Variation, replication and selection in evolving industries

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Abstract
Purpose – Variation, replication and selection processes are acknowledged as key constructs in studies on how industries evolve, but no theoretical and empirical contributions have applied these key constructs to analyzing industries in specific stages of their history. This paper aims to fill this gap, taking for reference the firm and its strategic action in particular.

Design/methodology/approach – After delineating and discussing the three processes of interest – variation, replication and selection – this paper analyzes three very different evolutionary contexts: “red” industries, that reached maturity maintaining a polypolistic structure, and that continue to evolve in this phase; the oligopolistic transformation undergone by certain industries; and the emergence of new market spaces around new products developed by firms.

Findings – Variations are mainly reactions to the competitive environment in the evolution of red industries or environment-modifying in the case of industries evolving toward an oligopoly, and in the creation of new market spaces. Horizontal replication through employee mobility prevails in red industries, while in the other two contexts firms driving the evolution raise barriers to replication, inhibiting both horizontal and vertical replication. While selection does not come about in a new market space as long as the barriers erected by the first comer remain in place, it occurs in the form of subset selection in the other two settings.

Originality/value – This paper takes an entirely novel approach and proposes a pluralist framing of how industries evolve, interpreting the different evolutionary situations on the strength of the key variables of variation, replication and selection.

Keywords Selection, Oligopoly, Variation, Replication, New market space, Red industry

Paper type Conceptual paper

Introduction
What does the evolution of an industry have in common with the evolution of a biological species, apart from the fact that they both occur in populations? Hodgson and Knudsen, the fathers of the approach known as “Generalized Darwinism,” find the answer to this question in three key, interrelated evolutionary processes that they (and others) see as essential ingredients of the evolution of biological species and industries alike, i.e. variation, replication and selection (Aldrich et al., 2008; Hodgson and Knudsen, 2010b). Even leaving the approach of Generalized Darwinism aside, these three processes [1] are acknowledged as key constructs in research on industry evolution, starting with the classic contribution from Nelson and Winter (1982).

That said, we can envisage the history of industries (in the sense of populations of firms competing and interacting with each other) [2] as going through phases that appear to differ when interpreted in evolutionary terms, and we can see these phases as not being invariant.

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in the generality of industries. However, then we come up against a discouraging lack of theoretical and empirical contributions analyzing these specific evolutionary contexts on the basis of the three key constructs of variation, replication and selection. To give an example of the questions remaining to be answered, how has the selection process worked (if it has worked) in sectors that have acquired an oligopolistic configuration over a period of time? The literature provides no answer to such a question.

The present paper aims to start filling this gap, taking the firm (particularly in its strategic action) for reference in the application of the three constructs. To do so, we look at three evolutionary contexts, chosen because they are very different from one another and because their relevance in industry evolution has meant that they have been widely analyzed in other studies, albeit from a different perspective from our own. The first context concerns industries that have reached maturity while retaining a polypolistic structure and that continue gradually to evolve. The second concerns the oligopolistic transformation some industries undergo as a result of variations that the most able companies succeed in developing and that are difficult for others to imitate. The third context involves the creation of a new market space by firms that develop new products (goods or services) and markets for them.

**Variation, replication and selection in evolving populations**

Given the causal link between a genotype – that in organizations coincides with a routine or set of routines (Aldrich et al., 2020; Hodgson and Knudsen, 2010b; Nelson and Winter, 1982) – and its phenotypic trait, a variation means a change in the former that causes a change in the latter. Variations can happen by chance (as in the case of genetic mutations) or they may be adaptive, due to some interaction between the organism (or organization) and the environment that helps the former to increase its fitness. Another important distinction to draw is between incremental variations as opposed to disruptive or discontinuous variations (Breslin, 2008).

