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# *Three Essays on Competitive Dynamics and Imitation*

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# Introduction to the thesis

This dissertation includes the research I conducted in the fields of competitive dynamics, imitation and experimental economics. It is composed of three essays.

The first essay deals with the performance implications of imitation of competitors' innovation. In this study we attempted to shed more light on the crucial role of timing when firms imitate a new product technology. On the baseline hypothesis that speed of new technology imitation is positively associated with performance we have explained how contingency factors at the technology pioneer- and environmental-level might vary this relationship.

The second essay sheds light on the Red Queen effect as a contest of imitative strategies among rivals. Across the study we show that, in these dynamics, imitation is a compulsory strategy, but only if rapid it allows firms to sustain their performance. We further show that this Red Queen effect depends on product technology heterogeneity in the market, a situation in which products in the market widely differ in terms of the technologies they are equipped with.

These two essays have been tested with data on handset technologies introduced in the UK market from 1997 to 2008. This setting is particularly suitable for testing the proposed hypotheses because our time window is characterized by massive changes in technologies, demand, and competitive intensity.

The third essay is an experimental work that deals with the issue of coordination. When firms have to transfer knowledge, within or between firms, they have to deal with intense processes of negotiation. Across the study we decided to observe linguistic interaction to provide some evidence on how is structured a process of negotiation through which individuals redefine meanings to coordinate with their peers.

**Speed of imitation of competitors' innovation. Performance implications and contingency factors.**

**Abstract**

Although the extant management literature offers some evidence on the performance implications of imitation of competitors' innovation, very few empirical studies have explored if performance is determined by the firm's *velocity* to imitate rivals' innovation. In this study we attempt to shed more light on the relationship between *speed of new technology imitation* and firm performance. Our baseline hypothesis is that speed of new technology imitation is positively associated with performance. Moreover, we develop hypotheses on the moderating effect of technology pioneer- and environmental-level factors. We test our hypotheses with data on handset technologies introduced in the UK market by 13 mobile phone vendors, from 1997 to 2008. Most of our hypotheses are supported. The main contribution of this article is in showing that the performance implications of speed of new technology imitation vary depending on various contingency factors.

*"You don't have to get the first bite on the apple to make out. The second or third juicy bite is good enough. Just be careful not to get the tenth skimpy one."* (Levitt, 1966: 66)

## 1. Introduction

The seminal work of Levitt (1966) pointed to the importance of the speed of competitors' imitation to increase the firm performance. Levitt examined a group of firms whose sales depended on regularly launching new products. He found that no firm had a formal strategy on how to respond to competitors' successful innovations. Firms were often far too slow to imitate competitors' new product offering, and this weakened their performance: "there is usually a great premium on speed. One wants not just to catch up quickly with the successful innovator but, more particularly, to do so faster than other would-be imitators who are also working against the clock" Levitt (1966: 64). Not much has changed since Levitt's 50 years ago analysis. Though imitating rivals' innovation is fairly common, lots of companies fail to do it effectively (Markides and Geroski, 2004; Schnaars, 1994; Shenkar, 2010a).

After the work of Levitt (1966), the topic of imitation has drawn the attention of various scholars in the management literature. Some authors have investigated the determinants of imitation. For example, Lieberman and Asaba, in their 2006 seminal paper organize decades of theories of imitation in two broad categories, and suggest that, when environmental uncertainty is low, firms tend to imitate direct competitors to maintain competitive parity, i.e., *rivalry-based imitation*, while when uncertainty is high, firms are likely to imitate the most successful competitors, because they are perceived as having superior information about future market trajectories, i.e., *information-based imitation*. Other authors have explored the performance implications of imitation strategies, obtaining quite mixed empirical findings. For example, some authors have shown that imitation is beneficial for firm performance because it decreases costs and competitive risks, increases the acceptability of organizational actions (Miller and Chen, 1996), legitimates the firm to industry norms (Chen and Hambrick, 1995), and helps to promote network effects and common standards, with broad potential benefits for firms and consumers. By contrast, other studies (Baum and Mezias, 1992; Porter, 1985, 1991) suggest that imitation likely leads to intense direct competition and then mediocre performance, and therefore it is better to have some extreme distinguishing characteristics. Finally, some authors (Deephouse, 1999) show that the relationship between imitation and performance is not linear, but best performing firms are those that are able to find a balance between imitation and differentiation.

Although the extant literature offers various evidence on the performance implications of imitation, on the one hand, most empirical studies have elaborated on the *imitation of competitors' strategic posture*, like assets allocation (Deephouse, 1999) or entry mode choices (Fernhaber and Li, 2010), while only very few studies have investigated the performance consequences of the *imitation of competitors' innovation*, like new products or technologies (Ethiraj and Zhu, 2008; Zhou, 2006; Lee and Zhou, 2012): "the question of the performance effects of imitation [of innovation] is much less studied […] The explanations for why imitation [of innovation] may be (un)successful are mostly conceptual in nature" (Ethiraj and Zhu, 2008: 798). On the other hand, very few empirical studies have explored if performance is determined not only by the imitation per se, but also by the firm's *velocity* to imitate rivals' innovation (Ethiraj and Zhu, 2008; Lee and Smith, 2000). This is surprisingly, given the importance of the *speed of competitive response to rivals*, described by the competitive dynamic literature as one of the main tools for the firm to defend its competitive position and sustain a competitive advantage (D'Aveni, 1994). In this study, we borrow from the imitation literature and competitive dynamics studies on response timing with the aim to shed more light on the relationship between *speed of imitation of competitors' innovation* and firm performance. In particular, in our analysis, the objects of imitation strategies are new product technologies, defined as any new software or hardware allowing the product to performance brand new functionalities (e.g., MP3 player and photo-camera on mobile phones). New product technologies can represent a cost and a risk for adopting firms, but may also offer the chance to achieve competitive advantage through product differentiation with respect to late imitators (Banker, Cao, Menon and Mudambi, 2013; Sinha and Noble, 2008). Our argument is that: (a) speed of new technology imitation can have important performance consequences for the imitators, and (b) the relationship between speed of new technology imitation and performance is shaped by a set of moderating forces.

We attempt to complement the extant imitation literature in several ways. First, while the importance of imitation speed was remarked about 50 years ago by Levitt (1966), and the more recent competitive dynamics literature has found that firms showing a high speed of competitive response are more successful (Chen and Hambrick, 1995; Smith et al., 1989), there is a shortage of empirical studies that look at the relationship between speed of imitation of competitors' innovation and firm performance. In fact, on the one hand most of previous research has measured imitation with binary variables, i.e., yes/no (Greve, 1996; Smith et al., 1991) or with distance/deviation indicators expressing the level of imitation (Deephouse, 1999), almost ignoring the *speed* component, with very few exceptions (Lee and Smith, 2000). On the other hand, the few studies exploring the performance implications of imitation speed, focus on how waiting to imitate a new product affects the performance of the imitator compared to the innovator (Ethiraj and Zhu, 2008; Lee and Smith, 2000), but scarce attention has been devoted to performance differences among imitation strategies, i.e. if and in which circumstances rapid imitators perform better than laggards.

Second, we seek to advance our understanding of the speed of new technology imitation–performance relationship by exploring the moderating effect of technology pioneer- and environmental-level factors.

As for technology pioneer-level factors, by distinguishing between different types of pioneers, i.e. the market leader vs. other competitors, we provide clear guidelines about which pioneers the firm should imitate rapidly to increase its performance, and which pioneers are instead likely to obstruct the effectiveness of the rapid imitation of new technologies. In fact, the extant imitation literature has offered various insights on the role of the market leader in driving imitation processes (Smith et al., 1992), but we found a lack of studies exploring if and how technology pioneers with different market power (i.e., market leader vs. other competitors) affect in a different manner the performance of rapid imitators (Baldwin and Childs, 1969).

With regard to environmental-level factors, we investigate if and how the relationship between speed of new technology imitation and performance is moderated by environmental uncertainty. Imitation theorists cast environmental uncertainty as an important exogenous factor influencing the firm's choice about which reference target to follow (Haunschild and Miner, 1997; Gaba and Terlaak, 2013). For example, when technological and/or market uncertainty are high, the market leader is the most likely imitation candidate (Bikhchandani, Hirshleifer and Welch, 1998) since it is perceived by rivals as having more information about how technologies and the demand will evolve. Although various studies have explored the role of uncertainty as a determinant of imitative behaviors (for a comprehensive review see Lieberman and Asaba, 2006), we found a shortage of studies analyzing the performance implications of imitation of innovations in uncertain environments, and if imitation performance when uncertainty is high depend on the type of innovator that firms are attempting to imitate.

By bridging information-based and rivalry-based imitation literature (Lieberman and Asaba, 2006) with studies on speed of competitive response (Chen and Hambrick, 1995; Smith et al., 1989), in this article we develop a set of hypotheses on the speed of new technology imitation–performance relationship that are synthesized in Figure 1. We test our hypotheses with data on handset technologies introduced in the UK market by 13 mobile phone vendors, from 1997 to 2008.

The paper proceeds as follows. We first draw on the imitation and competitive dynamics literature to develop a set of hypotheses. Next, we provide a description of the research context and the research methods respectively. We then present the results, and the article concludes with an explanation of the contributions of our findings to the imitation and competitive dynamics literatures, and with a discussion of the managerial implications for imitators and innovators.

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## 2. Theory and hypotheses

### *2.1. Speed of new technology imitation and performance*

The literature on first mover advantage suggests that the product or technology pioneer gains an advantage by securing a temporary monopoly market position due to the imitator's lag (D'Aveni, 1994; Lieberman and Montgomery, 1988). First moving firms can potentially exploit learning curve effects, secure supply of key components and establish preferential distribution channels before late imitators. While the first mover literature argues in favor of being the pioneer, there is a shortage of studies describing rapid imitation as a successful strategic alternative to moving first. We argue there are mainly two reasons why rapid new technology imitators will obtain higher performance with respect to laggards.

First, by imitating quickly, firms *avoid or attenuate (at least in the short run) the competition of late imitators* (Chen and MacMillan, 1992; Chen and Miller, 1994), and at the same time may attempt to *maintain competitive parity with the pioneer*. As suggested by various authors, firms with the most to gain from a technology are likely to adopt it earlier, before the technology is largely diffused among competitors. That is because faster imitators will face direct competition only against the technology pioneer, and will exploit a differentiation advantage with respect to slower imitators (Sinha and Noble, 2008; Smith et al., 1989). As suggested by Levitt (1966: 66): "Had many of these tardy imitations been launched about a year sooner, enormous profits would have been earned. The magnitude of these profits would have reflected not simply the acquisition of sales that were otherwise lost, but also the higher prices and profit margins existing in this earlier year. […] the trick is to be sure to get it early, when competitors are still few and margins still attractive." In the specific case of new technology imitation, a case in point is the Nokia's late adoption of breakthrough technological innovations introduced by rivals in the first half of the 2000s. In fact, while Nokia gained the industrial leadership in the second half of the 1990s thanks to its innovative capabilities, in the early 2000s it has been so committed to block the entrance of the operating system manufacturer Microsoft into mobile telephony that it failed to spot the importance of technology innovations like color displays and clamshell form factors. This lapse opened up space for smaller competitors that, adopting those technologies much earlier, stole share from the Finnish vendor (The Economist, 2004).

Second, products or technologies imitated rapidly can also *create consumer loyalty to the brand of the imitator*, and obstruct late imitators' attack. That is because once a firm imitates a new product technology very rapidly, it may become (one of) the reference point(s) for that technology, and as the technology diffuses the growing number of customers will be less likely to switch to late imitators products (unless they show a relevant technological superiority on several attributes, but in the short-run this is likely to happen only for few firms within the industry), and will remain loyal to first imitators (Lanzolla and Suarez, 2012), with positive effects for their performance.

The aforementioned line of logic suggests that firms that are slow to imitate pioneers' new technology will be at a competitive disadvantage. We thus propose the following hypothesis:

***Hypothesis 1.*** *Speed of new technology imitation is positively associated with performance.*

### *2.2. Speed of imitation of technologies introduced by the market leader*

Competitive dynamics scholars have argued that market leaders are likely to exert a strong influence on their rivals' competitive action. For example, market leaders may have their actions imitated since smaller firms may view the leader's market power as the outcome of successful strategic decisions (Smith, Grimm and Gannon, 1992). Still, as shown by some authors, in light of the leader's market power, mimicking its actions may also intensify competition (Chen, Su and Tsai, 2007), with negative effects on imitators' performance.

We contend that imitating quickly new technologies introduced by the market leader leads to lower performance than imitating quickly technologies introduced by other rivals. The reason is twofold.

First, the market leader has a reputation advantage with respect to smaller rivals. In fact, firms within the industry have different *reputation* that is often correlated with their size (Huber and Daft, 1987; Podolny and Phillips, 1996). Reputation is "a perceptual representation of a company's past actions and future prospects that describes the firm's overall appeal to all its key constituents when compared to other leading rivals" (Fombrun, 1996: 72). Various authors in the strategy literature have argued that firms with greater market shares send greater reputational signals to the market since their greater visibility is usually perceived by customers and stakeholders as the outcome of well executed organizational practices (Smith et al., 1991). In this light, marketing scholars have shown that consumers tend to be more loyal to new products and technologies if introduced by firms with greater reputation and visibility (Hardie, Johnson and Fader, 1993), and consumers will hardly switch to imitators products, unless they show a relevant technological superiority on several attributes (Hardie, Johnson and Fader, 1993). But in the short-run this latter situation is likely to happen only for few firms within the industry. If the market leader is the technology pioneer, in light of its strong reputation among consumers, we expect that its products (incorporating the new technology) will be preferred by consumers with respect to products of imitators (incorporating the same technology).

Second, by rapidly imitating the market leader, the imitator runs a high risk of dangerous *retaliation*. Consistent with the competitive dynamics literature, firms that carry out actions that trigger fewer total responses experience better performance while firms eliciting large responses will be at a competitive disadvantage (Chen and Miller, 1994). Large and small firms under direct competitive attack will vary in their responsiveness. Some authors have demonstrated that firms with greater resource endowments are more likely to respond (Smith et al., 1991). Market share leaders generally have greater resource endowments than their smaller counterparts to rapidly respond to rivals' attack. In contrast, smaller firms under attack often cannot retaliate, even if they desire to do so, because of resource constraints. Moreover, since firms are usually motivated to respond to rivals' attacks to defend their reputations (Fombrun and Shanley, 1990), the market leader, because of its greater reputation, has more pressure to respond to rivals' attack. In fact, since the decision to rapidly attack the market leader is likely to receive wide industry publicity because it is associated with many stakeholders (Fombrun and Shanley, 1990), the market leader may be especially motivated to show that it is not passive. In this light, on the one hand, when the market leader introduces a new product technology, it will be more strongly motivated to mobilize its extensive resources and to respond very quickly against imitators; on the other hand, given its resource endowment, the market leader's retaliation is likely to seriously constrain the performance of imitators' products. Conversely, smaller technology pioneers will be more hesitant to respond to imitators' attack, since, given their limited resources, they have to be more selective in retaliating. This allows rapid imitators to be more effective when copying non-market leader technology pioneers. For example, at the beginning of the 2010s, after have gained a solid market share leadership in the tablet industry thanks to the success of its iPad, Apple spent more on lawsuits against imitators (like Samsung) than on research and development (The Economist, 2012). As a result of Apple's success in these legal battles, sales of various models of competitors were banned in several countries, and their performance were seriously weakened. The above line of logic suggests the following hypothesis:

***Hypothesis 2.*** *Imitating quickly new technologies introduced by the market leader leads to lower performance than imitating quickly new technologies introduced by other rivals.*

### *2.3. Speed of new technology imitation and environmental uncertainty*

Uncertainty has been described as lack of information for decision making (Duncan 1972). In particular, *environmental uncertainty* refers to a situation where the management of a firm has little information about its external environment that is in a state of flux and, hence, largely unpredictably (Anderson and Tushman, 2001; Haunschild and Miner, 1997).

Authors in the imitation literature suggest that when environmental uncertainty is high, firms can more hardly predict the likely outcome of their strategic actions (Lieberman and Asaba, 2006), and this in turn impedes the effectiveness of their competitive moves against rivals, as imitation decisions (Jensen, 2003). This means that when uncertainty is high, the chance for the firm to obtain a (temporary) competitive advantage from the imitation of the new technology introduced by the pioneer is seriously compromised. In fact, at high levels of environmental uncertainty, the quality of information about the performance of the innovator's technology is poor and any possibility of using that information to develop a well performing product is relatively limited (Ethiraj and Zhu, 2008). In contrast, when environmental uncertainty is low, the quality of information about the new technology is greater, and this can help the imitator to evaluate more precisely the potential of the innovation (Bikhchandani et al., 1992), and make the rapid imitation process more effective.

Since high levels of environmental uncertainty make new technology imitation more risky, we expect the outcome of imitation is constrained in case the firm decides to imitate rapidly. In uncertain environments the firm, being unable to predict future market and technological trajectories, needs more time to monitor the technical performance of the new product technology. By imitating rapidly, the firm increases the risk of failure of its imitation strategy. We thus posit the following:

***Hypothesis 3.*** *Environmental uncertainty negatively moderates the relationship between speed of new technology imitation and performance*

### *2.4. Speed of new technology imitation, market leader and environmental uncertainty*

Information-based imitation theories suggest that when environmental uncertainty is high, and information asymmetries among industry rivals constrain their strategic choices, firms are likely to follow the behavior of rivals perceived as having superior information (Bikhchandani et al., 1992; Semadeni and Anderson, 2010). In fact, although imitating the market leader normally forces the firm to bear a dangerous direct competition, when environmental uncertainty is high, the pressure to solve information asymmetries offsets concerns related to competitive rivalry. "For example, small firms may follow larger rivals if they believe the latter are better informed. Similarly, firms that have been successful in the past are more likely to have their actions emulated" (Lieberman and Asaba, 2006: 371). In this light, market leaders, because of their historical reputation and demonstrated competencies are likely imitation candidates (Bikhchandani et al., 1998).

We contend that, when the environment changes from certain to uncertain, firms imitating quickly (i.e., high speed of imitation) technologies introduced by the market leader will increase their performance (or however their performance will not worsen), while firms imitating quickly technologies introduced by other rivals will see their performance to worse off. Specifically, although competitive dynamic scholars (Boyd and Bresser, 2008; Ferrier et al., 1999) have shown that by imitating the market leaders firms run a risk of retaliation (as explained in Hypothesis 2), we argue that when uncertainty is high the market leader, on the one hand is more capable than smaller rivals to understand which new product technologies will be successful, on the other hand it is less inclined to respond rapidly and aggressively against rivals' attack. That is because, when uncertainty is high, the leader is likely to invest relevant resources to understand in which directions the market and technological advancements will move (Dreyer and Gronhaug, 2004) and thus it will develop more precise projections about consumer needs; but its commitment to invest resources to cope with uncertainty restricts the number of strategic alternatives it considers (Boyd and Bresser, 2008), and weakens its ability to timely and effectively respond to rivals attacks. In turn, rivals can quickly imitate the leader innovations with lower risk of retaliation. By contrast, given the resource constraints of smaller rivals to develop projections in uncertain scenarios, imitating quickly their new product technologies entails a bigger risk, since they may not fit with consumer needs, with inevitable negative consequences on the pioneer and rapid imitators' performance.

