument implies that the evolutionary potential of a workgroup may increase by reducing the rate of employee turn over. If true, one of the most important roles for the manager is to provide the environment for the evolution of workgroups, to regulate the speed of employee turn over in the workgroup and to disband degenerate workgroups. The argument further implies that codification exercises will interfere with the workgroup and it may be this interference rather than codification *per se* which influences the team's basis of tacit knowledge. If this is the case, codification can, as employee turn over, be viewed as an instrument to infuse variation in workgroups in order to increase the group's creativity at the expense of some reliability and, in extreme cases, its long-term viability.

At least two general implications follow from the present argument. First, the above argument implies that an important role of the firm is to protect the evolutionary potential (learning properties) its workgroups in the face of a stochastic or uncertain environment. Second, the argument suggests that explicit analytic and deliberate cognition and implicit intuitive decision-making are not really rivalling modes of managerial behaviour in any form of complex and dynamic environment. Different situations call for a difference in emphasis (Bock & Griffin, 2000; Reason, 1990; Witt, 1986), and, implicit intuition can never substitute for deliberate decision making as little as the latter is possible without any form of tacit knowledge[iv].

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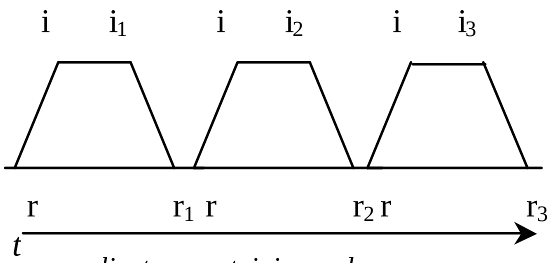
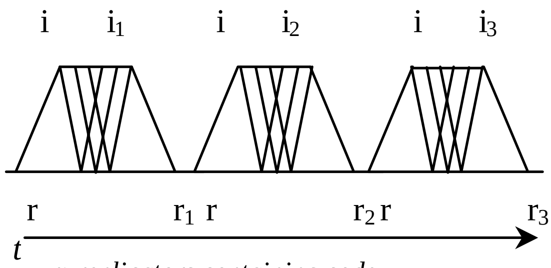
Figure 1

1. Darwinian Evolution (phylogenetic)
- Replication with random component + recombination
- Differential success in competitive interactions



r: replicators containing code,
i: interactors with behaviour patterns instructed by the replicating code

2. Lamarckian Evolution (phylogenetic)
- Environmental stimuli change the replicators' instructions
- Replication (actual process must be specified)
- Differential success in competitive interactions



r: replicators containing code,
i: interactors with behaviour patterns instructed by the replicating code

Figure 2. Sample size as the function of relative tolerance

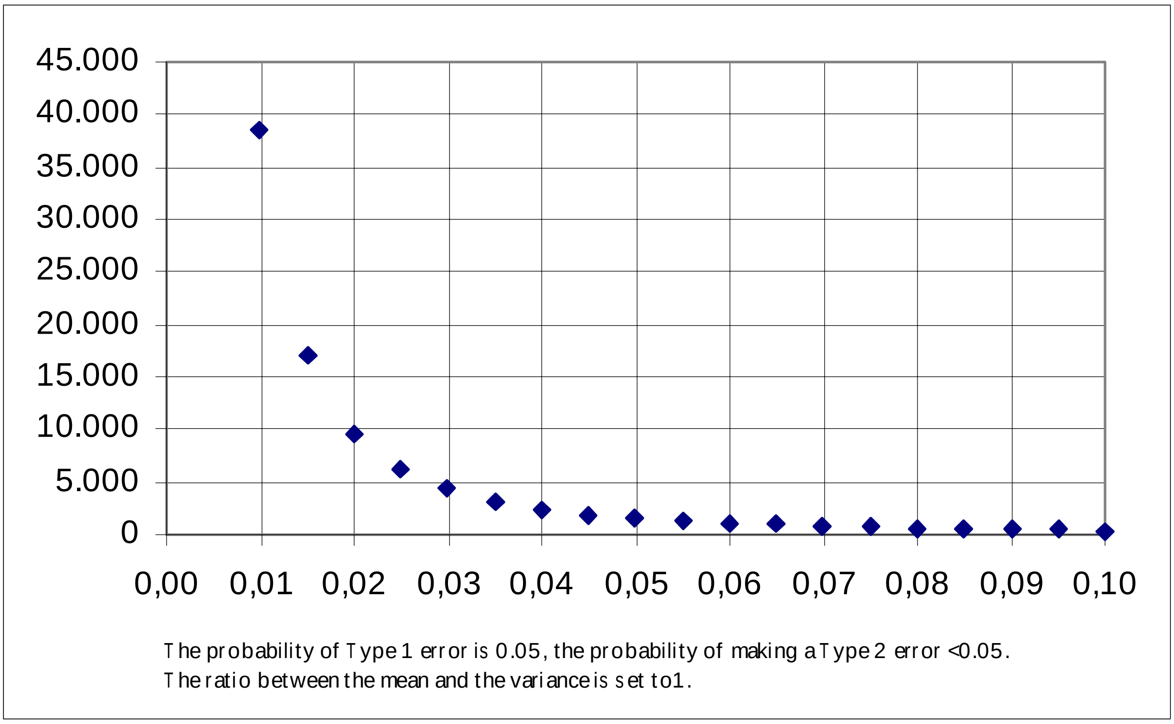


Table 1

	Environment	
Treatment	*Shift in regime*	*No shift in regime*
Adapt	Invalid estimates	Improve validity of estimates
Do not adapt	Improve reliability of estimates	Improve reliability of estimates

End-notes

[i] According to neo-Darwinian theory, information flows from genes to soma cells is prevented by Weismann's barrier, the molecular barrier that prevents Lamarckian inheritance. In its modern form Weismann's barrier translates into the central dogma which states that information can flow from DNA and RNA to proteins but never in the reverse direction, i.e., this defines the following relation between genes and soma cells: DNA <-> RNA -> protein. When referring to natural selection or Darwinian selection, the present article refers to the neo-Darwinian understanding.

[ii] There is much confusion on this point in evolutionary economics; however, deliberateness is not a necessary condition for Lamarckism. If routines can be changed deliberately, the explanation is certainly Lamarckian, but the reverse conclusion does not necessarily hold.

[iii] Due to limitations of space, the problem of technology turn over is not considered in detail.

[iv] This conclusion can only be upheld, if the problematic idea that economic "natural selection" will converge in maximizing behaviour is excused. But few defenders of this viewpoint remain (see e.g. March, 1994).