Replication is the process that leads to the creation of a copy of the structure of a given genotype (Hodgson and Knudsen, 2004, 2010a). This process may be “vertical,” when it is associated with the reproduction of an organism or organization, as in the case of spin-offs founded by employees who inherit the parent firms’ knowledge and replicate it in a new venture (Klepper, 2001). On the other hand, inter-firm imitation – through the mobility of experienced employees – can be defined as “horizontal” because it involves firms belonging to the same industry (Nelson and Winter, 1982; Wezel et al., 2006). In the biological world, horizontal replication takes the shape of horizontal gene transfer (Koonin, 2012).

Replication can take place within the same organism (organization) or involve two distinct organisms (organizations) in vertical or horizontal form. In the case of organizations and industries, Nelson and Winter (1982) were the first to highlight this point by comparing intra-organizational replication with inter-organizational imitation and emphasizing how the latter is more difficult to achieve than the former. However, difficult does not mean impossible, and imitation in fact plays an important role in the formal models developed by the two authors, as it did in the way in which Joseph Schumpeter (1934), the economist who inspired their work the most, conceived of dynamic competition.

Whenever variations affect the capacity of individuals in the population to survive and reproduce, positive variations will be increasingly reflected in future generations, and the opposite will apply to negative variations. This differential reproduction is natural selection in action, the idea on which Darwin (1859) developed his theory of evolution. Alongside this type of selection, Price (1995) also considers that of a subset of individuals being “picked out” from a set according to a given criterion of preference. This differential elimination may be carried out by some agent or factor in the environment (Hodgson and Knudsen, 2006).
Subset selection clearly differs from Darwinian selection, which cannot disregard the reproduction of organisms within a population (Gayon, 2011; Liagouras, 2013). Let us now consider the two modes of evolution that have traditionally been placed in opposition in the history of biological thought and beyond, i.e. Lamarckian and Darwinian evolution. While variations are strictly accidental according to the latter view, the Lamarckian approach sees them as the outcome of an interaction between an organism (organization) and its environment, i.e. they are adaptive. Since concerns the first key construct, the only thing the Darwinian and Lamarckian modes of evolution have in common is the incremental nature of variations, which do not allow for evolutionary leaps (Rhodes, 1987). According to Lamarck’s (1809) most important work, adaptive changes are conserved by the modified organisms and transmitted to their progeny. This reproductive or vertical form of replication is fully consistent with the approach of Darwin. However, in another work, Lamarck (1802, p. 61) wrote that each acquired change:

[...] propagates itself and thus passes to all the individuals that follow one another and that are submitted to the same circumstances, without them having been obliged to acquire it by the way that really created it.

This is clearly a form of horizontal replication. Then there is the Darwinian concept of natural selection, which is foreign to Lamarck’s idea of evolution (Mayr, 1982). According to Darwin, individuals of a given species sharing the same environment differ from one another, and it is on this diversity that selection takes effect. In short, the Darwinian model of evolution consists in a combination of accidental variations, vertical replications and natural selection, while the Lamarckian mode involves a combination of adaptive variations, vertical and horizontal replications and no selection.

**Evolving “red” industries**

The focus here is on industries in the position of being “a seller among very many” (Machlup, 1952, p. 85); in other words, they have reached maturity without taking on an oligopolistic configuration (Klepper, 2002a). Such a polypolistic structure is common to many industries today, and a far cry from the model of perfect competition because it includes firms of very different dimensions wielding different amounts of market power. Strongly non-symmetrical structures form largely as a result of globalization, which has unhinged the local or domestic markets in every industry, from furniture manufacturing (Carpano et al., 2006) to restaurants (Sun and Lee, 2013).

For these industries, there is intense competition in relation to unfavorable conditions of both supply (due to the large number of competitors) and demand (due to growth ranging from negative to very low). Kim and Mauborgne (2015) provide an effective description of the competitive situation of a mature industry using the metaphor of the red ocean (as opposed to the blue ocean, which is a new market space): red industries form a crowded market space where head-to-head competitors try to outperform each other to grab a greater share of existing demand.