In sum, the above line of logic suggests that as environmental uncertainty increases, the benefits associated with uncertainty reduction exploited by the firm's imitation of the technologies introduced by the market leader offset the risk of direct competition with the latter. We thus posit the following hypothesis:

***Hypothesis 4.*** *There is a three-way interaction between speed of imitation, technology introduced by the leader and environmental uncertainty: as environmental uncertainty increases, its negative effect on the speed of new technology imitation–performance relationship is weaker for technologies introduced by the leader.*

## 3. Methods

### *3.1. Sample*

We test the proposed hypotheses on the performance implications of speed of new technology imitation in the specific context of the UK mobile phone industry. For the purposes of this study, 22 product technologies introduced in the UK mobile phone industry by 13 handset vendors, operative from 1997 to 2008, were extracted from the specialist industry magazines *What Mobile*, *What CellPhone* and *Total Mobile*. We selected product technologies that were clearly reviewed in the abovementioned special interest magazines over the analyzed time period, and they are listed as follows: Voice dial, ringtone composer, infrared, games (pre-installed), downloadable ringtone, email client, WAP, EMS, polyphonic ringtone, recordable ringtone, SMS-chat, MP3 player, GPRS, Bluetooth, USB, color screen, MMS, photo-camera, true ringtone, video-camera, UMTS, EDGE. Although the whole observation period spanned from 1997 to 2008, the 22 new technologies were first introduced between January 1997 and July 2004. The reason for considering technologies introduced only up to 2004 was to have enough 'time' (from 2004 to 2008) to observe the imitation of the technologies that came last. Overall, 566 new mobile phones were introduced in the UK market over the 1997–2008 study period. Industry competitors are Nokia, Motorola, Samsung, LG, Ericsson, Sony, Sony-Ericsson, Siemens, Philips, Panasonic, Sagem, NEC, Alcatel, that represent almost the entire industry in the UK. We excluded from our sample smartphone devices, namely those handsets with an advanced operating system, whose boom was in 2008 after the launch of the Apple iPhone, because before 2008 they were targeted at different consumers and imply different technologies (Giachetti and Marchi, 2010). Over the analyzed study period, sales of smartphones represented a relatively minor portion of vendors' total sales. The unit of analysis in our model is the firm's speed of imitation of a given technology: if a firm adopted each of the selected 22 technologies within the whole 1997–2008 time period, our model would have 22 observations for that firm.

We believe the UK mobile phone industry from 1997 to 2008 to be a setting particularly suitable to test our hypotheses about speed of imitation, for five key reasons. First, the mobile phone industry, as other consumer electronics industries, has been often described as a fast changing environment characterized by rapid new product introduction and quick technological obsolescence, all factors that underline the relevance of speed of new technology adoption for handset vendors in order to remain competitive (Fine, 1998). Second, while the patent protection available in many product-based industries imposes barriers to imitation of new products, patent wars in the mobile phone industry have been observed only from the end of the 2000s, with the boom of smartphone devices and advanced operating systems (Carrier, 2012), and therefore after our study period. Third, most of technologies introduced in the mobile phone industry over our study period originate from other product categories (e.g., photo-camera, MP3 player, USB port, etc.) and then are often patented by suppliers that license them to mobile phone vendors (Funk, 2008). Moreover, even new technologies patented by mobile phone vendors, can be easily copied legally by means of reverse-engineering (Lee and Lim, 2001). These conditions lead to few legal impediments to technology imitation. Fourth, mobile phone vendors in our sample are very large firms that usually massively advertize product innovations in TV commercials, newspapers or special interest magazine. This means competitive actions related to product innovations are usually highly visible. Finally, since in most of empirical studies on imitation of innovation dynamics the object of the imitation process is new products (e.g., Ethiraj and Zhu, 2008; Lee and Smith, 2000; Rhee, Kim and Han, 2006) or new services (Semadeni and Anderson, 2010), the prevalence of product/service-based research on imitation raises a generalizability concern when applying those results to technology-based research (Sinha and Noble, 2008) and warrants studying different contexts to test imitation theories.

### *3.2. Measures*

#### *Dependent variable*

*Firm performance*. The natural logarithm of the number of handsets sold on a yearly basis was used as measure of performance. Both management scholars (e.g., Czarnitzki and Thorwarth, 2012) and industry specialists (e.g., Gartner Dataquest; Mintel International Group Limited) has often used the number of units sold as a measure of vendors' performance in consumer electronics industries. We transformed total units sold by using the natural log (*ln*) in order to correct for skewness. Data on handsets sold per vendors were collected from Mintel International Group Limited, Euromonitor International and firms' archival data. This variable was lagged one year ($t$+1) in order to account for any changes that may have occurred in a firm and the economy between the time before and after the firm launched its imitative technologies into the market (Lee and Zhou, 2012).

#### *Independent variables*

*Speed of new technology imitation (SOI)*. We define and measure the *speed of new technology imitation* as a multi-dimensional construct, composed by two related temporal aspects: imitation timing (*time*) and imitation order (*order*) (Lee and Smith, 2000; Smith *et al*., 2001). Imitation timing represents the elapsed time (in months) between the date of a new technology introduction by the pioneer $j$ and the date of imitation of the technology by the imitator $i$; imitation order reflects the position occupied by the new technology imitators in a temporal series of responses, starting with the first imitator to the last imitator. Imitation timing and imitation order were then integrated into a composite measure as follows:

$$(1)\ SOI_{i,k} = 1 \Big/ \left\{ \left[ time_{i,k} / \max(time) \right] \cdot \left[ order_{i,k} / \max(order) \right] \right\}$$

where $SOI_{i,k}$ is the speed of imitation of the technology $k$ by firm $i$, $time_{i,k}$ is the imitation timing of the technology $k$ by firm $i$, $order_{i,k}$ is the imitation order of the technology $k$ by firm $i$, *max(time)* and *max(order)* are the maximum imitation timing and imitation order in the sample respectively. By dividing *time* and *order* for their maximum, we transform the two count measures into ratios, giving the two temporal aspects the same range of variation.

*Technology introduced by the market leader*. To detect if imitation speeds differ depending if the technology pioneer is the market leader or other competitors, we used a dummy that assigns value 1 to technologies introduced for the first time in the UK by the market leader, and 0 to technologies introduced for the first time in the UK by the other competitors. Market leader was defined as the firm with largest market share in the UK market. Over the whole 1997–2008 time window Nokia remained the market share leader.

*Environmental uncertainty*. Various authors in the management literature have measured environmental uncertainty with composite indexes combining the variability of various industry-level variables (e.g., Luo, 2002). For the purpose of this study we developed a multi-item indicator, combining the three-year standard deviation of three industry-level variables: the UK annual GDP (Office for National Statistics – ONS), total annual device sales to end users in the UK, and the UK penetration rate (i.e., number of handsets per 100 inhabitants) (Authority for the UK communications industries – Ofcom). The three measures were averaged after we divided each of them for their maximum value in the sample, so that we obtained an indicator of uncertainty ranging from 0 to 1, with 1 representing the highest possible uncertainty. The main benefit of the composite index is that it allows to capture different uncertainty dimensions that actually manifest simultaneously in the environment. Thus, for example, an increase of an uncertainty dimension might be hampered (amplified) by a decrease (increase) of another dimension (Luo, 2002).

***Control variables***

We included several control variables at both the industry- and firm-level.

- *Industry-level controls*

*Industry concentration*. Authors in the management literature have long shown that the less an industry is concentrated, the more competition is likely to be intense, with possible negative effects on firms' performance. We measure industry concentration with the Herfindahl index, by using the UK market shares of handset vendors in our sample:[1]

(2) $H_t = 1 - \sum_{i=1}^{n} \delta_{i,t}^2$

where $\delta_{i,t}$ is the market share of the handset vendors *i* in year *t*. The higher the *H* index, the lower the level of industry concentration and, in turn, the higher the competition is likely to be intense (Scherer and Ross, 1990; Wiggins and Ruefli, 2002).

- *Firm-level controls*

*Average number of technologies per product*. Firms' products may be characterized by different levels of technological complexity, ranging from models including few functionalities to models equipped with several functionalities. In the UK mobile phone market it has been shown that usually consumers tend to assign a higher value to products incorporating more features (Mintel International Group). These products are in fact usually priced more by vendors. Since in our setting each technology is aimed to offer a specific

[1] Since in our analysis we excluded smartphone devices, also those vendors entirely focused on this product segment, like BlackBerry, were not considered in the competitive intensity index.
[2] We used dummy quarters instead of dummy years to avoid problems of multicollinearity with industry-level controls.
[3] In particular, information about patented technologies and patent owners were collected mainly from the *United States Patent and Trademark Office* (USPTO), the *European Patent Office* (EPO), and the *World Intellectual Property Organization* (WIPO). Information about whether new product technologies were licensed

functionality, we used the *average number of technologies per product* to control for the firm's positioning in the market, i.e., high-end vs. low-end.

*Number of innovations*. Although our arguments are mainly centered around the performance implications of rapid imitation, the extant literature on first mover advantage (Lieberman and Montgomery, 1988) have long argued and provided empirical evidence on the performance advantage of pioneer firms (Ethiraj and Zhu, 2008; Lee and Smith, 2000). We thus want to account for the extent to which the imitator was also pioneer the year in which imitated a new technology. This variable was measured as a count of new product technologies introduced by the imitator in the year *t*.

*Firm's focus of resources on the mobile phone industry (focal industry)*. Competitive dynamics scholars suggest that the extent to which a firm is likely to monitor the strategic behavior of industry competitors depends on the amount of resources it has invested in the focal industry relative to other industries in which it operates, and attention to competitors' action may affect the firm's performance (Doz and Kosonen, 2008; Miller and Chen, 1994). Since most of firms in our sample are business units of conglomerates, operative in many lines of business (i.e., in different industries), to measure if the firm, at the corporate level, has most of its resources in the mobile phone industry, we used a dummy, that takes value 1 if the conglomerate generates the majority of its revenue (i.e., more than 50%) in the mobile phone industry in the year *t*, and 0 otherwise (Gambardella and Torrisi, 1998). Information about conglomerates' revenue was collected mainly from their annual reports. We found this variable to be time-invariant for all players in our sample.

*Quarter of imitation*. Since technologies are imitated by the firm in a specific moment within the year, we accounted for temporal effects with a dummy (1-0) for the quarter in which the technology was imitated by the handset vendor.[2]

[2] We used dummy quarters instead of dummy years to avoid problems of multicollinearity with industry-level controls.

Table 1 presents the variables' descriptive statistics.

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Please insert Table 1 around here
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## 4. Results

We tested our hypotheses with random-effects regression models, mainly for two reasons: (1) to ensure that error due to serial correlation in our panel dataset was specified and analyzed (Erez, Bloom and Wells, 1996), (2) to allow for time invariant variables to be included in the regression model (Cameron and Trivedi, 2009). Robust regression takes into account heteroskedasticity-robust and clustered standard errors, controlling for potential outliers (Wooldridge, 2002). Moreover all variables were standardized (mean-centered) to prevent multicollinearity (Aiken and West, 1991). The sample contained 181 observations. Each observation corresponds to the imitation of a certain technology by the firm. Not all firms in our sample adopted all the 22 sampled technologies. Table 2 presents the results of the regression analyses.

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Please insert Table 2 around here
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Model 1 shows the effect of the control variables on the firm's SOI. In Model 2 the main effects of SOI and moderators are added. In Model 3 we added the two-way interactions. Finally, in Model 4, the *full model*, the three-way interactions were added. The hypothesis would require a statistically significant increase in variance explained (a significant increment of the Wald test) in Model 4 with respect to Models 1, 2 and 3, as well as findings consistent with the hypothesis. Model 4 in Table 2, shows that the addition of the two-way and three-way interactions with respect to Model 2 (Wald-$\chi^2$ = 52.97, $p$ =.01), and the three-way interaction with respect to Model 3 (Wald-$\chi^2$ = 4.68, $p$ =.05) significantly increases the overall variance explained. The *R2* increases from .090 in Model 1 to .564 in Model 4. This finding suggested that it was appropriate to examine the nature of these relationships.

As shown in Model 4 (Table 2), there is a statistically significant, positive relationship between SOI and performance ($\beta$=.330, $p$<.05) thereby supporting Hypothesis 1.

Hypothesis 2 predicted a negative moderating effect on the relationship between SOI and firm performance of the technology introduced by the market leader. As shown in Model 4 (Table 2) the interaction between technology introduced by the market leader and SOI is negative and significant (SOI × Leader: $\beta$ = -.359, $p$<.05), supporting Hypothesis 2. Figure 2 is a graphical representation of the interaction according to standard procedures (Aiken and West, 1991).

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Please insert Figure 2 around here
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In the Hypothesis 3 we predicted a negative moderating effect of the environmental uncertainty on the relationship between SOI and firm performance. The coefficient of the interaction is not significant (SOI × Uncertainty: $\beta$ = .088, $p$>.10), therefore Hypothesis 3 is not supported.

Hypothesis 4 predicted a three-way interaction of SOI, technology introduced by the market leader and environmental uncertainty on firm performance, in a way that when environmental uncertainty is high, imitating quickly new technologies introduced by the leader is less detrimental for firm performance than imitating quickly new technologies introduced by other rivals. Using the procedure outlined by Aiken and West (1991) we plotted the high and low level of each variable (one standard deviation above and below the mean) to assess whether the form of the significant interaction (SOI × Leader × Uncertainty: $\beta$ = .232, $p$<.05) is consistent with our hypothesis. Figure 3 describes the pattern of the moderated result related to Hypothesis 4. The highest performances are obtained when the SOI is high, the technology is not introduced by the leader, and there is a low level of environmental uncertainty (Figure 3, slope 4). Following the procedure of Dawson and Richter (2006) we calculated the unbiased beta weight for each slope and the *t*-test for each pairwise comparison (Table 3). The results show that environmental uncertainty significantly positively moderates the relationship between SOI and firm performance when the new technology is introduced by the market leader (slope 1 – slope 2, $p<.01$), while does not significantly moderates the relationship between SOI and performance when the new technology is introduced by other (non-leader) rivals (slope 3 – slope 4, $p>.10$). This finding lends support to Hypothesis 4.

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Please insert Table 3 and Figure 3 around here
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## 5. Robustness checks

We performed a number of tests to confirm the robustness of our statistical findings. First, we calculated variance inflation factors (VIFs) to determine whether there was multicollinearity in the analyses. In the regression equations including control and independent variables but excluding interaction terms, the average VIF equals to 1.56, with the highest VIF values nevertheless lower than 2.21, suggesting no serious problem of multicollinearity (Chatterjee and Hadi, 2006).

Second, we wanted to account also for the possibility that some laggards do take lots of time before adopting certain technologies because they are not interested in them. We thus address this issue by repeating the analysis considering only those technologies the handset vendor imitated within 36 months after their introduction (Model 5) (in our sample approximately the data after the third quartile, i.e. 38 months) (Sinha and Noble, 2008; Suarez and Lanzolla, 2007). Model 5 shows that results remain consistent with the ones in Model 4.

Finally, it is worth noting that, while in our model we explore the effect of speed of imitation on firm performance, some scholars in the competitive dynamics literature have shown that, conversely, performance may also influence response speed. In fact, high-performing firms are likely to possess an ample amount of slack resources to pay for a speedy response (Markides and Geroski, 2004). Under this scenario, the independent variable in our model would be endogenously determined. Although our lagged dependent variable partially solve potential problems of endogeneity, we dealt with this issue also with instrumental variables, which are those variables (omitted within the model) that are correlated with the endogenous and not correlated with the dependent variable (Davidson and McKinnon, 1993). We used two instruments, whose appropriateness in our model was confirmed by the Sargan-Hansen test (Baum et al., 2007). The first instrument we used is a measure of the type of *Intellectual Property (IP) protection*. IP protection is likely to discourage rapid imitation. To define the variable, we went back to the published documentation about the technologies being considered, and we distinguished among the three following IP types: 1 = proprietary technology, not licensed (thus requiring some reverse-engineering to be imitated); 2 = licensed by mobile phone manufacturer; 3 = licensed by mobile phone suppliers.[3] A dummy per each IP type was introduced. A dummy *radical (vs. incremental) technology* was our second instrument. Radical technologies, often changing the product architecture and thus inhering uncertainty for firms and customers, are more difficult to be imitated rapidly (Abrahamson, 1996). Chandy and Tellis (1998) and Sorescu et al. (2003) have defined radical innovations as those that satisfy two criteria, related to the impact of the innovations on (a) the consumer demand and (b) the other existing technologies. In particular, a radical innovation is an innovation that: 1) fundamentally changes the way consumers use their product (market dimension), and 2) renders obsolete, or drastically reduces the competitiveness of those products that do not incorporate it (technology dimension). Taking

[3] In particular, information about patented technologies and patent owners were collected mainly from the *United States Patent and Trademark Office* (USPTO), the *European Patent Office* (EPO), and the *World Intellectual Property Organization* (WIPO). Information about whether new product technologies were licensed or not to third parties were collected from the *Factiva* database, a business information and research tool owned by Dow Jones & Company, and were triangulated in interviews with marketing and product managers of some of the main mobile phone manufacturers operating in the UK.

as a reference this definition, after have analyzed public documentation and conducted interviews with industry experts about the radicalness of technologies in our sample, we defined as radical the following new technologies: MP3 player, photo-camera, color screen, MMS, Bluetooth and UMTS. In order to test for the presence of endogeneity, we used a Durbin-Wu-Hausman test (Baum et al., 2007). The test cannot reject its null hypothesis that speed of imitation may be treated as exogenous (using a significance level of $p < 0.10$), thus suggesting endogeneity is not a problem in our regression model.

## 6. Discussion

### *6.1. Implications*

The extant management literature has long viewed innovation as a critical competitive strategy for firms to increase their performance with respect to rivals (Zhou and Wu, 2010). However, imitation of competitors' innovation as an alternative competitive strategy has received less attention until recently (Shenkar, 2010a). In fact, although after the work of Levitt (1966), the topic of imitation has drawn the attention of various scholar (Lieberman and Asaba, 2006), very few empirical studies have explored if firm's performance is determined not only by the imitation per se, but also by the firm's *velocity* to imitate rivals' innovation (Ethiraj and Zhu, 2008; Lee and Smith, 2000). To address this gap, we have examined speed of imitation strategies and firm performance in the UK mobile phone industry, by measuring speed of imitation in terms of new product technology imitation timing and imitation order. Our findings suggest that, overall, best performing challengers are those that imitate more rapidly new product technologies introduced by rivals.

Second, the extant literature on speed of imitation has ignored contingency factors that may affect its performance implications. This is surprisingly since both firm and environmental characteristics may rapidly change over time, especially in technology-intensive industries (Eisenhardt, 1989), like the mobile phone one (Giachetti and Marchi, 2010), becoming contingencies facilitating or inhibiting the effectiveness of speed of imitation of competitors' innovation. To address this research gap, we have assessed contingency conditions of speed of imitation strategy, at the technology pioneer- and environmental-level. In particular, in this article, the pioneer market dominance (i.e., market share leader or not) was used as pioneer-level moderator, and environmental uncertainty was used as environmental-level moderator.

Although, overall, we found that best performing imitators are those that imitate more rapidly new product technologies introduced by rivals (Hypothesis 1), the significant effects of moderators on the speed of imitation–performance relationship suggest that technology pioneer- and environmental-level contingences should be taken into account.

We found that imitating quickly *technologies introduced by the market leader* may be detrimental for firm's performance (Hypothesis 2), unless the environment is highly *uncertain* (Hypothesis 4). In fact, when the environment changes from certain to uncertain, performance of firms imitating quickly new technologies introduced by the leader is less penalized than performance of firms imitating quickly new technologies introduced by other rivals. This results complement both the rivalry-based imitation (i.e., imitation for competitive purposes, when environmental uncertainty is low) and information-based imitation (i.e., imitation aimed to gather information about the environment to mitigate uncertainty) literature (Lieberman and Asaba, 2006), pointing to the importance for the firm to use rapid imitation to maintain competitive parity with non-leader pioneers when environmental uncertainty is low, while orient the rapid imitation attacks towards the market leader pioneers when uncertainty is high. Firms that imitate the leader pioneers when uncertainty is low or deviate from the leader pioneers when uncertainty is high, will be at a competitive disadvantage.

### *6.2. Limitations and avenues for future research*

As any study, this one too has its limitations. One important concern has to do with the generalizability of the results. We conducted our study in the UK, a developed country characterized by a relatively high level of mobile phone diffusion rate, and where most of established vendors have expanded their sales activities. Related research could extend our model not only to other developed countries, such as the United States and Germany, but also to emerging economies where handsets and related technologies took time to diffuse, such as China and India.

Second, this research does not include some interesting intra-organizational contingency factors discussed in the management and marketing literature, such as marketing capability, ownership type (Lee and Zhou, 2012), organizational structures (Jonsson and Regner, 2009), and imitation capabilities (Shenkar, 2010b; Zhou and Wu, 2010). Future research could expand our framework by investigating the roles of these imitator-level variables.