Looking at a red industry from an evolutionary standpoint, variations that firms can develop are aimed at reducing costs or increasing differentiation and are normally of an incremental nature (Badrinas and Vilà, 2015; Kim and Mauborgne, 2015). The red industry’s long history will have generated a knowledge base shared by the actors (firms and institutions) working in it. A high cognitive proximity (Nooteboom, 2000) facilitates the mobility of employees and the transfer of knowledge from one firm to another (Breschi and Lissoni, 2001; Camuffo and Grandinetti, 2011; Wezel et al., 2006). Such episodes of mobility nourish this cognitive proximity within the sector, both on the side of hiring firms and on that of firms losing employees, if we take the employees’ social capital into account (Corredoira and
In short, the replication mechanism mediated by employee mobility, i.e. horizontal replication, is distinctive of such a mature stage, when variations introduced by incumbent firms will generally be of modest extent, and may easily be replicated by competitors with the help of key employees, i.e. those who have experience of the variation.

The outcome of the replication process may not be an exact copy of the knowledge available in the parent company, however, in which case, there is a hybrid process of replication and variation. This is what Hodgson and Knudsen (2010a) call generative replication, which can produce different types of variation: imperfect (accidental) variations that do not work in the recipient organizations; variations predisposed to adapt the knowledge imported in the new organizational context; variations that amount to innovations, the value of which transcends the organizations in which they are developed. The third, and most interesting for the industry’s evolution are achieved by imitators who are destined in turn to be imitated themselves.

Unlike horizontal replication, vertical replication through spin-offs is not a distinctive feature of red industries. Employees in incumbent firms are hardly motivated to use the knowledge they have acquired to create new ventures in a market that has the color of blood (Grandinetti, 2018). To be more precise, new ventures have to cope with their initial inexperience. This liability of newness, as Stinchcombe (1965) called it, is mitigated when new ventures are founded by people who have worked in firms in the same industry (Klepper, 2009). However, an industry where the competition is intense makes experienced employees doubt whether their cognitive advantage will suffice, and reduces their propensity to become entrepreneurs.

Regarding selection, a mature and polypolistic industry could evolve in the absence of selection, and therefore in the Lamarckian form, when the changes introduced by innovative firms spread rapidly to the rest of the industry’s population. More realistically, selection comes into play because the firm capabilities that are relevant from the evolutionary standpoint are not evenly distributed within the industry population. As well as firms capable of introducing favorable variations and firms capable of imitating them, there are also firms that have neither of these capabilities. This difference creates the conditions for the selection process to take place. However, this is not a matter of Darwinian natural selection, which takes effect in the presence of vertical replication and offspring (Gayon, 2011). It is a case of subset selection, as described by Price (1995), where the intense competition causes the expulsion (or weakening at least) of any incumbents or new ventures unable to introduce or imitate favorable variations. Tough competition is an environmental factor that favors subset selection, not Darwinian selection, as Alchian (1950) first claimed (though many other economists and management scholars subsequently agreed with this authoritative scholar).

Drawing on the salient aspects emerging from the above outline of the evolutionary scenario of a mature industry – adaptive variation, horizontal replication and subset selection – it appears not only fully Lamarckian because it involves (subset) selection but also completely not Darwinian.
When evolution leads to an oligopoly
Several mature industries have acquired an oligopolistic rather than a polypolistic configuration. Scholars of industrial organization and evolutionary economics have paid great attention to this oligopolistic transformation, in general, or in relation to specific industries. In particular, studies taking a historical perspective have highlighted how an oligopolistic structure is the result of a differential growth achieved by firms able to interact with their competitive environment from an advantageous position because of capabilities accumulated over time (Dekkers, 2005; Izzo, 2017; Klepper, 2002a; Klepper and Simons, 2000; Malerba et al., 2016).