Finally, it is interesting to note that, although our results show that, when uncertainty is high, imitating (rapidly) the market leader might be a good choice, the literature on technological change has shown that when a disruptive innovation is introduced in the market, generating high uncertainty for firms, the leader may take the wrong direction and fall in the so called ‘competency trap’ (Tushman and Anderson, 1986). In this situation imitating the market leader might not be the best way to increase performance. For example, in the global mobile phone industry, over the 1990s Motorola progressively lost its global leadership because continued to invest in analog phones and was not willing to exploit the advantages offered at the beginning of the 1990s by the emerging digital standard, while Nokia was surpassed by Samsung in 2012 because it was not able to exploit the advantages offered by the new generation of smartphones, triggered in 2008 by Apple with its iPhone and by Google with its Android operating system. It is worth noting that our results in the UK market do not contradict these two changes in global industrial leadership, since on the one hand our focus is on speed of new technology imitation and not on the inertial adoption of obsolete technologies, and on the other hand the time window analyzed in our paper is between 1997 and 2008, thus not considering the two technological discontinuities abovementioned. However, future studies might replicate our analysis of the performance implications of imitation dynamics distinguishing between different types of uncertainty, for example uncertainty triggered by disruptive and not-disruptive innovations.

## 7. Conclusions

How quickly should firms imitate rivals' innovation? This study takes an important step by treating speed of imitation of competitors' innovation as a core competitive strategy for firms operating in technology intensive industries, and identifies boundary conditions that may influence its effectiveness. Our results show that on the surface, early imitators will gain superior performance outcomes. Nonetheless, when technology pioneer- and environmental-level contingent factors are taken into consideration, the story may change radically. Managers of firms operating in technology intensive industries should be aware of these contingencies when imitating rivals' innovation.

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**Table 1. Descriptive statistics**

| | | Mean | Sd | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **Performance** | 6.255 | 1.531 | 1.000 | | | | | | | |
| **2** | **SOI** | 27.935 | 56.160 | 0.210** | 1.000 | | | | | | |
| **3** | **Leader** | 0.315 | 0.466 | -0.063 | -0.019 | 1.000 | | | | | |
| **4** | **Uncertainty** | 0.538 | 0.134 | 0.050 | -0.095 | 0.100 | 1.000 | | | | |
| **5** | **Industry concentration** | 0.761 | 0.048 | 0.031 | -0.018 | 0.078 | -0.221** | 1.000 | | | |
| **6** | **Number of innovations** | 0.365 | 0.691 | -0.203** | -0.045 | -0.031 | -0.177* | 0.028 | 1.000 | | |
| **7** | **Technologies per product** | 10.040 | 5.289 | -0.150* | -0.042 | -0.172* | -0.641** | -0.125+ | 0.294** | 1.000 | |
| **8** | **Focus on focal industry** | 0.481 | 0.501 | 0.205** | 0.209** | -0.033 | -0.012 | 0.019 | -0.236** | -0.120 | 1.000 |

*Notes:*
*N = 181*
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

**Table 2. Speed of new technology imitation on firm performance: Robust Random-Effects regression analyses**

| | *Full sample* | | | | *Imitation within 36 months* |
|---|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 3** | **Model 4** | **Model 5** |
| **Constant** | 0.205 | 0.198 | -0.158 | -0.148 | 0.188 |
| | (0.779) | (0.717) | (-0.495) | (-0.463) | (0.553) |
| ***Main effect*** | | | | | |
| **SOI (H1)** | | $-0.039^{+}$ | $0.352^{*}$ | $0.330^{*}$ | $0.267^{+}$ |
| | | (-1.896) | (2.433) | (2.338) | (1.791) |
| ***Moderators*** | | | | | |
| **Leader** | | 0.008 | -0.188 | -0.148 | 0.084 |
| | | (0.205) | (-1.089) | (-0.810) | (0.611) |
| **Uncertainty** | | 0.062 | $-0.202^{+}$ | $-0.207^{+}$ | -0.080 |
| | | (1.636) | (-1.663) | (-1.715) | (-0.600) |
| ***Interactions*** | | | | | |
| **SOI x Leader (H2)** | | | $-0.496^{**}$ | $-0.359^{*}$ | $-0.439^{**}$ |
| | | | (-3.916) | (-2.442) | (-3.266) |
| **SOI x Uncertainty (H3)** | | | $0.144^{*}$ | 0.088 | 0.032 |
| | | | (2.224) | (1.307) | (0.468) |
| **Leader x Uncertainty** | | | 0.192 | 0.216 | 0.043 |
| | | | (1.319) | (1.497) | (0.230) |
| **SOI x Leader x Uncertainty (H4)** | | | | $0.232^{*}$ | $0.216^{+}$ |
| | | | | (2.162) | (1.823) |
| ***Controls*** | | | | | |
| **Industry concentration** | 0.042 | 0.062 | 0.026 | 0.036 | 0.025 |
| | (0.645) | (0.893) | (0.213) | (0.288) | (0.189) |
| **Number of Innovations** | -0.054 | -0.056 | -0.066 | -0.070 | -0.101 |
| | (-1.443) | (-1.451) | (-0.402) | (-0.429) | (-0.643) |
| **Technologies per product** | 0.184 | $0.227^{+}$ | -0.219 | -0.239 | -0.083 |
| | (1.606) | (1.845) | (-1.053) | (-1.130) | (-0.349) |
| **Focus on focal industry** | 0.347 | 0.360 | 0.127 | 0.125 | 0.217 |
| | (1.334) | (1.365) | (0.484) | (0.472) | (0.872) |
| **Quarter introduction dummy** | *included* | *included* | *included* | *included* | *included* |
| *N* | 181 | 181 | 181 | 181 | 124 |
| *R2-between* | 0.090 | 0.076 | 0.559 | 0.564 | 0.534 |
| $\chi^2$ | $67.05^{**}$ | $150.00^{**}$ | $669.69^{**}$ | $1739.55^{**}$ | $193.24^{**}$ |
| $\Delta$(vs. Model1) $\chi^2$ | | $7.61^{+}$ | $27.43^{**}$ | $87.90^{**}$ | |
| $\Delta$(vs. Model2) $\chi^2$ | | | $20.28^{**}$ | $52.97^{**}$ | |
| $\Delta$(vs. Model3) $\chi^2$ | | | | $4.68^{*}$ | |

*Notes:*
All variables are standardized; *t* statistics in parentheses; + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

**Table 3. Slope difference for the three-way interaction (SOI x Leader x Uncertainty)**

| Pair of slopes | t-value for slope difference | p-value for slope difference |
|---|---|---|
| (1) and (2) | 3.168 | 0.002 |
| (1) and (3) | -0.544 | 0.587 |
| (1) and (4) | -0.054 | 0.957 |
| (2) and (3) | -4.317 | 0.000 |
| (2) and (4) | -5.343 | 0.000 |
| (3) and (4) | 0.706 | 0.481 |

**Figure 1. Research model: performance implications of speed of new technology imitation**

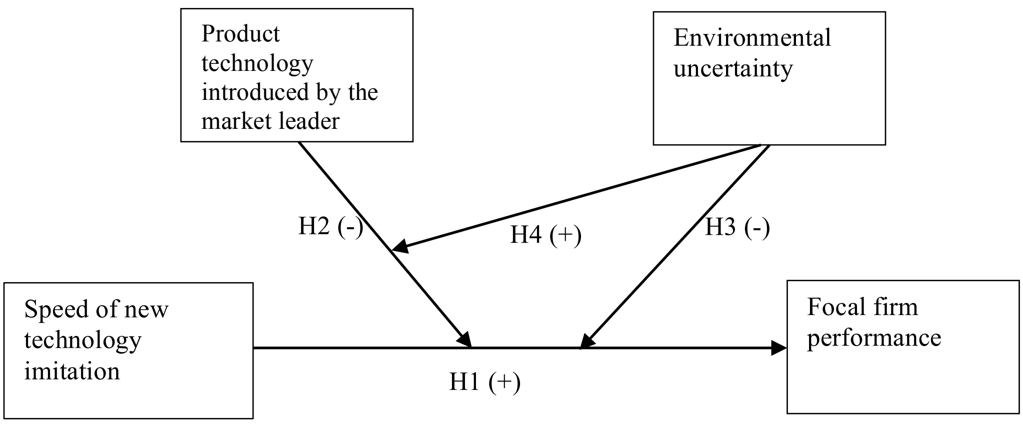


**Figure 2. Two-way interaction (SOI x Market leader)**

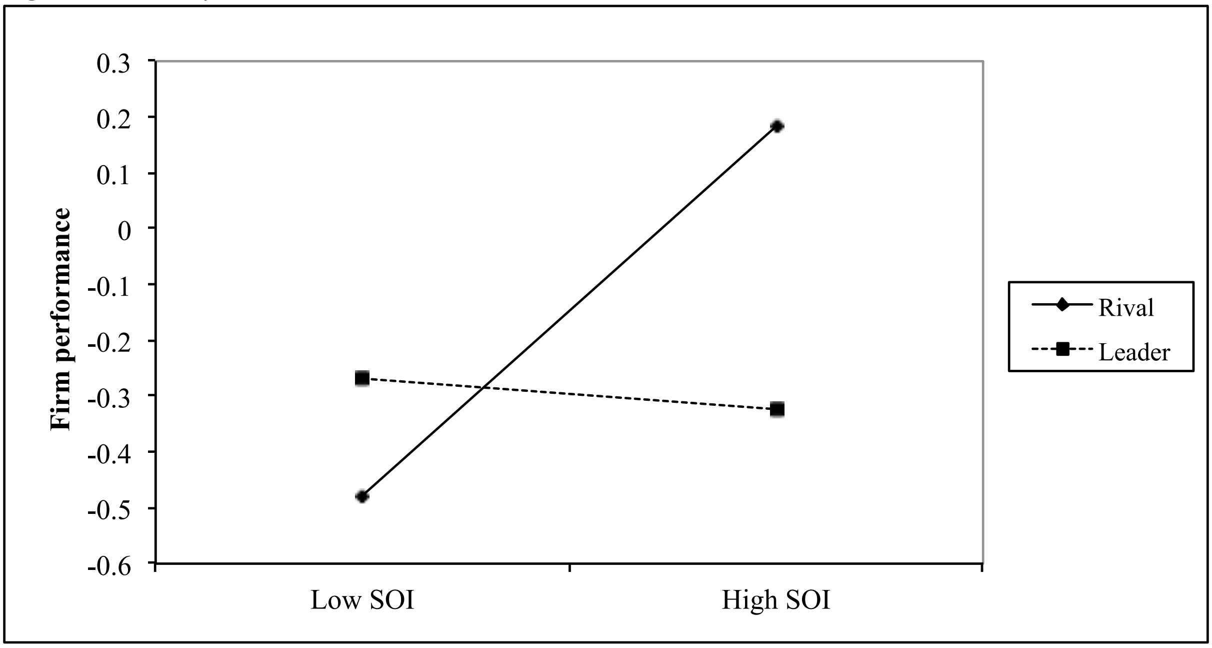
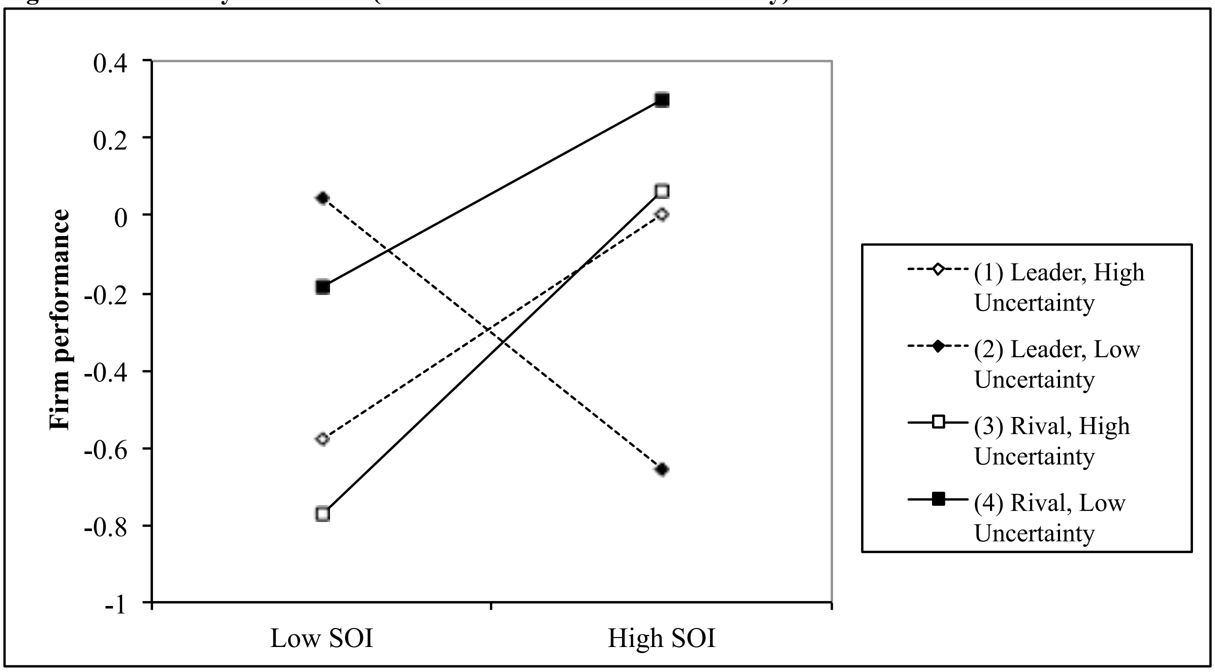



**Figure 3. Three-way interaction (SOI x Market leader x Uncertainty)**



**The Red Queen Competition: A product technology imitation perspective**

**Abstract**

The paper sheds light on the Red Queen effect as a contest of imitative strategies among rivals. The results from the analysis of imitation of new product technologies in the UK mobile phone industry confirms the existence of Red Queen competition, whereby a firm's rapid imitative actions increase performance but also increase the number of rivals' imitative actions, which, in turn, negatively affect the initial firm's performance. We further show that this Red Queen effect depends on product technology heterogeneity in the market, a situation in which products in the market widely differ in terms of the technologies they are equipped with.

## INTRODUCTION

Research on competitive dynamics argues that firm strategy evolves in response to the behavior of other firms in the same industry. In a technologically dynamic environment in which competition is often based on innovative products, firms must respond to moves made by their rivals, or risk falling behind. Such response falls into two categories: Firms can introduce innovations that give them advantage over competitors, or firms must imitate innovations introduced by their rivals in order to maintain their market position. In a *technologically dynamic environment* where technology advances through the competition between alternative technologies promoted by rivalrous organizations (Tushman and Anderson, 1986) and innovations only confer temporary advantage (D'Aveni, 1994), firms must constantly introduce and adopt innovations if they wish to maintain their strategic position relative to their competitors (Bayus, 1998). Imitation in this environment is, indeed, a competitive race in which maintaining existing competitive position calls for increasing investments. Evolutionary theorists have called such a competitive race 'Red Queen' competition (Barnett & McKendrick, 2004; Derfus, Maggitti, Grimm & Smith, 2008).

In particular, since the work of Nelson & Winter (1982), evolutionary theory of the firm has shown that the competitive race to discover performance opportunities is the main determinant of a firm competitive advantage. Evolutionary theory of the firm also suggests that this race can never be won once for all: the innovations created by high performing firms trigger technological and market changes that undermine past gains, and open the way for competitive challenges by incumbents and new firms. This so called 'Red Queen effect' was first noted by the biologist van Valen (1973) who borrowed the term from the Red Queen's warning to Alice in Lewis Carroll's *Through the Looking-Glass*: "Now, here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!" (Carroll, 1960: 345).

Organizational researchers see the Red Queen effect as the result of competitive dynamics in which the tacit collusion among rivals, that is a central feature of oligopoly theory, is undermined by the action of firms trying to attain competitive advantage (Barnett & McKendrick, 2004). Specifically, the Red Queen competition arises when gains by a focal firm comes at the expense of rivals, who react to the threat by responding with moves that in turn pose a challenge to the focal firm. In this self-escalating, coevolving system of Red Queen competition, each firm is compelled by industry rivals to participate in a continuous and escalating battle. The dynamics of the battle will vary depending on the type of industry in which firms operate, but the basic causal mechanism, as Barnett and McKendrick (2004) note, is essentially the same: in response to competition firms develop solutions that shore up its position. But these solutions become problems for rivals whose solutions in turn increase the constraints on the first organization, and so on.

The idea of actions and reactions among firms in an industry reflects competitive dynamics (Smith, Grimm, Gannon and Chen, 1991). These action/reaction dynamics reveals a firm's search for higher profit and a stronger competitive position (MacMillan, McCaffrey, and Van Wijk, 1985), and the driver of these dynamics is the awareness of competitors (Derfus et al., 2008). Authors have shown that aggressive competitive actions, such as those more rapid (Ferrier et al., 1999; Smith et al., 1992; Young, Smith, & Grimm, 1996) and more complex (Deephouse, 1999; Ferrier et al., 1999; Miller & Chen, 1994, 1996) are related to better organizational performance. Firm actions have been generally classified as innovative and imitative. Building on the work of Derfus et al. (2008), we focus on imitative moves in Red Queen competition, specifically we look at imitation of new product technologies.

Imitation has emerged as important determinants of competitiveness in several industries. To maintain their competitiveness, firms monitor advances in product technology of other firms in the industry (Greve, 1998; Ocasio, 1997; Greve and Taylor, 2000) and either introduce new technologies in order to differentiate their offer from competitors, or more often they mimic what successful rivals have launched in order to maintain competitive parity and reduce environmental uncertainty (Lieberman and Asaba, 2006).

There is a large body of literature on imitation, both on its antecedents (Lieberman and Asaba, 2006), and its performance outcomes. Lieberman and Asaba (2006) in their review of the imitation literature identify two motives for imitation: information-based and rivalry-based motives for imitation. In the *information-based imitation* framework environmental uncertainty is seen as a necessary condition that influences rivals' actions (Abrahamson and Rosenkopf, 1993, 1997; Bikhchandani, Hirshleifer and Welch, 1992; Semadeni and Anderson, 2010). According to this perspective, market knowledge is heterogeneous in uncertain environments (i.e., information asymmetry is high) and the best performing firms may be perceived by their competitors as having superior knowledge about consumers, future industry dynamics or technological trajectories (Bikhchandani, Hirshleifer and Welch, 1992). In particular, authors suggest that these firms, because of their strong reputation, will act as 'fashion leaders', establishing a trajectory of actions within their market sector that their peers will tend to follow (Abrahamson, 1996; Bikhchandani et al., 1992). In contrast to this type of information-based imitation, *rivalry-based imitation* theories center on firms' efforts to maintain competitive parity, or the 'competitive status quo' (Baum and Korn, 1996; Gimeno and Woo, 1996). In this context, imitation is used more as a competitive tool to neutralize the aggressive rivals' actions than as a mechanism to handle perceived information asymmetry or environmental uncertainty.

Rivalry-based theories of imitation are clearly consistent with Red Queen competition. As noted by Lieberman and Asaba (2006: 380) "Rivalry-based imitation often proceeds over many rounds, where firms repeatedly match each other's moves. This process can strengthen firms that imitate relative to those that do not, thus making it a form of the 'Red Queen' effect discussed in the organizational literature". Firms imitate their rivals in a variety of areas. In many instances, such imitation is little more than adopting what are rapidly becoming standard industry practices, but in other the imitation focuses on strategic moves that are central to maintain competitive position.  In technologically dynamic environments imitation often focuses on new product technologies, namely technologies that have been introduced only recently in the market and that are not widely diffused among the product portfolio of existing competitors.

In this paper we combine current theory of Red Queen competition with rivalry-based theories of imitation in order to examine the extent to which a focal firm uses imitation of new product technologies to enhance performance, stimulates rivals to respond with other imitative actions, and show the extent to which rivals' imitative actions affect the focal firm's performance.