Interpreting the emergence of an oligopoly using the categories of evolutionary analysis discussed in this paper, we could say that leading companies develop complex variations that are difficult to replicate, making both vertical replication via spin-offs and horizontal replication through key employee mobility less likely (Furlan and Grandinetti, 2020). Raising barriers to inter-organizational replication thus increases the cognitive distance between firms within an industry, eliminating the condition that explains the evolution of red industries, as we have seen. Precisely, there is an increase in the cognitive distance between the limited group of firms destined to remain as oligopolists (which still form a heterogeneous group from the “genetic” standpoint) and the other incumbents, which gradually exit the market. Here again, we can see Price’s subset selection (1995) at work, or rather a variant of it, since the outcome is not just the permanence in the market of the most capable firms but also their differential intra-organizational growth (Andersen, 2004). This is how Nelson and Winter conceived selection in their influential Evolutionary Theory of Economic Change (Nelson and Winter, 1982).

The oligopolistic transformation of an industry is also a gradualistic evolutionary pattern (Dekkers, 2005). As there is nothing like the differential growth of firms in the biological world (Gayon, 2011; Nelson, 1995), this pattern has little of Lamarck’s mode of evolution and nothing of Darwin’s. With the former, it only shares the non-accidental nature of variations. The interaction between firm and environment that lies behind adaptive variations nonetheless seems to differ in evolving red industries and emerging oligopolies as regards the greater degrees of freedom available to the emerging oligopolists in their strategic action. In particular, their adaptive variations modify the environment to some extent. This capacity is reinforced when the oligopolistic configuration of the industry becomes well-established, also by virtue of the collusive practices typical of industries of this type (Caves and Porter, 1978).

The differential growth leading to the formation of an oligopoly is not replicative in nature within the growing organization – except in the case of chain organizations, which grow by establishing outlets for delivering a product or providing a service. It is worth pausing a moment on this particular type of firm growth, outside the confines of oligopolistic transformations because it is intriguing from an evolutionary point of view. It has been studied as a case of intra-organizational routine replication (Friesl and Larty, 2013), covering both the replication that takes place within the boundaries of a given company and the replication associated with the development of franchising chains. In presenting the key elements of this replication strategy, Winter and Szulanski (2001) refine the concept of “template” already introduced by Nelson and Winter (1982). They define it as a working example of a successful routine or set of routines, accessible only to the replicating firm, which gives it an advantage over any potential imitator.

Looking at the growth of chain organizations, Winter and Szulanski (2001) associate (intra-organizational) replication with adaptation in the form of a dilemma: the benefits of exploiting existing knowledge and routines that have already been amply tested and can
serve as a template would point toward an exact replication, but the place where the umpteenth outlet (be it a factory, a store, a fast-food outlet or a branch of a bank) is opened may demand a learning effort to adapt to peculiarities of the new local context. Szulanski and Jensen (2008) and Winter et al. (2012) compare the replication hypothesis with the adaptation hypothesis, finding empirical support for the former. Instead, Jonsson and Foss (2011) describe the solution to the replication dilemma adopted by Ikea in its international development strategy as a replication that is flexible and, at the same time, hierarchical. When opening a new store, best practices and standardized work routines are transferred from the firm’s headquarters to the new outlet, while other routines – concerning pricing, for instance – may vary in response to local conditions.

Both Winter and Szulanski (2001) and Jonsson and Foss (2011) see growth by replication as an intrinsically dynamic process. The experiential knowledge produced in various ways in the network of outlets is monitored and analyzed at the firm’s headquarters, and the replication format or template is modified accordingly. The new template is used to open new outlets but also to update existing outlets. The knowledge flows between the center and the periphery of the organization seem to involve a sort of subset selection, but on closer inspection, we can see that it is a selective practice intrinsic in the complex process of variation (and its replication) specific to chain organizations. If we wanted to see it as a form of selection, we would be talking about subset selection within organizations (Knudsen, 2002). However, our analysis does not deal with internal or managerial selection, a concept which has been given different meanings by different authors (Breslin, 2008).

Returning to the oligopolistic transformation of a sector, this cannot be framed as either a Lamarckian or a Darwinian mode of evolution. The differential growth of the firms in such an industry leads this type of evolution to be classifiable only in the domain of human organizations.