Specifically, we contend that the extent of new product technology imitation by the focal firm, or what we call in this paper '*imitation scope*', expressing the extent to which a firm (in a given period) imitates a wide number (as opposed to a narrow number) of new product technologies introduced by competitors, positively affects its performance only if the focal firm imitates these new technologies relatively rapidly with respect to competitors. If the *speed of imitation* of new product technologies is low, the scope of the focal firm's imitation relates negatively with performance. The imitative actions initiated by the focal firm put pressure on competitors' products, that will try to emulate the firm's imitative actions both in terms of scope and speed to maintain competitive parity, so we expect the scope of the firm's imitative actions in a given period to increase *the scope and speed of rivals' imitation of new product technologies* in the following period, expressed by the number of technologies imitated by rivals. We also expect that the scope and speed of rivals' imitation of new product technologies have a negative effect on the focal firm performance, so to close the Red Queen cycle. Finally, we expect the Red Queen effect, and in particular the relationship between focal firm imitative actions and rivals' imitative actions, and between rivals' imitation actions and performance, to be negatively moderated by *product technology heterogeneity in the market*, a situation in which products in the market widely differ in terms of the technologies they are equipped with. Essentially high product technology heterogeneity corresponds to low 'degree of design dominance'. Various authors in the management literature have analyzed factors leading to a *dominant design* (Klepper, 1997; Utterback and Suarez, 1993), but this concept has been never analyzed as a contingent factor capable to shape imitative behaviors in a Red Queen competition. We explain how the information content that is present in dominant designs constrains or empowers the rivalry into specific technological trajectories.

Figure 1 depicts our research model, with the hypothesized relationships, all of which were supported by our empirical analysis.

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Like Barnett and Hansen (1996) and Derfus et al. (2008), we assume that a firm facing competition is likely to initiate competitive actions, and then not to remain passive. This is a necessary condition for firms' survival. In our context of imitation of innovations, we assume that a firm exposed to competitive rivalry in a technologically dynamic industry is likely to imitate new technologies introduced by pioneers to exploit the advantages offered by these innovations.

The focal firms' imitative actions increase their performance and may result in a decline in rivals' performance, thus prompting those rivals to engage in similar competitive posture (both in terms of scope and speed). We do not assume that the imitations of all new technologies are effective or costless, but we do assume that the average performance benefits of imitating new product technologies, especially if they are imitated rapidly, outweigh the costs. Otherwise, firms would not have a motivation to imitate.

Our goal is to model this self-escalating, coevolving system of focal firm and rivals' imitation of new product technologies. Our research is important as it may offer insights into how firms can successfully use imitation of new product technologies under Red Queen competitive pressures.

## THEORY BACKGROUND AND HYPOTHESES

### Scope and speed of a firm's imitation of new product technologies and its performance

#### *The competitive advantage of more active firms*

Studies in the competitive dynamics literature have shown that more active firms, i.e. those that initiate faster more competitive actions, are more likely to improve their performance (Ferrier, Smith, & Grimm, 1999; Young et al., 1996), while firms that are more passive than their rivals are at the competitive disadvantage (Miller & Chen, 1994). The explanation of this relationship between intensity of competitive activity and performance is that more active firms are more likely to keep pace with a rapidly changing environment and are perceived by rivals as more aggressive competitors than are less active firms (Smith et al., 2001).

The Red Queen literature extends these points recognizing the role that learning from the performance of competitive actions taken by rivals may play in fueling competition, and how taking new actions may help a firm to catch up with rivals performance (Barnett & Sorenson, 2002; Barnett & McKendrick, 2004). The learning from the actions of others that drives the Red Queen competition allows firms that are more active to gain competitive advantage (Derfus et al., 2008) and survive over time by breaking the self-reinforcing cycle that leads to over-exploitation of existing routines (March, 1991).

***How much to copy: imitation scope as a competitive weapon***

Our analysis focuses on a specific type of competitive action, i.e. the imitation of new product technologies. Authors have described imitation as a key mean to learn from the behavior of competitors, as well as an action designed to mitigate rivalry and competitive risk (Lieberman and Asaba, 2006). While previous studies have focused on the conditions that allow imitation to be successful (e.g., Ethiraj and Zhou, 2008), the question of scope, i.e. 'how much to copy', has received only modest attention (Csaszar and Siggelkow, 2010). In fact, most of studies on the performance implications of imitation of innovations, have analyzed the imitation of single products or technologies at the time, but in most technologically dynamic industries product competitiveness is determined by a plurality of new product features available in a certain point in time (e.g. for the case of the PC industry, see Bayus, 1998), and firms try to maintain competitive parity with rivals' products by carefully considering if and how many of these features should be installed in their new product models (Miller and Chen, 1996). In the specific context of new product technology imitation, we introduce the concept of *imitation scope*, expressing the extent to which a firm (in a given period) imitates a wide number (as opposed to a narrow number) of new product technologies introduced by competitors. The scope of competitive actions, or strategic complexity, is a construct that has been already introduced in the competitive dynamics literature, referring to the extent to which a firm competes by means of a complex (as opposed to narrow) repertoire of actions (Ferrier et al., 1999; Rindova et al., 2010).

Imitation scope is akin to this construct, but focuses on the variety (i.e. scope) of a specific type of action, i.e. imitation of new product technologies (previously introduced by competitors) in a certain point in time.

We contend that those organizations with a wider imitation scope have a better chance to outperform rivals, while firms imitating a narrow number of new product technologies are more likely to be at a competitive disadvantage. The reason is twofold. Firms with a wider scope may have a greater ability in adapting to changes and exploit opportunities related to new technologies. Indeed, in a given product category, the knowledge necessary for the imitation of a new technology (related to a certain technological system) facilitates the acquisition of the knowledge required to exploit the advantages offered by other technologies (related to the same technological system), and to better evaluate the possible investments in new technologies (Levinthal and March, 1993). Second, a firm increasing the scope of its imitation, increases the probability of future interaction with rivals owning a similar technological design configuration. This process should favor a mechanism of forbearance that facilitate the adoption and spread of collusive strategies (tit-for-tat) (Baum and Korn, 1999). In fact firms that have adopted similar technologies in the past have to remain alert to rapidly discover the optimal subsequent configuration. Therefore when firms compete with each other on similar design configuration, they can more easily sustain collusion, because deviations toward a different design can be met by aggressive responses in completely different directions (Lieberman and Asaba, 2006).

***Imitation scope calls for imitations speed***

Still, while the imitation scope can offer the firm a number of benefits, the firm is not moving alone in the external environment, but has to continuously confront with the competitive moves undertaken by rivals. Studies on the Red Queen effect, and on competitive dynamics more in general, have argued that to defend their temporary competitive advantage, firms need to respond as fast as they can to rivals actions and the related opportunities (D'Aveni, 1994; Derfus et al., 2008). As also suggested by the first mover advantage literature (Lieberman and Montgomery, 1988), pioneers and fast imitators benefit from several advantages that may severely obstacle the performance of late imitators. For example, in consumer electronics industries, like mobile phone or personal computer, first adopters of new product technologies often benefit from 'spatial preemption', by filling product differentiation niches before late adopters (Rindova et al., 2010) or by taking advantage of the disproportionate attention in the consumer's mind, forcing late new technology adopters to introduce truly superior products, or else advertise more intensively in order to be noticed by the consumer (Carpenter and Nakamoto, 1989, 1994). Therefore, the emerging benefits of a set of new product technologies opportunity may have no effect (or negative effect) on a firm performance if the technologies are adopted too late with respect to rivals. This would suggest that imitation scope is beneficial for firm performance only if new product technologies are imitated rapidly, before rivals. For this reason a firm whose imitation tends to lags behind its rivals, has difficulties in building trust relationships with customers that do not consider valuable its obsolete technical competencies (Szulanski et al. 2004). On the contrary, rapid imitators with a wide scope will be perceived by consumers as innovative and trustworthy as technology pioneers. Given these arguments, we predict:

***Hypothesis 1:*** *With the scope of rivals' imitation of new product technologies held constant, as the scope of the focal firm's imitation of new product technologies increases, focal firm performance increases only if new product technologies are imitated rapidly. For low level of speed of new technology imitation the relationship between the scope of the focal firm's imitation of new product technologies and its performance is either negative or not significant.*

**Scope of a firm's imitation of new product technologies and the scope and speed of rivals' imitative actions**

Red Queen competition also suggests that as the number of focal firm actions increases, the number of rival firm actions increases too (Derfus et al., 2008). That is because the greater the focal firm's competitive activity, the more competitors are likely to feel their performance are at stake, and then are likely to respond (Barnett & Hansen, 1996; Barnett & McKendrick, 2004). In other words, one firm's increase in performance can become another firm's problem, and this latter is not likely to remain passive.

Recent research in the competitive dynamics literature supports the co-evolutionary nature of action and countermoves. In fact, various authors have found a positive relationship between firm actions and rival actions (Grimm & Smith, 1997).

The extant studies analyzing the relationship between firm action and rivals' countermoves have focused both on single types of action (Chen and MacMillan, 1992; Chen, Smith and Grimm, 1992; MacMillan, McCaffery, and Van Wijk, 1985; Smith et al, 1989), the firm's repertoire of actions, i.e. actions of different types (Ferrier et al., 1999; Miller and Chen, 1994, 1996) and sequence of actions (Ferrier, 2001; Ferrier and Lee, 2002). In these latter approach it is emphasized the holistic effect of sequences of actions "that communicate an overarching strategic logic" (Rindova et al., 2010; Wiggins and Ruefli, 2005).

In the specific case of imitative actions, since according to the Red Queen effect, all advantages are temporary because firms interact and the successful action evokes reaction from rivals, we expect that as firms imitate a wider range of product technologies, the scope and speed of rivals' imitation of new product technologies (in the following period) will increase too. A first reason for that is the significant 'liability of newness' (Stinchcombe, 1965): firms cannot wait for later opportunities, but need to be concerned with short-term profit of their actions (from Hypothesis 1). In this case, the larger is the imitative action of the focal firm, the greater are the opportunities that it is trying to exploit. Indeed, when a firm leads with the successful imitation of a new product or technology, it puts pressure on competitors' products and technologies, perhaps to the point of rendering them obsolete. According to rivalry-based imitation, those competitors must act intensively and rapidly if they want to maintain competitive parity. The cycle repeats again and again as rivals struggle for profits and market share. That is, the improved firm performance derived from intense and rapid imitation of new product technologies may come at the expense of rivals' performance, which, in turn, may prompt rivals to trigger aggressive imitative actions to emulate the focal firm's successful imitations. In this sense, learning and competition are codependent. Together, they explain the incremental and relative process by which firms evolve as they try to improve performance.

Thus, we predict:

***Hypothesis 2a:*** *As the scope of the firm's imitation of new product technologies increases, the scope of rivals' imitation of new product technologies increases.*

***Hypothesis 2b:*** *As the scope of the firm's imitation of new product technologies increases, the speed of rivals' imitation of new product technologies increases.*

**Scope and speed of rivals' imitation of new product technologies and the focal firm performance**

Various studies in the management and strategy literature have analyzed if and how the intensity of competitive rivalry affects industry members' performance. Young et al. (1996) use as empirical setting a sample of software firms, and find that increases in the number of rival actions have a detrimental effect on the focal firm performance. Similarly, Chen and Miller

(1994) and Smith and colleagues (1992) analyses of competitive dynamics in the airline industry shows that higher levels of rival responses decreased the focal firm performance. Moreover, these streams of research have demonstrated that there is a link between action and performance by aggregating the characteristics and frequency of specific responses over a finite time period (Ferrier et al., 1999; Smith et al., 1992; Young, Smith, & Grimm, 1996). Therefore, more actions a rivals carries out and the greater the speed of execution, the better it can sustain its relative competitive advantage. Studies on the Red Queen effect have also examined the performance outcomes of competitive intensity. Barnett and Hansen (1996), using a sample of all the major competitors in 11 different industries across a broad spectrum of the U.S. economy have shown that the positive performance outcomes gained by the focal firm triggers rivals' competitive response in an attempt to emulate the focal firm success. Likewise, in their analysis of the Red Queen competition through the lenses of the competitive dynamics literature, Derfus et al. (2008) show that as the number of rival firm actions and the speed of rival actions increase, focal firm performance decreases. Echoing this, we expect that the scope and speed of rivals' imitative actions relates negatively with the focal firm's performance.

***Hypothesis3a:*** *With the scope of the focal firm's imitation of new product technologies held constant, the effect of the scope of rivals' imitation of new product technologies on firm performance is negative.*

***Hypothesis 3b:*** *With the scope of the focal firm's imitation of new product technologies held constant, the effect of the speed of rivals' imitation of new product technologies on firm performance is negative.*

**The moderating effect of product technology heterogeneity in the market**

We contend that, the extent to which the focal firm's imitative actions trigger rivals' imitative actions (Hypothesis 2) and the extent to which rivals' imitative actions affect the focal firm's performance (Hypothesis 3), depend on a key characteristic in the environment: the *level of product technology heterogeneity in the market*, expressing the extent to which products launched by all competitors are equipped with similar or different technologies. At the two extremes, a low level of product heterogeneity is a situation of 'high degree of design dominance', while a high level of product heterogeneity is a situation of 'low degree of design dominance'. High product technology heterogeneity, i.e. low degree of design dominance, has been regarded as a situation in which firms have to cope with 'casual ambiguity', namely a scenario in which firms cannot easily understand which are the new technologies whose adoption would foster a competitive advantage (Lippman and Rumelt, 1982; Peteraf, 1993; Makadok, 1998; Szulanski et al., 2004). When confronting with high product technology heterogeneity, (a) how will rivals respond to the imitation strategy of the focal firm? (b) how rivals imitative actions will affect the performance outcomes of the focal firm?

***Product technology heterogeneity: focal firm's scope of imitation and rivals' imitation response***

We contend that product technology heterogeneity moderates the relationship between scope of firm's imitation and both scope and speed of rivals' imitation as follows.

We contend that when there is *low product technology heterogeneity* in the market, and then high degree of design dominance (a clear product configuration is present in the market), rivals are more committed to imitate new product technologies to exploit differentiation advantages (from the dominant design) with respect to laggard imitators of these innovations. In other words, we contend that when products are similar in terms of features, the new product technologies offer differentiation opportunities for pioneers and fast imitators, e.g. special preemption and abnormal consumer attention to the brands of products first offering new design configurations, thus encouraging the imitation of these new technologies (i.e., higher imitation scope and speed).

By contrast, we expect that, when there is *high product technology heterogeneity* in the market, and then there is not a clear dominant product configuration, rivals want to reduce the risk to commit mistakes when imitating new product technologies in a scenario in which there are few information about which will be the more successful and accepted technologies by the market. Moreover, the poor information about the potential of the various existing technologies does not allow to disambiguate market segments, and therefore competitive threats are unclear, and norms of mutual forbearance are unlikely to exist (Chen et al., 2010). Thus, firms cannot easily predict the likely outcome of imitative actions. As noted by some authors, "decision makers confronting conflicting mimetic requirements and practices find it difficult to make an imitation decision because conformity to one undermines the isomorphic support of other elements" (Rhee et al., 2006: 504). Likewise, others have shown that decision makers who face conflicting external information reduce the attention paid to such data when updating their private information, and are then likely to take non-conforming decisions (Cameron, 2005). In essence, obstacles to processing observed information—caused by heterogeneous information—reduce imitation (Gaba and Terlaak, 2013). In this light, we expect that when product technology heterogeneity is high, there are obstacles to processing information about the very heterogeneous product configurations—caused by heterogeneous information— and this reduces the scope and speed of imitation of new technologies. This line of logic suggests that:

***Hypothesis 4a:*** *Product technology heterogeneity negatively moderates the relationship between the scope of the firm's imitation of new product technologies and the scope of rivals' imitative actions.*

***Hypothesis 4b:*** *Product technology heterogeneity negatively moderates the relationship between the scope of the firm's imitation of new product technologies and the speed of rivals' imitative actions.*

***Product technology heterogeneity: scope and speed of rivals' imitation and firm performance***

We contend that product technology heterogeneity moderates the relationship between scope and speed of rivals' imitation and firm performance as follows.

When there is *low product technology heterogeneity*, and then a high degree of design dominance, firms and consumers have a clear idea of the most successful product configuration (i.e., which are the technologies that a product should incorporate to adequately perform in the market). The introduction of new product technologies, on the one hand offers rapid imitators the chance to differentiate from laggards/followers, on the other hand firms that intensively imitate new product technologies run the risk to deviate from the dominant design. If new product technologies are introduced and the focal firm decides to imitate them aggressively, the rivals' decision to emulate the focal firm's strategy to intensively imitate new product technologies fosters the diffusion of these new technologies. In fact, some authors in the imitation literature have noted that frequency of imitation of a newly introduced technology may serve as a valid proxy indicator that the innovation has technical value (Abrahamson and Rosenkopf, 1993). Rogers (1995) and others (e.g., Mansfield, 1961) have suggested that frequent imitation of beneficial innovations will create more (correct) information about an innovation's value, which in turn causes more adoption by others (Haunschild and Miner, 1997). The rivals' imitations of new technologies previously imitated by the focal firm offer some benefits for the latter. In particular, rivals' imitation fostering the rapid diffusion of innovations previously imitated by the focal firm may directly create positive externalities and technical value (Farrell and Saloner, 1985; Teece, 1986), with greater benefits for early imitators (i.e., the focal firm): the greater adoption of the new technologies by the focal firm's competitors generate positive network externalities for the focal firm with respect to rivals, that in this context are follower imitators with respect to the focal firm.

By contrast, when there is *high product technology heterogeneity*, and then a low degree of design dominance, the market is populated by products with different technologies. In this scenario of 'casual ambiguity', firms cannot easily understand which is the set of technologies that facilitate the achievement of a competitive advantage (Makadok, 1998; Szulanski et al., 2004). By intensively imitating new product technologies the firm runs the risk to create confusion in the mind of consumers that are already exposed to a wide product variety. Rivals can observe the performance outcomes of the focal firm's imitative strategy and imitate by investing resources mainly in those new technologies that have demonstrated greater acceptance by consumers. This means that, after have observed the focal firm's imitate strategy, the scope and speed of rivals' imitation of new product technologies are likely to hurt the focal firm's performance.

We thus hypothesize:

***Hypothesis 5a:*** *Product technology heterogeneity negatively moderates the relationship between the scope of the rivals' imitation of new product technologies and focal firm performance..*

***Hypothesis 5b:*** *Product technology heterogeneity negatively moderates the relationship between the speed of the rivals' imitation of new product technologies and focal firm performance.*

**METHODS**

**Sample and setting**

We test the proposed hypotheses in the specific context of the UK mobile phone industry. This choice allows us to satisfy the requirements that firms must compete in the same market so that their specific actions and performance could be directly connected (Derfus et al., 2008). Our sample includes handset vendors operative in the UK mobile phone industry in the period from 1997 to 2008, during which, overall 566 new mobile phones were introduced. Sampled firms are: Nokia, Motorola, Samsung, LG, Ericsson, Sony, Sony-Ericsson, Siemens, Philips, Panasonic, Sagem, NEC, Alcatel, that represented almost the entire industry in the UK. It is worth noting that, in order to define the boundaries of the competitive arena in the selected industry, we decided to exclude from out sample smartphone devices, i.e. those handsets equipped with an advanced operating system, and characterized by a specific set of features. In fact, during the analysed time period, smartphones were targeted mainly at business users. Smartphone diffusion was relatively low before 2008, and during the whole time period considered for our analysis, their sales represented only a minor portion of handset vendors' revenue. Information about product innovations introduced by the 13 mobile phone vendors in the UK market were collected from the specialist industry magazines *What Mobile*, *What CellPhone* and *Total Mobile.*

**New product technologies, technological systems and imitation**

The mobile phone industry, as other consumer electronics industries, has been often described as a fast changing environment, characterized by rapid new product technology introduction and quick technological obsolescence, all factors that solicit the firms' attention to monitor the new product technologies introduced by competitors and their performance. New product technologies are the 'object' of the imitation in our study. We define a product technology as any hardware or software allowing the handset to performance a certain function. Since technologies may evolve over time, we considered both the first version of a technology introduced in the market and successive ameliorations. Information on 64 product technologies was collected from the above-mentioned special interest magazines. The sampled product technologies were also grouped in technological systems. Following the work on complex systems of Murmann and Frenken (2006), we define a technological system as a man-made system that is constructed from technologies that function collectively to produce a number of functions for users. Essentially, a technological system is a group of technologies allowing the product to perform functions of a certain type. For example, in mobile phones both infrared, Bluetooth and USB port are technologies allowing connectivity between devices, and thus belonging to the same technological system.[1]

We grouped the 64 technologies in seven technological systems: networking; high speed transfer; phone call; connectivity; messaging; display; technological convergence.