The creation of a new market space as an evolutionary leap
Sometimes, an incumbent among very many or a new entrant succeeds in escaping the rigid competitive rules governing red industries and carving out a new market space (Buenstorf, 2016). In their bestseller Blue Ocean Strategy, Kim and Mauborgne (2015) often mention Cirque du Soleil as an excellent example of this. The idea that enabled this start-up to make a clean break with the red industry of the circus consisted in: creating a new, uncontested market space; making the competition irrelevant; bringing out a new demand; breaking the differentiation-cost trade-off theorized by Porter (1985); and aligning the firm’s value chain and value network with this strategy. The birth and success of Cirque du Soleil ticks all these boxes, but its most interesting feature for the purposes of our analysis concerns the creation of a new market space in the vast market of entertainment, and specifically of urban live entertainment. This was done by means of a combination or brokerage à la Burt (2004) between two knowledge domains – circus and theater – which resulted in the creation of a completely original type of entertainment. The originality of this innovation and, of course, the ability to do all that was needed to put it into practice triggered the extraordinary success of Cirque du Soleil, which was created in 1984 and is still hard to imitate (Kim and Mauborgne, 2015). Interestingly, it was not created by an incumbent organization in the circus or theatre industry, but by a group of street performers in Montreal (Cohendet et al., 2010).

Considering Cirque du Soleil as a product, its birth corresponded to the emergence of a new product market within the larger entertainment market. Seen from this point of view, the case is similar to that of other new products (goods or services) that prompted the emergence of a new market space around them because of their capacity to meet a need in a novel way. Here it is useful to distinguish the technological history of an innovative product
from its arrival on the market and the consequent emergence of a new product market. The
former process corresponds to the “genotypic” construction of a variation, the latter to its
“phenotypic” expression, observable and assessable by actors in the competitive
environment. The time elapsing between the start of the first process and the start of the
second may be very long and the path tortuous, however. A good example is the case of the
microwave oven: it took 20 years from the (serendipitous) birth of the idea at Raytheon – a
US military contractor – to when the company managed to develop a product appealing to
consumers and a winning marketing strategy (Andriani and Carignani, 2014).
Cirque du Soleil (service) and Raytheon’s microwave oven (good) were offered to consumers,
and perceived by the latter, as products that did not previously exist on the market.
New market spaces can also be created by innovations that lead to the re-conceptualization of
existing products, however. An emblematic example is the case of Swatch, the first watch to be
presented as “a creative, artistic, emotional, and fashion accessory” (Garel, 2015, p. 35).
Equally emblematic, though less famous, is the case of “easy to wear” jewelry designed by Morellato, an
Italian fashion company (Furlan and Grandinetti, 2011).
Some new market spaces that have emerged in recent times are the outcome of the
construction of digital platforms (de Reuver et al., 2018). Such spaces are not new product
markets but stem from a completely new conception and development of an existing product,
something similar to the cases just mentioned. Airbnb and Uber (Van Alstyne et al., 2016)
are the most often-mentioned cases of these platform-based market spaces. Platforms involve the
rise of a system of interdependent actors governed by a platform leader, i.e. the company that
creates the platform by establishing its standards and rules of participation (Gawer and
Henderson, 2007; Parker et al., 2016). In certain platforms, some participants can develop their
own complementary products, technologies or services (Gawer and Cusumano, 2014).
From the evolutionary standpoint, the creation of a new market space is a phenomenon
of discontinuous type that finds no correspondence in biological evolution. The firm that
succeeds in making this evolutionary leap may be a new venture, an incumbent or a firm
belonging to another sector and interested in diversifying its business. In any case, the firm
succeeds in creating a variation, or set of variations, that always modifies the environment,
starting from its impact on consumers who, by appreciating its phenotypic expression,
complete the firm’s job of creating the new market space. The knowledge that “blue”
variations incorporate is also rather distant from the knowledge available to firms in the
reference sector, i.e. they are disruptive variations. When the new product is launched on the
market, a barrier to horizontal replication is initially created while it is too early for any spin-
offs to emerge. The first-comer firm is thus in the advantageous condition of a monopoly for
a more or less lengthy period of time. In evolutionary terms, this means there can be no type
of selection. The first-comer firm may succeed in retaining the market space it has created
uncontested, also by introducing new variations, as Cirque du Soleil has managed to do.
Usually, however, after a variable amount of time that depends on the height of the barriers
to replication, new entrants begin to populate this market space (Teece, 1986), ending an
evolutionary phase that proceeded in the absence of any competitive selection. The new
entrants may arise as a result of spinning off from the first comer or imitation by other
companies.