**Measures**

Depending on the relationship analysed (Figure 1), dependent and independent variables are the following:

*Scope of the focal firm's imitation of new product technologies [t]*. Consistent with the extant literature (Derfus et al., 2008), we define and measure the *scope of a firm's imitation* as the total number of new product technologies (belonging to a specific technological system) imitated within the year *t*. In our analysis we wanted to consider only the imitation of *new* technologies, namely those technologies only recently introduced and not largely adopted by competitors. That is because we assume technologies that are imitated very slowly are not likely to be imitated for

[1] Some authors have suggested that the boundaries of a technological system can be defined by two factors. First, product technologies are structured in terms of technological interdependence within the system, therefore each

competitive purposes. We thus consider only the imitation of technologies that, when imitated by the firm, were present in no more than 50% of products launched in the market. Along the whole observation period we could observe more than 600 imitative actions.

*Average speed of the focal firm's imitation of new product technologies*. We define and measure the *speed of focal firm's imitation* as the average time it takes for the focal firm to adopt new product technologies, related to a specific technological system, introduced by rivals. Essentially, we want to capture the speed of imitation of those new product technologies used to operationalized the imitation scope. To do this, first, we computed the time to imitation, in days, per each of the technologies imitated by the firm in a certain year *t*. Second, we normalized this latter value by diving it for the maximum imitation time for that technology in the sample, so to transform the variable from count to ratio. Third, we computed the mean of the firm's imitation timing of technologies belonging to a certain technological system ($avtime_{i,t}$). We finally operationalized the average speed of the focal firm's imitation ($AS_{i,t}$) as in equation 1. The resulting measure, ranging from 0 to 1, equates high (i.e., closer to 1) focal firm's imitation speed values to fast firm imitation speed and low (i.e., closer to 0) focal imitation speed values to slow firm imitation speed.

(1) $AS_{i,t} = 1 - (avtime_{i,t})$

*Average speed of rivals' imitation of new product technologies*. As in other competitive dynamics research (e.g., Ferrier et al., 1999; Young et al., 1996), rivals speed of imitative action quantifies the average length of time it took rivals to act after a new product technology is introduced. Following the procedure outlined by Derfus et al. (2008), to calculate this measure, we take the mean of the average speed of imitation of all focal firm's rivals in a certain time *t*.

The resulting measure equates high rivals' imitation speed values to fast rivals' imitation speed and low rivals' imitation speed values to slow rivals' imitation speed.

*Scope of rivals imitation of new product technologies [t+1]*. We operationalized the *scope of a rivals' imitations* by subtracting the total number of imitations realized by the focal firm at time *t+1* from the total number of actions taken by all competitors in a focal technological system. In this way we account only for those actions subsequent to the focal firm's imitative actions.

*Focal firm performance [t+1]*. Focal firm performance was operationalized using the number of handsets sold on a yearly basis. This measure is widely used by both management scholars (e.g., Czarnitzki and Thorwarth, 2012) and industry specialists (e.g., Gartner Dataquest; Mintel International Group Limited). Data on handsets sold per vendors were collected from Mintel International Group Limited, Euromonitor International and firms' archival data.

*Product technology heterogeneity [t]*. We operationalized the measure of product technology heterogeneity with the Shannon entropy index (1948), expressing the average amount of information contained in a 'message', in our context the set of technologies mounted in existing products. In our specific setting, the index measures the extent to which products differ in terms of technologies belonging to a certain technological system. A uniform distribution of the type of technologies products are equipped with reflects a situation in which firms have come up very many different designs, while a skewed distribution represent a situation in which firms slightly differ in their choice of design. As such, the index can be used as an indicator of technological heterogeneity, and then of the extent to which products within the industry differ in terms of the mounted technologies or have a dominant design (Frenken et al., 1999). The Shannon entropy value of a technological system is given by the following equation 2:

(2) $H_i = -\sum_{k=1}^{S} \ln(p_k) \times p_k$

Where $H_i$ is the level of product technology heterogeneity within the technological system $i$, $p_k$ is the percentage of products (introduced in year $t$) equipped with the technology $k$ (therefore $0 \leq p_k \leq 1$), $S$ is the number of technologies introduced and related to the technological system $i$.

The Shannon entropy index is equal to zero when all products introduced at time $t$ in the market are equipped with the same set of technologies related to the technological system $i$. This means that there is a dominant design in terms of the set of technologies related to $i$. In this extreme case $p_k$ would be equal to 1, which implies that the entropy of the product population equals zero:

(3) $H_i = -\ln(1) \times 1 = 0$

Entropy is positive otherwise, and the larger its value, the larger is the variety in the population. Specifically, the larger the value of $Hi$, a) the higher the number of technologies in the technological system, 2) the lower their diffusion among existing products. This means that as $H_i$ increases, the more heterogeneous are products in terms of technologies (related to a certain technological system) they are equipped with. The maximum level of the entropy depends on the size of the technological domain ($S$), namely the entire number of technologies part of the technological domain. When all the technologies have an equal frequency $p_k = 1/S$, the entropy of this distribution is equal to:

(4) $H_{max} = -S \times \left\{ \left(\frac{1}{S}\right) \times ln\left(\frac{1}{S}\right) \right\} = \ln(S)$

We also included various control variables, potentially affecting both firms' action and their performance:

*Focal firm number of innovations*. Although we are analyzing competitive dynamics related to imitative efforts, we want to account also for the number of innovation introduced by the imitator into the technological system. This variable was measured as a count of new product technologies introduced by the imitator in the year *t*.

*Rivals number of innovations*. The effect of imitative effort has to be controlled for the number of alternative competitive actions exercised by rivals in the year *t*. We define and measure the total number of innovations of the rivals in the technological domain as a count of the new product technologies introduced by rivals in the year *t*.

*Focal firm relative market position*. Studies on the Red Queen effect have argued that a firm relative size can influence its performance and rivals' response to its actions (Derfus et al., 2008). Relative market position was measured with a dummy variable that values 1 if the level of sales of the firm in the year *t* was above the industry median, and 0 otherwise.

*Industry concentration*. Authors in the management literature have long shown that industry concentration is related to competition intensity and may strongly affect the firms' performance and the intensity of their competitive actions (Derfus et al, 2008). We measure industry concentration with the Herfindahl index, by using the UK market shares of handset vendors in our sample:[2]

(4) $C_i = 1 - \sum_{i=1}^{n} \delta_{i,t}^2$

where $\delta_{i,t}$ is the market share of the handset vendors *i* in year *t*. The higher the *C* index, the lower the level of industry concentration, and then we assume the higher the level of competition intensity because largest rivals are less likely to collude (Scherer and Ross, 1990; Wiggins and Ruefli, 2002).

## RESULTS

[2] Since in our analysis we excluded smartphone devices, also those vendors entirely focused on this product segment, like BlackBerry, were not considered in the competitive intensity index.

Table 1 reports variables descriptive statistics. We tested hypotheses by means of two regression models: (1) a robust fixed effect regression when the dependent variable is the focal firm performance; (2) a robust fixed effect Poisson regression when the dependent variable is rival total actions, a count-type variable (Cameron and Trivedi, 2009). Hausman test suggested the use of fixed-effects was preferable than random-effects. Our regression models take into account the imitation strategies of 64 product technologies belonging to 7 technological systems, introduced and imitated in the UK market by 13 firms within the 1997-2008 time window, leading to a 644 observation-model. Not all technologies were adopted by all industry rivals, and not all rivals were operative over the entire time period analysed.

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Please insert Table 1 around here

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Models 1-4 in Table 2 report the results for regressions relating firm imitation, speed of firm imitation and rival imitation to firm performance. Models 1 and 3 include only main effects while in models 2 and 4, the full models, interactions are added. The regression results that examine the impact of firm imitation and speed of firm imitation on rivals' imitation are presented in the models 5-7. Model 5 includes only main effects while in models 6 and 7, the full models, interactions are added.

Hypothesis 1 states that with the scope of rivals imitation of new product technologies held constant, as the scope of the focal firm's imitation of new product technologies increases, focal firm performance increases only if new product technologies are imitated rapidly. As seen in models 2 and 4, the coefficient of scope of focal firm's imitation is negative and significant ($\beta$=-.056, $p$<.05; $\beta$=-.052, $p$<.05), the coefficient of firm's average speed of imitation is not significant, while their interaction is positive and significant in Model 2 ($\beta$=.043, $p$<.05) and not significant in Model 4, this latter including as independent variable rivals average speed of imitation instead of rivals imitation scope. Following the procedure of Derfus et al. (2008), we plot the significant interaction between scope of focal firm imitation and average speed of imitation as in Figure 2. Specifically, the plot in Figure 2 shows the actual focal firm average speed of imitation and focal firm imitation scope associated with various level of performance. As predicted in Hypothesis 1, when the average imitation speed is low, the negative relationship between scope of firm imitation and performance is negative, while it becomes positive for high levels of imitation speed. Taking into account the not significant interaction between scope and speed in Model 4, we conclude Hypothesis 1 is partially supported.

Hypotheses 2a-2b state that as the scope of the firm's imitation of new product technologies increases, the scope and speed of rivals' imitation of new product technologies increases. These hypotheses are supported. Specifically, models 6 and 7 in Table 2 report a significant, positive coefficient for the relationship between scope of the focal firm imitation and the scope of rivals' imitation ($\beta$=.174, $p$<.01), and for the relationship between scope of the focal firm imitation and the speed of rivals' imitation ($\beta$=.098, $p$<.05), respectively.

Hypotheses 3a-3b state that with the scope of the focal firm's imitation of new product technologies held constant, there is a negative relationship between the scope and speed of rivals' imitation of new product technologies on a focal firm performance. As seen in models 2 and 4, the coefficient of scope of rivals' imitation is negative and significant ($\beta$=-0.039, $p$<.01), as that the coefficient of speed of rivals' imitation ($\beta$=-0.080, $p$<.1), thus supporting the hypotheses 3a-3b.

Hypotheses 4a-4b state that product technology heterogeneity negatively moderates the relationship between the scope of the firm's imitation of new product technologies and the scope and speed of rivals' imitative actions. As shown in Model 6 the coefficient of the interaction between product technology heterogeneity and scope of firm's imitation is negative and significant ($\beta$=-.058, $p$<.10), while the coefficient of the interaction between product technology heterogeneity and speed of firm's imitation is not significant (Model 7). These results partially support Hypothesis 4.

Hypotheses 5a-5b state that product technology heterogeneity negatively moderates the relationship between the scope and speed of rivals' imitation of new product technologies and focal firm performance. As shown in models 2 and 4, the negative and significant coefficients of the interaction between product technology heterogeneity and scope of firm's imitation ($\beta$= -0.048, $p$<.01), and of the interaction between product technology heterogeneity and speed of firm's imitation ($\beta$= -0.051, $p$<.05), provide support to hypotheses 5a-5b. Plotting the data from the Model 2 we graphically present the form of the significant interactions (Scope of rivals' imitation × product technology heterogeneity; Speed of rivals' imitation × product technology heterogeneity) in figures 3 and 4. Specifically, we see in Figure 3 the actual scope of rivals' imitation and product technology heterogeneity associated with various level of performance, while in Figure 4 the actual average speed of rivals' imitation and product technology heterogeneity associated with various level of performance. As expected, when the product technology heterogeneity is low, the relationship between scope of rivals' imitation and focal firm performance is positive, while it becomes negative for high levels of product technology heterogeneity, thus supporting Hypothesis 5a. Figure 4 illustrates this relationship in terms of rivals' speed of imitation. As product technology heterogeneity increases the negative relationship between rivals' speed of imitation and focal firm performance becomes more and more stronger.

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Please insert Figures 2, 3 and 4 around here

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**DISCUSSION**

This study has shed light on a 'Red Queen' approach to imitation in technologically dynamic industries. The extent literature that analysed the conditions under which imitation is successful has not recognised the role that learning from the outcomes of imitative actions may play in fuelling competition and evolution. To address this gap we have developed a model of Red Queen competition where the scope of imitation of new product technologies is the result of competitive threat.

In line with Red Queen theory, our model shows that a focal firm's aggressive actions trigger rivals' countermoves that in turn negatively affect a focal firm performance. In particular, this co-evolutionary nature of competition, in our imitation model shows that firms that imitate rapidly a wide set of technologies (i.e., wide imitation scope) trigger rivals' imitative actions which negatively impact the focal firms' performance. Indeed this supports the idea that rivalry-based imitation has a co-evolutionary nature in which the benefits a focal firm gains from the rapid imitation of rivals are eroded by the rivals response (Barnett and McKendrick, 2004). Although portions of this baseline model have been tested elsewhere, we are aware of no previous study that has examined both the positive and negative effects of imitative actions, and imitation scope in particular, as we do in the present study. The analysis of these self-reinforcing mechanism of competition enables us to shed light on the positive and negative aspects of imitative actions, and to clarify the relative importance of these aspects with regard to firm performance.

Our first interesting result is that the scope of new product technology imitation positively affects focal firm performance only if imitation happens rapidly with respect to competitors (Hypothesis 1). In fact firms are not moving alone in the external environment and therefore they have to rapidly face the competitive moves undertaken by rivals. It is in these conditions that a focal firm can be recognised as pioneer by customers and therefore a larger scope of imitation of new product technology is beneficial. In line with the Red Queen argument, we also found that a focal firm imitation scope triggers rivals imitative actions both in terms of scope and speed (Hypotheses 2a-2b), suggesting that the more the focal firm expands its set of imitated technologies, the more rivals perceive this strategy as a threat for their competitive position. Finally, to close the Red Queen cycle, we found rivals imitation scope and speed have a negative effect on the focal firm performance (Hypotheses 3a-3b).

In an effort to better understand the boundaries of the Red Queen competition in a technological dynamic industry, we also developed a theory on how Red Queen evolution might depend upon a specific industry condition: the level of product technology heterogeneity in the market, expressing the degree of design dominance in a certain technological system. Importantly, our results indicate that this factor significantly moderates the effects of a focal firm imitation scope on rivals imitation scope and speed and, subsequently, the effect of rivals imitation scope and speed on the focal firm performance. First, we speculated and find that this moderating factor mitigate the rivals' response to the focal firm imitative actions. That is because in a scenario in which there is little information about which will be the more successful and accepted technologies by the market rivals (i.e., high product technology heterogeneity in the market), rivals try to reduce the risk to commit mistake when imitating innovations introduced by others, decreasing the scope and speed of their imitative actions. This result reveals that the attention to the competitive threats is driven by the amount of information available about the potential of the various existing technologies. Second, we speculated and find that product technology heterogeneity amplify the negative effect of rivals' initiative response on the focal firm performance. That is because, when uncertainty about the performance of new technologies is high, rivals may observe the performance outcomes of the focal firm's imitative strategy and imitate only new technologies that have demonstrated greater acceptance by consumers. In this way they strengthen their competitive position with respect to the focal firm by investing only in value enhancing technologies. Our study of this contextual moderating factor went well beyond antecedent research from industry life cycle and dominant design (Agarwal & Gort, 1996; Agarwal, Sarkar, & Echambadi, 2002; Carroll & Hannan, 1989). In fact, the technological change literature (Tushman and Anderson, 1986) testing this theory about competition in technology dynamic industries have focused mainly on the characteristics of the industry structure over the various stages of the industry evolution (Agarwal & Bayus, 2002) and often assumed or not measured the role of competitive actions, and imitative actions in particular. In contrast, our study explores the relationship between imitative actions and performance in the context of varying degrees of design dominance. We can therefore speculate that the process of technological change is driven by a Red Queen competition where the experience and the performance implications of imitative actions shape the firm decision to adopt a certain product technology configuration.

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**Table 1. Descriptive statistics**

| | | mean | sd | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Performance** | 1684.886 | 2189.830 | 1.000 | | | | | | | | | |
| 2 | **Focal firm imitation scope** | 0.530 | 0.884 | 0.058 | 1.000 | | | | | | | | |
| 3 | **Focal firm average speed of imitation** | 0.133 | 0.247 | 0.119** | 0.620** | 1.000 | | | | | | | |
| 4 | **Rival average speed of imitation** | 0.326 | 0.249 | -0.188** | -0.041 | 0.074+ | 1.000 | | | | | | |
| 5 | **Rivals imitation scope** | 4.648 | 4.423 | -0.076+ | 0.265** | 0.219** | 0.183** | 1.000 | | | | | |
| 6 | **Product technology heterogeneity** | 1.660 | 0.959 | 0.158** | 0.354** | 0.106** | -0.300** | 0.259** | 1.000 | | | | |
| 7 | **Focal firm N. Innovations** | 0.081 | 0.329 | 0.035 | 0.051 | 0.080* | 0.051 | 0.100* | 0.070+ | 1.000 | | | |
| 8 | **Rivals N. Innovations** | 0.831 | 1.126 | -0.132** | 0.076+ | 0.071+ | 0.222** | 0.185** | -0.012 | 0.016 | 1.000 | | |
| 9 | **Focal firm relative market position** | 0.486 | 0.500 | 0.625** | 0.082* | 0.172** | -0.018 | 0.011 | 0.003 | 0.054 | 0.003 | 1.000 | |
| 10 | **Industry concentration** | 0.776 | 0.047 | -0.066+ | -0.158** | -0.051 | 0.082* | -0.292** | -0.260** | -0.019 | 0.092* | -0.065+ | 1.000 |

N = 644

$^{+}$ $p < 0.10$, $^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$

**Table 2. Results of robust fixed-effects regression analysis**

| | Robust fixed-effects | | | | Robust fixed-effects Poisson | | Robust fixed-effects |
|---|---|---|---|---|---|---|---|
| | **Model 1** Firm sales (t+1) | **Model 2** Firm sales (t+1) | **Model 3** Firm sales (t+1) | **Model 4** Firm sales (t+1) | **Model 5** Rivals' imitation (t+1) | **Model 6** Rivals' imitation (t+1) | **Model 7** Rivals' imitation speed (t+1) |
| Constant | 0.018$^{**}$ | 0.004 | 0.015$^{**}$ | -0.018 | | | -0.050$^{**}$ |
| | (5.007) | (0.279) | (3.955) | (-1.074) | | | (-4.069) |
| ***Dependent variables*** | | | | | | | |
| Focal firm imitation scope (t) | -0.041$^{+}$ | -0.056$^{*}$ | -0.044$^{+}$ | -0.052$^{*}$ | 0.135$^{**}$ | 0.174$^{**}$ | 0.098$^{*}$ |
| | (-1.862) | (-2.488) | (-1.950) | (-2.253) | (4.769) | (4.482) | (2.189) |
| Focal firm average speed of imitation (t) | 0.012 | -0.008 | 0.012 | -0.002 | | | |
| | (0.383) | (-0.215) | (0.400) | (-0.065) | | | |
| Rivals imitation scope (t+1) | -0.043$^{*}$ | -0.039$^{+}$ | | | | | |
| | (-2.013) | (-1.785) | | | | | |
| Rivals average speed of imitation (t+1) | | | -0.062$^{*}$ | -0.080$^{**}$ | | | |
| | | | (-2.498) | (-3.337) | | | |
| Product technology heterogeneity (t) | 0.183$^{**}$ | 0.191$^{**}$ | 0.147$^{**}$ | 0.137$^{**}$ | -0.039 | -0.035 | -0.627$^{**}$ |
| | (4.932) | (5.114) | (3.720) | (3.647) | (-1.030) | (-0.931) | (-16.319) |
| ***Interactions*** | | | | | | | |
| Focal firm imitation scope × Focal firm average speed of imitation | | 0.043$^{*}$ | | 0.028 | | | |
| | | (2.062) | | (1.315) | | | |
| Rivals imitation scope × Product technology heterogeneity | | -0.048$^{**}$ | | | | | |
| | | (-2.903) | | | | | |
| Rivals average speed of imitation× Product technology heterogeneity | | | | -0.051$^{*}$ | | | |
| | | | | (-2.296) | | | |
| Focal firm imitation scope × Product technology heterogeneity | | | | | | -0.058$^{+}$ | -0.020 |
| | | | | | | (-1.715) | (-0.523) |
| ***Controls*** | | | | | | | |
| Focal firm number of innovations (t) | -0.041 | -0.040 | -0.041 | -0.040 | | | |
| | (-1.383) | (-1.325) | (-1.326) | (-1.311) | | | |
| Rivals number of innovations (t) | | | | | 0.056$^{+}$ | 0.061$^{*}$ | 0.050 |
| | | | | | (1.935) | (2.158) | (0.902) |
| Relative market position (t) | 0.302$^{**}$ | 0.303$^{**}$ | 0.303$^{**}$ | 0.304$^{**}$ | -0.021 | -0.012 | 0.007 |
| | (7.455) | (7.375) | (7.470) | (7.371) | (-0.445) | (-0.243) | (0.106) |
| Industry concentration (t) | 0.041$^{*}$ | 0.052$^{*}$ | 0.051$^{*}$ | 0.044$^{*}$ | -0.277$^{**}$ | -0.268$^{**}$ | -0.057$^{+}$ |
| | (2.047) | (2.571) | (2.562) | (2.194) | (-5.719) | (-5.476) | (-1.772) |
| *N* | 644 | 644 | 644 | 644 | 644 | 644 | 644 |
| *Adj R2* | 0.262 | 0.271 | 0.270 | 0.279 | | | 0.194 |
| *R2 overall* | 0.404 | 0.405 | 0.412 | 0.414 | | | 0.104 |
| *Wald Chi-square* | | | | | 60.031 | 66.941 | |

Standardized coefficients are reported; *t* statistics in parentheses

$^{+}$ $p < 0.1$, $^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$

**Figure 1. Research model**

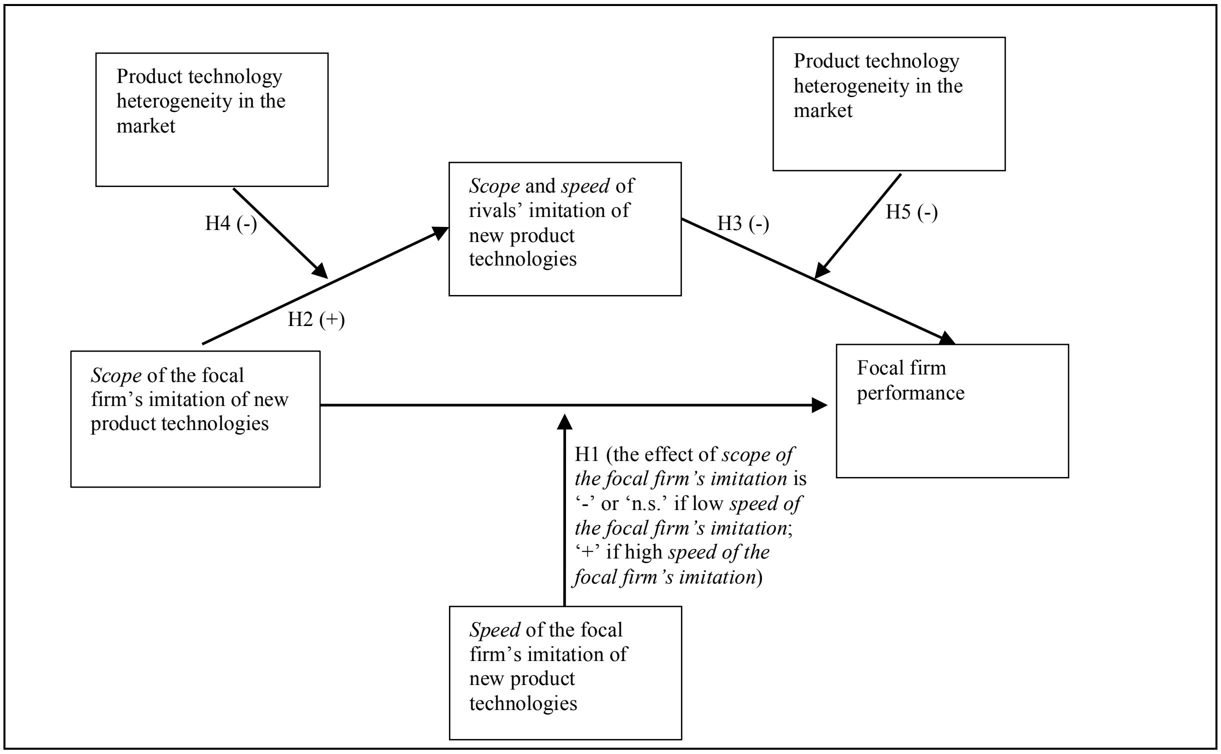



**Figure 2. Scope of firm's imitation, average speed of imitation and firm performance**

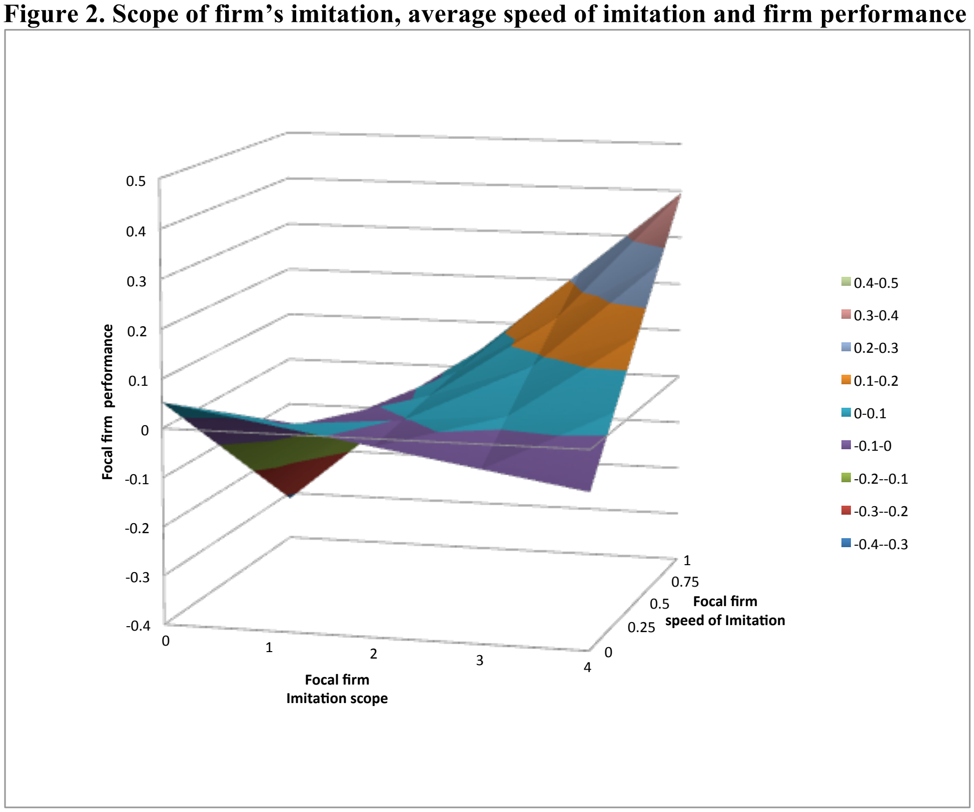


**Figure 3. Rivals' scope of imitation, product technology heterogeneity and firm performance**

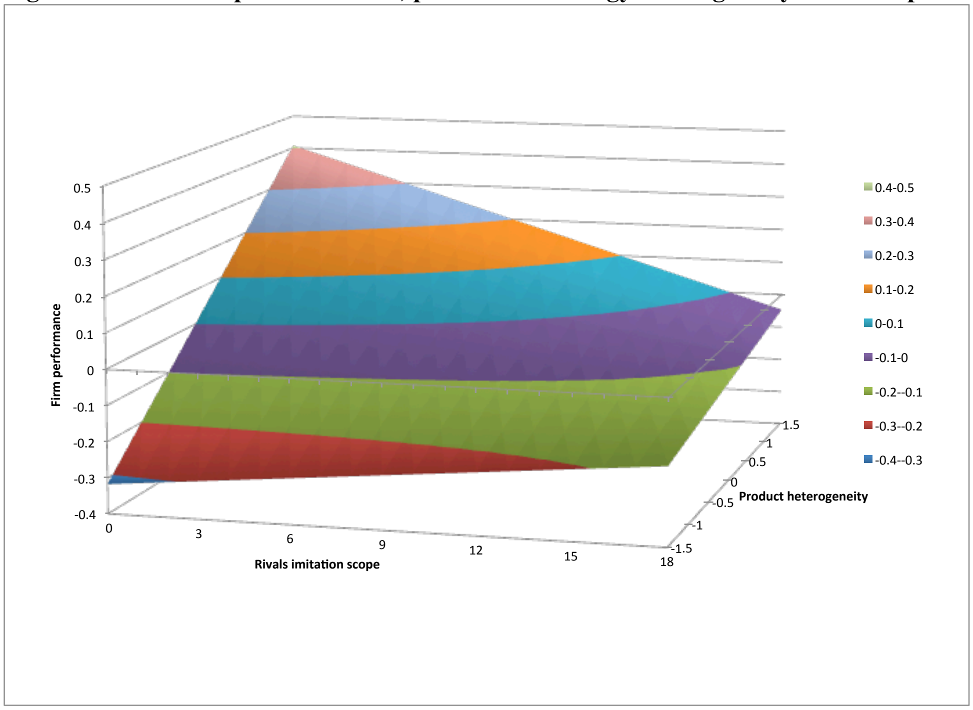
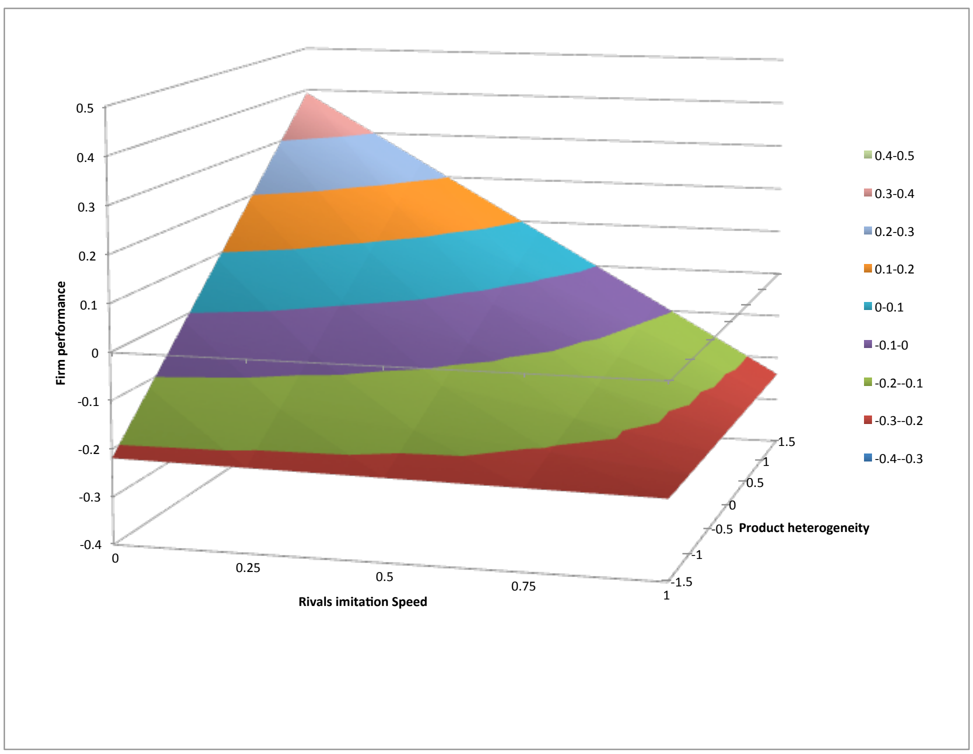



**Figure 4. Rivals' speed of imitation, product technology heterogeneity and firm performance**



**An experiment on meaning negotiation**


**Abstract**

This paper explores how participant coordinate their use of language to achieve a common goal. In particular it is analyzed the process of interaction as a negotiation process that implies not only a convenience to agree, but also diverging interest on what to agree upon. Previous studies have observed that establishing any particular description scheme individuals prefers interactive principles of coordinating output with input, trying to use the description with the most recent general input. In particular restricted contexts a negotiation of the description results less convenient, but it has not been studied which are the processes through which agents, starting from different conceptual representation of an object converge to an agreement.

To ascertain the extent to which the coordination of language follows an explicit negotiation of individual cognitive representation, we generated such patches in laboratory crossing pairs that have born sunk cost to build a common ground.

The results of these studies suggest that when there are no sunk costs due to previous coordination on a common ground individuals tend to prefer a more efficient asymmetric strategy, where people coordinate on one of the previously defined description (sometimes with forms typical of the division of labor). On the contrary the presence of sunk costs related to coordination forces individuals to bear the costs of negotiation, which, despite being more inefficient, allow individual to obtain closer semantic representation.

**Foreword**

In the previous chapters I have studied how the imitative strategies are practices widely used by firms to improve their performance. Indeed imitation is a crucial means of organizational learning that can be experiences within and between firms' boundaries. I have previously given evidence of how firms can obtain a competitive advantage inferring technological trends, and opportunities from rivals' action and environmental contingencies. For example, imitation of new product technologies can come in many forms. In the previous chapter we have mainly taken in consideration how firms expend substantial resources to identify and evaluate rapidly technological opportunities but, with similar effects, firms can hire consultant or experts that have worked with rivals or they may try to in touch with well-connected venture capitalist trying to get access to the best practices of their rivals. Therefore firms are exhorted to invest in capabilities that allow them to more quickly and extensively copy others.

This chapter attempt to shed light on the practices that enable a broader knowledge transfer such as codifying knowledge (Zander and Kogut, 1995) and building trust relationships (Szulanski et al. 2004). To deal with that we used the model of a communication as it provides processes, concepts and logic by which organizations relate and respond each other. The metaphor has been already used in the competitive dynamics literature to understand competitive-response timing (Smith and Grimm, 1991). In the simplest form communication can be seen as the transmission of messages from a sender to a receiver. What it is less clear is how sender and receiver contribute to the communication, and how this can be established by the acts of communication. Therefore in this chapter we are going to analyze the principles that govern the division of coordination labor between interlocutors. We have found that often, in the coordination practices, one interlocutor surrender to the other to more efficiently achieve coordination. Indeed this is a widely known practice in natural language transmission contexts (e.g. from parents to child, or from native to immigrant) where imitation serves to conversational alignment.

My effort was motivated by the fact that competitive dynamics and hypercompetition have emerged as important paradigms for understanding dynamic aspects of competition, but evidences are giving mixed result from the analyses of culturally different markets or of established vs. nascent markets.

A difference on how firms gain advantages in these markets requires novel theoretical approaches. A deeper understanding of the mechanism underlying the coordination processes may offer an explanation for the apparent idiosyncratic behaviors.

## 1 Introduction

The use of language is a joint activity to achieve a common goal of communicative success. Clark (1996) proposed that conversation shares fundamental features with other joint activities such as dancing or rowing in pairs[1]. What defines these types of activities is coordination: a mutual process by which actors take in consideration the intentions and actions of the their partners in planning and performance of their own action (pp.61-62: 1996). This is what happens in ball-room dancing. It can be easily experienced that, dancing with different kinds of partner, different kinds of dance are learnt. The reason is that this is an activity that requires continuous coordination: for example partners interrupt when someone treads on toe, they evaluate the error and try to joint construct the dancing figure they have to realize. Similarly certain styles of communication can be interpreted as very tightly coupled activity. For example during conversation individuals may require a continuous and precise coordination to monitor and evaluate partner information transmission to align their

[1] In the case of tango the coordination process requires a mutual involvement of the two parts. In fact what could resemble an asymmetric dance where the speaker (man) drive the hearer (women) in this dance. This

representations that are useful for understanding each other. As in the dancing example, the picture that we can get from this interaction is a continuous shift of individual descriptions; these ones produces idiosyncratic conventions typical of the specific contexts in which they emerge.

In this chapter we will look at meaning negotiation as process in which individuals starting with a different conceptual representation of a picture converge to an agreement during the course of particular types of dialogues. The dialogues considered were recorded during a computer game design to elicit conversation in a restricted setting. In the game players collaborate solving a "referring problem" where verbal communication is the only medium available to the agents. The types of processes by which agents manage to coordinate are a form of problem solving where strategies useful to attain coordination requires that actors coordinate both on the content of the communication, and on the processes implemented to achieve it. As in Clark's contribution (Clark and Schaefer, 1989), the process is typically a sequence of offers and counter-offers that can be accepted or rejected. Interlocutors jointly participate to these activities breaking the boundaries of the assigned role of speaker and listener. Therefore they try to establish a shared conception of what is discussed, finding agreements that are coherent to this model.

The chapter divides in four sections. The first consists in a brief discussion of meaning negotiation as the case of a potential misalignment between individuals' representations. In the second section we reported the experimental framework used to observe the process of negotiation. General results related to the efficiency of the mechanisms of agreement are reported in the third section. We performed a semantic analysis in the fourth section, which examined the description used to refer to each picture. We could therefore examine which were the final agreements and we could infer the mechanism through which this conceptual coordination may have come about.

## 2 Theory: Meaning negotiation

Meaning negotiation suggest that lexicon does not uniquely identify the meaning of an utterance, and thus there is room left for a process of further determination through some type of interaction among communicating agents.

This mechanism of negotiation can be observed in several ordinary communications that have been explored by previous scholars. For example a popular interactive web games, the ESP by von Ahn (2006), effectively represent this idea. Two individual that do not know each other's identity are randomly matched to solve a coordination-labelling task. Their goal is to agree on an appropriate label for an image. Once they agree they move to the next image until time is over. This game is very powerful in collecting metadata on image recognition as it exploits the participants' playfulness. In this context individuals are motivated to achieve a common understanding but individuals' interpretation rarely coincide, determining a really difficult ex ante agreement. Recent results have shown that under coordination incentives individuals tend to select the categorization according to criteria that reflect the task at hand and interaction with others (Paolacci et al., 2012). This means that categorization is a social process, but how a convergence on a sufficient agreed lexicon can be achieved during a communicative interaction?

The phenomenon of lexical entrainment (Garrod and Anderson, 1987; Brennan, 1996; Pickering and Garrod, 2004) offers several insights in this direction. Individuals develop heuristics to understand each other during conversation. Mainly this process explains the tendency to adopt a term introduced by the interlocutor in the conversation. These terms can be temporary conversational pact that individuals develop during their conversation to overcome, for example, the ambiguity due to different synonyms. Indeed as individuals do not agree *ex ante* on the lexical choice, and differences in their preferred one may actually mark subtle differences in the way they conceptualize the situation at hand, once such a "pact" is reached, individuals can repeatedly and confidently refer to an object with the same term arriving to define a similar lexicon.

Brennan and Clark notice some features of conceptual pacts which are worth reporting here. First of all, "conceptual pacts are established by speakers and addressees jointly" (Brennan and Clark 1996, 149). They are the result of an interactive process that may involve different rounds, lexical proposals and counterproposals, and may imply also disagreement. If the partner accepts a proposal, the contribution enters the common ground, so that both interlocutors assume that is shared knowledge. For this reason lexical pacts are considered specific to a given speaker-addressee pair. In other words they tend to reflect the specific relation between the two and the process through which an agreement has been reached – the same speaker may reach different pacts with different addressees. Although the interlocutors tend to converge to the same expression, this convergence could be not necessary for the common ground even if it would greatly impoverish conversation. In fact the emergence of conceptual pacts on the early stages of a conversation has been shown to be a good predictor of the overall cooperative success of communication (Reitter et al., 2007; Nenkova et al., 2008).