Concluding remarks
The evolutionary contexts on which our analysis focuses – red industries, oligopolistic
transformation and the emergence of new market spaces – differ in some ways as regards
the three key constructs of variation, replication and selection (Table 1).
Variations developed by firms are always the result of the firms’ interaction with their competitive environment, but this interaction means different things in the three cases analyzed. To be specific, variations developed by innovative firms are mainly reactive to the competitive environment in the evolution of red industries, where the potential for variation is very limited, or environment-modifying in industries that evolve toward an oligopoly and in the creation of new market spaces. The first two evolutionary patterns have in common their gradualistic nature (incremental variations), while new market spaces arise from disruptive variations.

Horizontal replication through employee mobility prevails in red industries, while in the other two evolutionary contexts the firms driving evolution raise barriers to replication, inhibiting both horizontal replication and vertical replication through spin-offs. In the case of the formation of an oligopoly, the firms that give rise to this evolutionary process because of their capacity for differential growth can grow as networks (chains) of peripheral units. In this case, we can speak of intra-organizational replication or, more precisely, of a sequence of replication episodes in each of which the decision-maker must choose between pure replication and adaptive replication (Winter and Szulanski, 2001). Adaptive replication is an evolutionary hybrid of variation and replication that warrants more attention in studies on organizational evolution. This is especially true considering that it concerns both intra- and inter-organizational replication in its two main forms. In other words, the replication dilemma formulated by Winter and Szulanski (2001) has a general scope that goes beyond the boundaries of replication as a firm’s growth strategy (Furlan and Grandinetti, 2020).

It is also worth noting that adaptive replication, like the other types of variation we have discussed, is directed, voluntary, i.e. not accidental. Our analysis leads us to believe that it is these variations that shape evolution and that the role attributed to random variations by the proponents of Generalized Darwinism (Hodgson and Knudsen, 2010a), which are due largely to replication errors, has been exaggerated.

Finally, there is the matter of selection. While there is no selection involved in a new market space as long as the barriers to replication raised by the firstcomer hold up, there is selection at work in industries tending toward an oligopoly and in red industries. Although these two situations differ in many respects, they have one thing in common, in that competitive selection divides the organizational population into two subsets based on the companies’ capabilities to introduce or imitate (replicate) variations.

These results encourage us to further analyze the contexts discussed here, and extend the analysis to other situations, such as the peopling of a new market space after its monopolistic phase, when spin-offs should represent the main mechanism of replication (Klepper, 2002b) or the reproduction and evolution of oligopolistic configurations, taking the

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Table 1. Variation, replication and selection in specific evolutionary contexts
“intra-specific” differences between incumbent firms into account (Nelson, 1991). The core idea is to arrive at a pluralist framing of how industries evolve, interpreting the different evolutionary situations on the grounds of the key variables of variation, replication and selection.

Notes

1. The terms “replication” and “retention” are sometimes used as synonyms (Breslin, 2008; Hodgson, 2013). We prefer the former because the latter is more ambiguous, as it refers to the concept of selective retention defined by the psychologist Campbell (1960, p. 380) in his theory of creative thought as “a mechanism for preserving and reproducing the selected variations.”

2. This analogy between industries and (organizational) populations has been advanced by Nelson and Winter (1982) and has become the standard reference for studies dealing with industry evolution. It differs substantially from the concept of organizational population as defined by the founders and other scholars of the population ecology of organizations. For Hannan and Freeman (1977), in fact, an organizational population is a set of organizations with share the same form at a given place and time.

References


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