The presence of a substantial misalignment can be remedied through an interactive repair process (Pickering and Garrod, 2004). Speaker may try to understand the listener comprehension, and therefore reformulate his description. The ubiquitousness of vague terms in human communication is an example of how it is common that we negotiate case by case the meaning of a certain predicate. Contracts are practices where we can often observe the use of vague predicate that make them adaptable in different contexts. This means that parts might try to avoid building a contract (or a language) which effectively specify the particular distinction which they may wish to express, while finding more fruitful to achieve an higher degree of "semantic" coordination.

To capture the essence of a meaning negotiation problem it is necessary to define the level at which the process of information alignment is realized. As a general example considers the achievement of joint attention in children's pointing (Bates, 1976; Brinck, 2004; Gärdenfors and Warglien, 2013). An agreement on the meaning of pointing is realized when the child and the mother align their attention to a part in the surrounding space as a result of the child's directional gesture. When this convergence happens, the sign proposed by the child to describe the desire of having an object agrees with the comprehension offered by the mother (with the gaze or picking the desired object). In this situation we can delineate at least two levels: a language consisting of signs or phonemes (in the case of the mother) and a situated level (description level) result of the interactive interpretations of the interlocutors.

In this process of interactions agent align their representations and descriptions to those of the peer. The interlocutors use language to drive others attention and negotiate a meaning on the sign, or description used.

From the figure 1 we can see how this process is realized. Whenever an individual have to refer to an object he uses his language giving an interpretation of the image. A major part of the information at the disposal of the interlocutor to give its description is in his language. Therefore any description will be the result of a linguistic production of the individual mental scheme. As in the case of child learning the individual mental scheme cannot be enough to find an agreement. Therefore description are going to be the result of the negotiation of interpretations, defining a common ground over which subsequent interactions are going to be evaluated.

In the literature the case most widely studied is the one in which there is no role for individual preference for a given conceptualization. This can be due to different lexical preference to conceptualize a certain object, or to incomprehensible conceptualization of a definite object. In this case it could be necessary the implementation of an exchange in terms of conceptual shifts that, similar to what we used to refer as negotiation.

The origin of this misalignment can be related to the individual mental scheme that has driven individuals' attention toward different salient features. In other situation it can be the result of a precise utility evaluation. This can be the case of the interpretation of even precise norms such as the final whistle in a football match. Despite the temporal precision of the norm its implementation can be so contextual that sometime can embarrass the referee. Teams have diverging interests in interpreting this norm, and despite the role of the referee, the decision often evaluated partial. In this situation the referee decides what makes it more acceptable to diverge giving its interpretation of the language game of the football game. In many other case judges are not always present and it is interesting to understand which is the point up interlocutors might prefer an open disagreement.

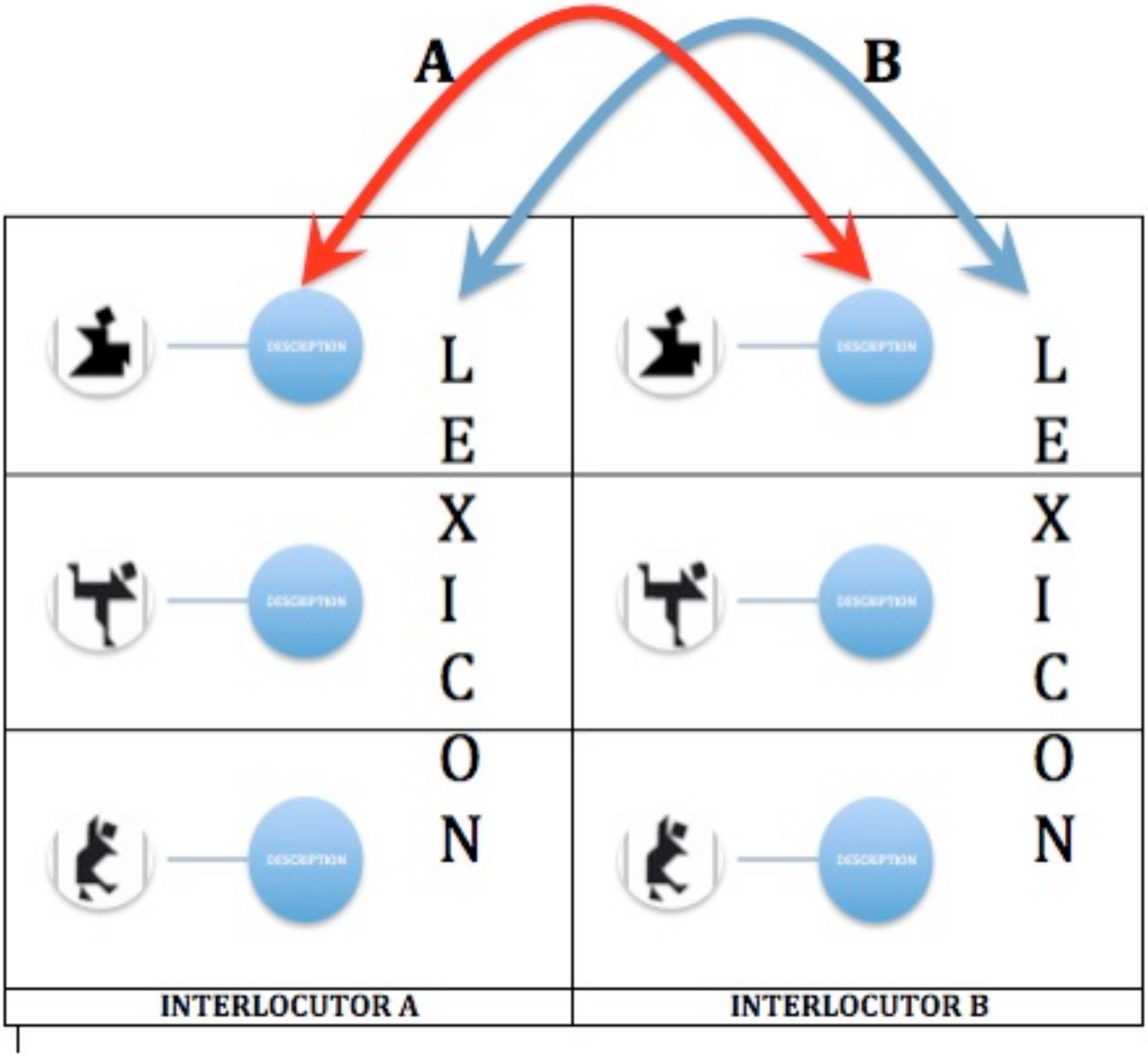



Figure 1: Agreement on the description and on the lexicon

In this paper, we will argue a lexical and conceptual co-ordination is often achieved within any particular dialogue through a strong collaborative effort. In support of this claim, we present evidence to indicate that pairs have developed idiosyncratic languages, which are dependent upon local and transient conventions set up during the course of the dialogue

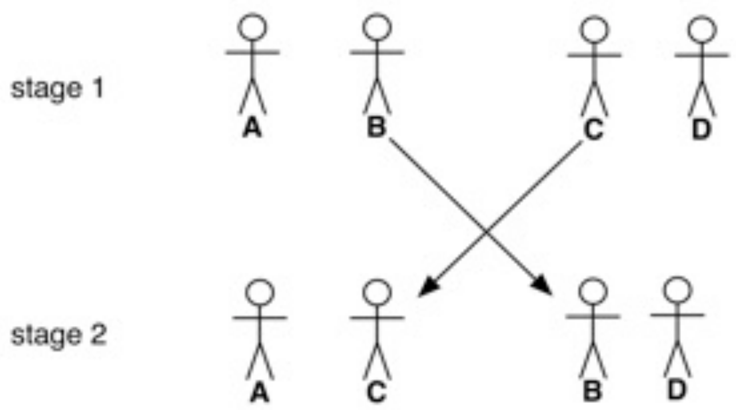
Then we observed how a utilitarian preference over a certain conceptualization could change the way in which pairs organize the mechanism of alignment. We present evidence that negotiated interaction are present at the level of the concept despite the inefficient effect of their implementation.

## 3 Experimental methods

Our experiment develops a paradigm first explored by Clark and Wilkes Gibbs (1986). The experiment is played on PCs and entirely managed by a computerized "game master". There are dyads of (randomly paired) players. Each player faces a same set of 16 tangram pictures on a computer screen. However, the pictures are in a different random order for each player. Tangram pictures have been chosen because of the potential multiplicity of their interpretations and description (Clark and Wilkes Gibbs 1986).

There are two stages and 160 rounds in each stage. At each round, one of the players is drawn by the computerised "game manager" as the *speaker*, while the other player is the *responder*. The speaker sees one of the 16 tangram pictures on the right of the screen as the *target*, while the responder needs to find out which of the 16 pictures corresponds to the target seen by the speaker. In order to coordinate, they can speak through an audio channel (all players have a set of noise insulating headphones with a microphone).[2] The responder can indicate a picture as a candidate solution by clicking on it. If the picture is the right one, a new role of speaker is randomly drawn and pictures are again sorted in random order. Players are rewarded for the time of task completion (the shorter the better) and for errors made before the correct identification in each round (the less errors the better).

The experiment has two stages. In the first stage, dyads play the game we have just described. After the first phase, players are again paired in new dyads, different form the original ones. Thus, each player brings into the second stage the lexicon it has acquired during the first stage, but in each new dyad players have potentially different lexica. The dyads play again the game of stage one, and each player writes at the end his/her private dictionary.




At the beginning and at the end of the first stage, each player has to write a sort of private "dictionary" where he associates to each pictures a short description if it. Thus, for each player there are two dictionaries, one before the first stage is played, and one after the first stage is played. A third dictionary has to be written at the end of stage 3. We will use

[2] All conversations are recorded and timed with millisecond accuracy, in order to track exactly the correspondence between speech and moves by the players.

these vocabularies to compare and analyse lexical changes in the way each player refers to each picture.

We recruited 48 undergraduate students at Ca' Foscari University of Venice, (25 women and 23 men), to participate to an experiment on meaning negotiation. They were invited in groups of four. All instructions for the study were presented on paper (Appendix A).

## 4 Results

Some aggregate performance results describe the overall patterns of learning in the experiment. The two fundamental measures that reflect increase in coordination are the time to identify the correct picture, and the number of errors (mistaken identifications) before the right choice is made.

Fig. 2 captures both measures for stage 1 (blue) and stage 2 (red), over the 160 rounds of each stage. It appears that in both stages the process of developing a common language appears smooth and converges to low levels of error. (with an average close to 1 error in the last rounds, coordination levels achieved are very high in both stages). However, stage 2 presents superior performance. Stage 2 displays a time to completion curve which is systematically below that one of stage 1. This does not necessarily reflect a direct advantage that the new pairs inherit from stage 1 language (as we will see below the new pairs start from dictionaries which dissimilarity is not far from that exist at the beginning of phase 1). It may also reflect a general effect of "learning to play the game", which includes faster communication, a better use of the computer interface, land cognitive strategies to find faster and more effective coordination with the partner. A similar pattern, although slightly less smooth, appears for errors (the number of trials before the responder identifies the correct picture).

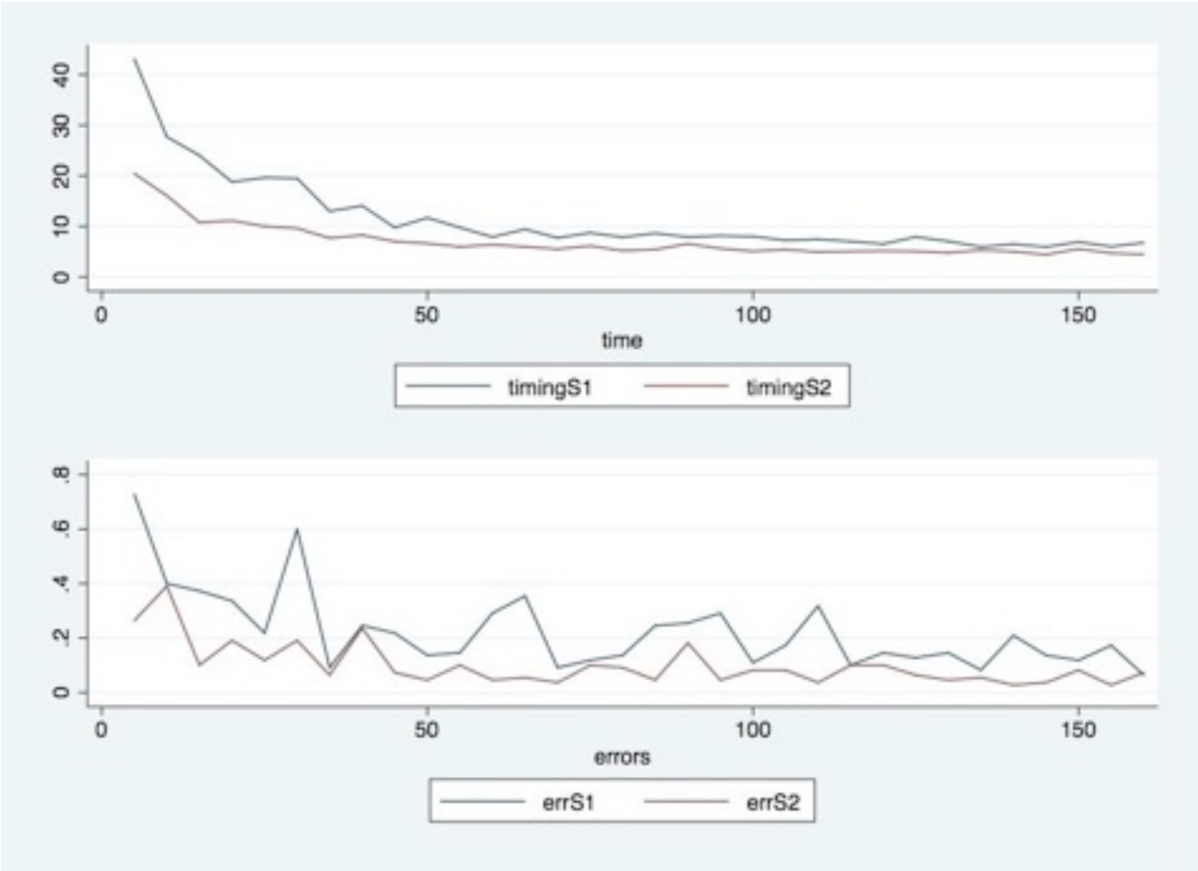



Fig. 2

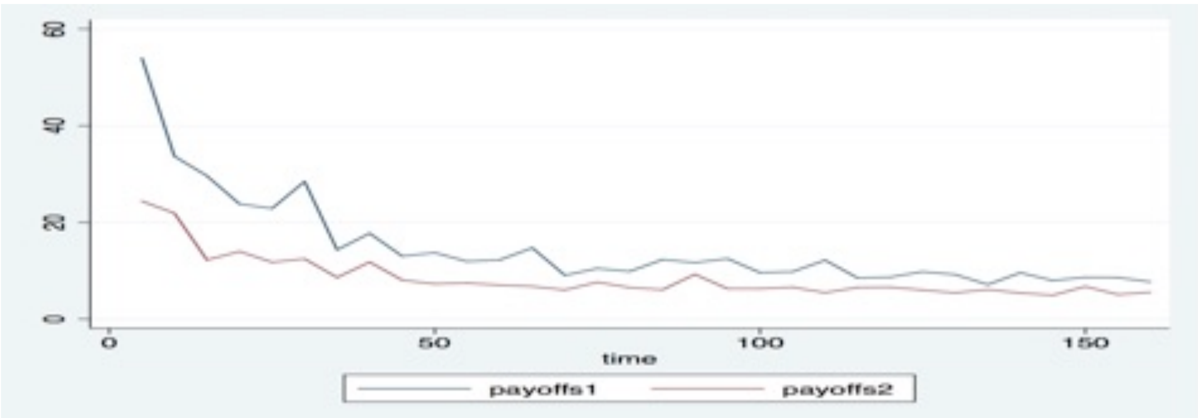



Fig. 3 shows how these overall patterns translate in payoff generation.

### *4.1 Results on meaning negotiation*

It is important to observe that the second stage introduces a potential motivational discontinuity. At the beginning of stage 1, each subject has invested a minimal effort in associating lexical terms to each picture. At the end of the first stage, however, the situation is heavily changed. Participants have made considerable efforts in developing a common code, and have thus sunk important cognitive costs in it. While these costs cannot be directly evaluated, it is reasonable to assume that they are much higher than at the beginning of the game. We may thus expect that “conceding” tot he other player’s lexicon in the second stage might be more less acceptable than in the first stage. Thus, we may expect that while coordination, common interest considerations may prevail in the first stage, peculiar misalignments of preferences can happen in stage 2, accentuating the proper “bargaining” nature of the process of lexical agreement.

The effects of this change in motivations do not appear in the treatment of section 4. However, it is likely that the very broad categories used to code the lexicon of agents in section 4 may hide most of this negotiation process. We have thus adopted a much finer grain of analysis of the lexica produced in each dictionary to evaluate the processes of lexical convergence and understand whether the motivational change of phase 2 may affect the nature of the lexical agreements reached by the players.

In order to analyse the meaning negotiation process, we have constructed a measure of distance among expression in the dictionaries. The method is an adaptation of common methods in computational linguistics (see Widdows 2004), and is reported in Appendix 2.

Table 4 summarises the most important differences between dictionaries. Column A represents the average distance for each pair of the dictionary expression at the beginning of stage 1 and stage 2 respectively. Column D represents the average distance for each pair at the end of each stage.

**SESSION 1**

| | B | C | A | D | B-C | B+C | *Normalized* |
|---|---|---|---|---|---|---|---|
| team01 | avgdelta_tL1_Jac | avgdelta_tL1_peer1Jac | avgdelta_peer1_Jac(t0) | avgdelta_peer1_Jac | avgasymmetry_peer1Jac | avg_asym2_ | NormASY |
| | 0,82 | 0,78 | 0,94 | 0,29 | 0,32 | 1,60 | 0,28 |
| 1 | 0,75 | 0,94 | 0,84 | 0,57 | 0,19 | 1,69 | 0,20 |
| 2 | 0,84 | 0,86 | 0,88 | 0,59 | 0,17 | 1,70 | 0,11 |
| 3 | 0,89 | 0,19 | 0,96 | 0,45 | 0,86 | 1,08 | 0,88 |
| 4 | 0,60 | 0,75 | 0,92 | 0,40 | 0,53 | 1,35 | 0,58 |
| 5 | 0,88 | 0,80 | 0,86 | 0,50 | 0,17 | 1,68 | 0,14 |
| 6 | 0,86 | 0,92 | 0,97 | 0,67 | 0,14 | 1,78 | 0,09 |
| 7 | 0,87 | 0,94 | 0,93 | 0,21 | 0,14 | 1,81 | 0,09 |
| 8 | 0,94 | 0,69 | 1,00 | 0,12 | 0,37 | 1,63 | 0,33 |
| 9 | 0,84 | 0,76 | 0,94 | 0,23 | 0,23 | 1,60 | 0,22 |
| 10 | 0,79 | 0,98 | 1,00 | 0,32 | 0,22 | 1,77 | 0,16 |
| 11 | 0,83 | 0,88 | 0,95 | 0,32 | 0,20 | 1,70 | 0,13 |
| 12 | 0,86 | 0,70 | 0,98 | 0,19 | 0,39 | 1,57 | 0,33 |
| 13 | 0,84 | 0,88 | 1,00 | 0,19 | 0,28 | 1,72 | 0,22 |
| 14 | 0,97 | 0,53 | 0,99 | 0,21 | 0,50 | 1,50 | 0,46 |
| 15 | 0,89 | 0,77 | 0,98 | 0,19 | 0,34 | 1,66 | 0,29 |
| 16 | 0,81 | 0,84 | 0,94 | 0,50 | 0,34 | 1,66 | 0,31 |
| 17 | 0,75 | 0,65 | 0,95 | 0,04 | 0,48 | 1,40 | 0,45 |
| 18 | 0,77 | 0,85 | 0,92 | 0,04 | 0,29 | 1,63 | 0,21 |
| 19 | 0,79 | 0,86 | 0,97 | 0,25 | 0,34 | 1,66 | 0,31 |
| 20 | 0,64 | 0,86 | 0,94 | 0,20 | 0,40 | 1,50 | 0,37 |
| 21 | 0,79 | 0,74 | 0,86 | 0,14 | 0,26 | 1,53 | 0,22 |
| 22 | 0,85 | 0,77 | 0,83 | 0,13 | 0,08 | 1,63 | 0,11 |

**SESSION 2**

| | B | C | A | D | B-C | B+C | *Normalized* |
|---|---|---|---|---|---|---|---|
| team02 | avg_delta_tL1_Jac | avg_delta_tL1_peer2Jac | avg_deltaT1_peer2_Jac | avg_delta_peer2_Jac | avg_asymmetry_peer2Jac | avg_asym2_peer2Jac | avg_Zasymmetry_peer2Jac |
| | 0,92 | 0,93 | 0,93 | 0,14 | 0,12 | 1,85 | 0,11 |
| 1 | 0,50 | 0,79 | 0,96 | 0,35 | 0,63 | 1,29 | 0,63 |
| 2 | 0,43 | 0,88 | 0,92 | 0,27 | 0,48 | 1,31 | 0,44 |
| 3 | 1,00 | 1,00 | 0,94 | 0,34 | 0,00 | 2,00 | 0,00 |
| 4 | 1,00 | 1,00 | 1,00 | 0,13 | 0,00 | 2,00 | 0,00 |
| 5 | 0,96 | 0,93 | 0,85 | 0,46 | 0,07 | 1,89 | 0,05 |
| 6 | 0,98 | 1,00 | 0,92 | 0,05 | 0,02 | 1,98 | 0,01 |
| 7 | 0,65 | 0,61 | 0,91 | 0,09 | 0,53 | 1,27 | 0,57 |
| 8 | 0,89 | 0,41 | 0,94 | 0,15 | 0,55 | 1,30 | 0,55 |
| 9 | 1,00 | 1,00 | 0,94 | 0,00 | 0,00 | 2,00 | 0,00 |
| 10 | 1,00 | 0,98 | 0,92 | 0,32 | 0,02 | 1,98 | 0,01 |
| 11 | 0,96 | 1,00 | 0,82 | 0,30 | 0,04 | 1,96 | 0,02 |
| 12 | 0,95 | 0,99 | 0,86 | 0,06 | 0,03 | 1,94 | 0,02 |
| 13 | 1,00 | 0,98 | 1,00 | 0,08 | 0,02 | 1,98 | 0,01 |
| 14 | 1,00 | 1,00 | 1,00 | 0,00 | 0,00 | 2,00 | 0,00 |
| 15 | 1,00 | 0,98 | 0,92 | 0,15 | 0,02 | 1,98 | 0,01 |
| 16 | 0,97 | 0,97 | 0,94 | 0,03 | 0,06 | 1,94 | 0,04 |
| 17 | 0,99 | 1,00 | 0,89 | 0,00 | 0,01 | 1,99 | 0,01 |
| 18 | 0,95 | 0,99 | 0,90 | 0,06 | 0,06 | 1,94 | 0,04 |
| 19 | 1,00 | 1,00 | 0,95 | 0,00 | 0,00 | 2,00 | 0,00 |
| 20 | 1,00 | 1,00 | 0,97 | 0,07 | 0,00 | 2,00 | 0,00 |
| 21 | 1,00 | 1,00 | 0,95 | 0,20 | 0,00 | 2,00 | 0,00 |
| 22 | 1,00 | 1,00 | 0,95 | 0,00 | 0,00 | 2,00 | 0,00 |

Table 4

A first result is worth stressing. The distance between dictionaries in each pair, averaged over all pairs, is .94 at the beginning of phase 1 and reduces to 0.29 at the end of stage 1. The difference is of course significant at the .0001 level. This shows the degree of convergence between the lexica in each pair. At the same time, as pairs are reshuffled at the beginning of phase 2, the same dictionaries show an average within-pair distance of .93! In other words, while lexica have converged within pairs during stage 1, they have remained at he same distance they had at the beginning of the game if one compares random individuals. This demonstrates how much idiosyncratic and path-dependent such codes are even after the first stage. At the end of the second stage, distance reduces again to 0.14. Thus average distance is also lower at the end of phase 2 as compared to phase 1 and the difference is significant at the 0.0001 level.

It is also important to look at the distance from their initial dictionary players have to undertake to reach agreement with their partners. For each pair these distances are represented by columns B and C in the table 4. The column "normalized" provides a normalized measure of the asymmetry between the two players in a pair. Asymmetry captures difference sin how far each player in pair had to go at the end of the stage from his initial position. Once more, two observations are worth stressing. Although in stage two pairs have been able to find on average closer dictionaries, in order to do so they have had to go father for their original position. The sum of B and C is 1.60 in the first stage, and 1.85 in stage 2 (different at the 0.001 level). What really differs between the two stages, however, is the degree of asymmetry between players. This is much lower in stage 2 than in stage 1 (0.11 vs. 0.28). This clearly captures that subjects in stage 2 appear more sensitive to fairness considerations: they are less willing to "concede" unilaterally to the other player, even if reaching a fair agreement implies making a longer way from their initial position. In other words, they are willing to pay a price in terms of semantic distance to obtain a more fair meaning negotiation outcome.

Fig. 4 captures the average data aver all pairs in form of a trapezium, where A is the original distance between dictionaries, D is their initial distance, and C and D are the distance for his/her original dictionary for each player,

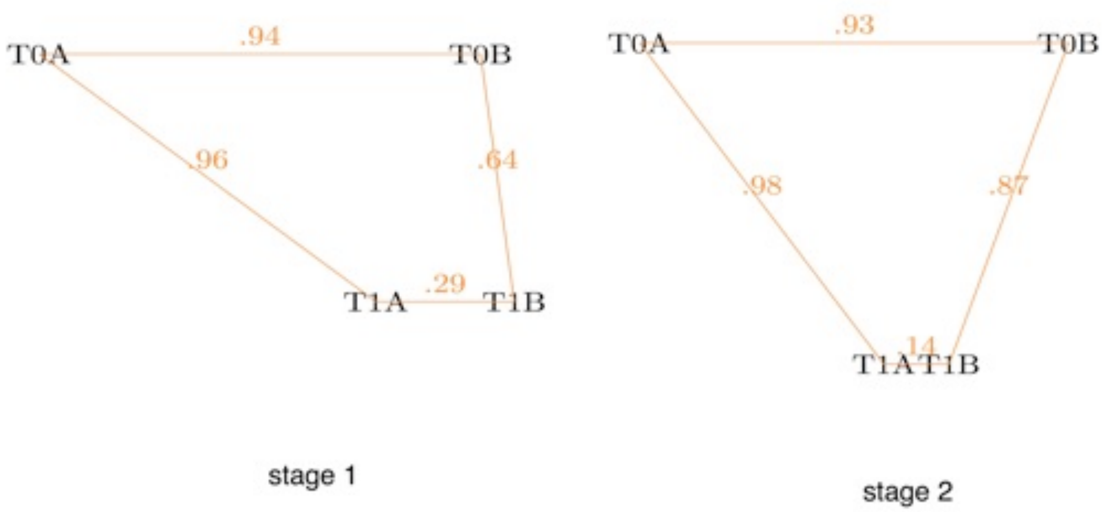



Fig 4

The trade-off between efficiency and fairness is very clear if one looks at fig 5, that plots the asymmetry in each pair against the total distance from the original dictionaries (B+C). To gain in fairness, subjects have to search farther away.

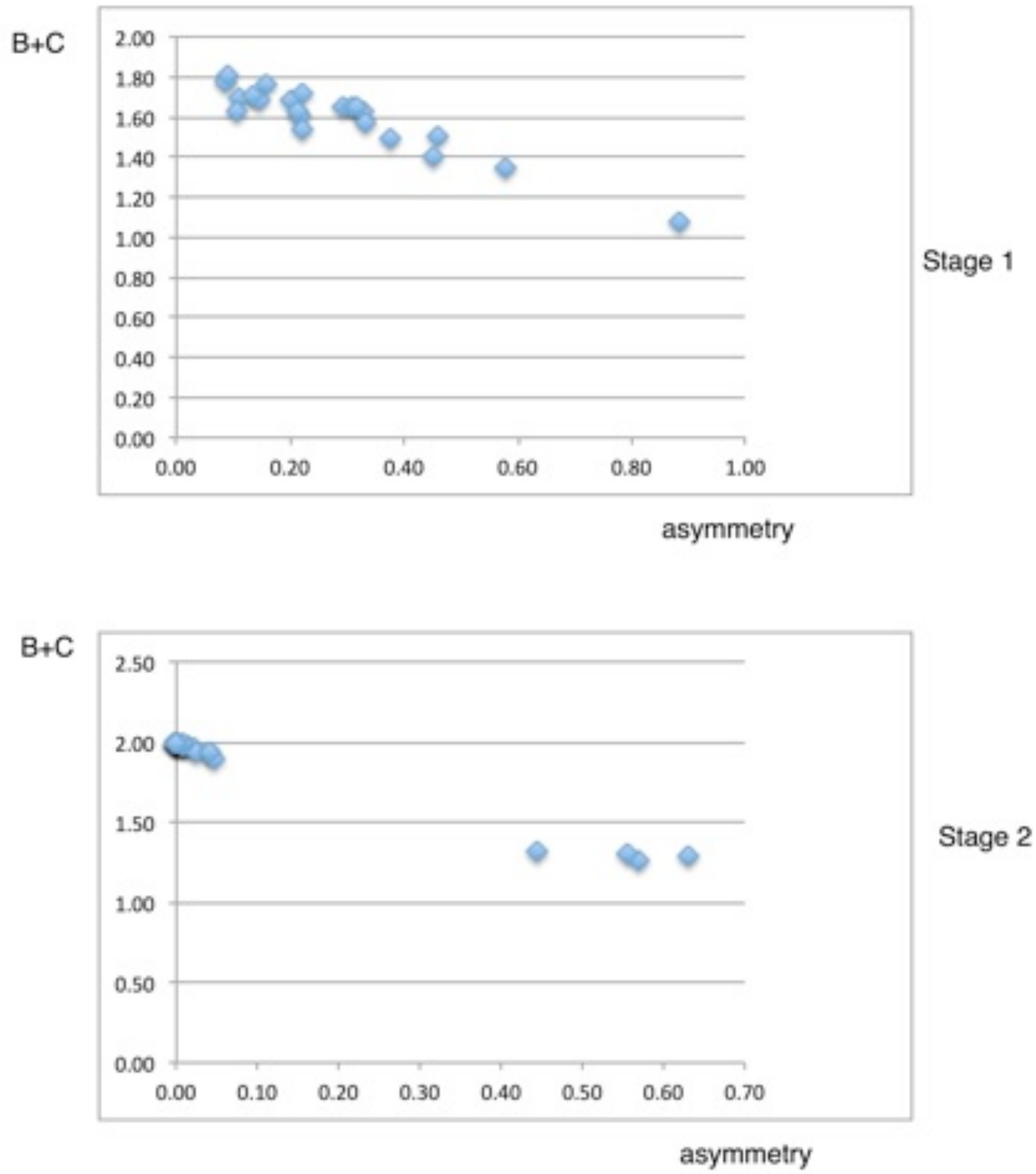



Fig. 5

This result shows that subjects seem to respond to the motivational difference between stage 1 and 2, and that they care more for fairness at the expense of efficiency. This also sees to point to an interesting structural problem. Fair solutions are hard to find between the two original points stated by players before the game. This may suggest that the space of semantic compromises is not convex.

Other indicators clearly point to a change in the way the game is played in stage 2. For example, in stage 1 of the experiment the degree of asymmetry between players is negatively correlated to the time it takes to reach an agreement ($\rho$=-0.39, p=.07)- which suggests that propensity of a subject to concede to the other makes it easier to find a solution. The picture changes radically in stage 2, when the degree of asymmetry correlates positively with the time it takes to reach a solution ($\rho$=-0.59, p=0.004). Thus, in the second stage - consistently with the idea that subjects are less willing to concede - an asymmetric agreement takes more time to be achieved, suggesting that the time of negotiation has increased. Another inversion between stages is quite puzzling. The pre-communication distance between subjects' dictionaries appears positively correlated with asymmetry in the first stage, although significance is weak ($\rho$=-0.35, p=0.110). However, in the second stage, the correlation becomes negative ($\rho$=-0.59, p=0.013). As a result, in the second stage pairs of subjects starting from more distant positions take less time to agree than pairs of subjects starting form closer positions. An interpretation seems to be that it is harder to find intermediate "fair" solutions when players are close, and this generates a longer (and less effective) search for solutions in the word space.

## 5 Conclusions

The experiment is the first, to our knowledge, to produce evidence that lexical agreements is a process of meaning negotiation whose outcome is affected by the relative willingness to concede of interlocutors. In particular, by using a two-stages design to manipulate the cost agents have sunk in generating a code, we show the emergence of a preference for symmetric outcomes in the second stage of the experiment. This supports the hypothesis that "semantic fairness" plays an important role in the process of lexical agreement.

In the next future, the main task will be to analyse in detail the conversational process that leads to convergence to new dictionaries. We expect that a closer reconstruction of the conversational dynamics leading to agreement will further illuminate the process of meaning negotiation and will help to better explain how individual cognition and lexical preferences are mapped through communication into common meaning and a shared lexicon.

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**APPENDIX A (Instructions)**

**Le istruzioni**

Benvenuti a l'esperimento di Negoziazione del Significato! Prima di iniziare l'esperimento, si prega di ascoltare con attenzione ad istruzioni, al termine del quale imparerete:

- Qual è il vostro compito
- Come funziona l’esperimento
- Come viene calcolata la vostra ricompensa finanziaria

Allora cominciamo!

**1 . Qual è il vostro compito?**

In coppia con altro partecipante dovete riuscire a coordinarvi in un gioco d’identificazione di immagini. Vi è permesso di parlare, e non sono imposti limiti di tempo e descrittivi, ma più siete rapidi, e minori sono gli errori che commetterete più elevata sarà la vincita a disposizione. Tutte le scelte, e le registrazioni audio utilizzate per questo esperimento saranno utilizzate garantendo l’anonimità dei partecipanti.

**2. Come funziona l’esperimento?**

L’esperimento coinvolge 4 partecipanti, divisi in due coppie, e durerà un totale di 320 periodi divisi in due sessioni di 160 periodi. Il compito che dovrà essere svolto sarà sempre lo stesso, ma nella seconda sessione giocherete con un nuovo compagno.

Il gioco si svolge a coppie, ed il risultato di ogni sessione viene attribuito in maniera eguale ai due membri.

Ecco le fasi del gioco

1. 1. L’esperimento inizia richiedendovi di indicare un nome e/o un aggettivo con cui descrivere ognuna delle sedici figure con cui avrete a che fare nel corso dell’esperimento. Prendetevi il vostro tempo, non appena siete pronti cliccate il tasto SUBMIT, ed attendete che anche il vostro compagno abbia finito
2. 2. Controllato il funzionamento di microfono e cuffie, la prima sessione dell’esperimento ha inizio.
3. 3. A sinistra dello schermo sono presentate le sedici figure che avete visto nel primo periodo, probabilmente in ordine diverso. Alla destra viene indicato qual’è il vostro ruolo nella coppia per quel determinato turno. Se appare un punto di domanda, dovete cercare di capire le indicazioni del vostro compagno, se appare una figura il vostro compito è quello di cercare di fornire al vostro compagno tutti gli indizi

necessari. Non appena viene individuata la figura corretta, si passa al turno successivo.

4. 4. L'esperiemento viene ripetuto per 160 volte. Alla destra dello schermo trovate alcune informazioni relative al tempo trascorso, il numero di errori commessi nel turno ed il numero di round

5. 5. Non appena terminata la prima sessione vi viene richiesto di fornire un nome e/o un aggettivo con cui descrivere le sedici immagini. Una delle immagini verrà estratta alla fine dell'esperimento e se coinciderò con quella del vostro compagno potrete aggiudicarvi un bonus di 200 gettoni.

6. 6. Terminata la prima sessione l'esperimento viene ripetuto (p.ti 2-5= con un nuovo compagno

**3. Quello che devi ricordare :**

I turni sono assegnati in modo casuale tra tutti i giocatori
È possibile scegliere una figura solo quando e' il tuo turno
Il risultato di ogni sessione viene attribuito in maniera eguale ai membri della coppia di quella sessione

**4 . Come viene calcolata la vostra ricompensa finanziaria**

Come sapete, il vostro profitto totale è costituito dalle parti fisse e variabili non puo superare 25€
La parte fissa è 8 €, questo è il vostro guadagno sicuro
La vostra parte variabile viene calcolata al base di il vostro profitto totale
Il vostro profitto totale e' misurato in unità sperimentali, non in euro (200u.s.=1euro). Questo viene calcolato in base al tempo impiegato ed al numero di errori commessi.

**APPENDIX B (measuring semantic distances)**

1. We describe the vocabulary as a vector space with *n*-dimensions, equal to the number of words of the vocabulary, formed by a collection of elements called *descriptions* whose components can take value $\{0,1\}$.
2. A word can be represented as a point in the space and described by the components of the n-tuple $\overline{w} = (0,0..,1,0,..)$. Each component takes value 0, except for that one corresponding to the word-*j* ("animal"): $\forall i \ \ w_{i\neq j} = 0, w_j = 0$.
3. A description can be represented as a point in the space and described by the components of the n-tuple $\overline{d} = (0,1..,1,0,..)$. Those take value one for the words used in the description, and zero for the remaining words. Therefore, a description using the words ($\overline{w_s}$=red, $\overline{w_j}$=animal) is summarized in the string $\overline{d} = \overline{w_s} \cup \overline{w_j}$.
4. Inside the vector space we defined a norm to measure the distance between the descriptions of each item. In particular we defined:
   a. $\Delta(\overline{d}_{i,i,0}, \overline{d}_{i,pi,0})$.The distance between the description given for $item_i$ at $time_0$ by the $individual_i$ and the description given for $item_i$ at $time_0$ by peer of the $individual_i$. (Side A of the trapezoid)
   b. $\Delta(\overline{d}_{i,i,0}, \overline{d}_{i,i,1})$.The distance between the description given for $item_i$ at $time_0$ by the $individual_i$ and the description given for $item_i$ at $time_1$ by the $individual_i$. (Side B of the trapezoid)
   c. $\Delta(\overline{d}_{i,pi,0}, \overline{d}_{i,pi,1})$.The distance between the description given for $item_i$ at $time_0$ by the peer of $individual_i$ and the description given for $item_i$ at $time_1$ by the peer of $individual_i$. (Side C of the trapezoid).
   d. $\Delta(\overline{d}_{i,i,1}, \overline{d}_{i,pi,1})$.The distance between the description given for $item_i$ at $time_1$ by the $individual_i$ and the description given for $item_i$ at $time_1$ by the peer of the $individual_i$. (Side D of the trapezoid).
5. The norm introduced in this vector space is the Jaccard distance, which measures dissimilarity between sample sets. It is obtained by dividing the difference of the sizes of the union and the intersection of two sets by the size of the union.
   For example given two descriptions, $\overline{d}_{i,j,0}$ and $\overline{d}_{i,j,1}$, the Jaccard distance is equal to this ratio:

$$J = \Delta(\overline{d}_{i,i,0}, \overline{d}_{i,i,1}) = \frac{M_{01} + M_{10}}{M_{01} + M_{10} + M_{11}}$$

$M_{01}$= number of components of the n-tuple $\overline{d}_{i,i,1}$ such that:
$\overline{d}_{i,j,0} = 1 \ \& \ \overline{d}_{i,i,1} = 0$

$M_{10}$= number of components of the n-tuple $\overline{d}_{i,i,1}$ such that:
$\overline{d}_{i,j,0} = 0 \ \& \ \overline{d}_{i,i,1} = 1$

$M_{11}$= number of components of the n-tuple $\overline{d}_{i,i,1}$ such that:
$\overline{d}_{i,j,0} = 1 \ \& \ \overline{d}_{i,i,1} = 1$