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ABSTRACT

The paper shows that the interaction between population and firm knowledge produces a non-monotonic change in the assimilation gap. The assimilation gap follows a convex curve experiencing an upward slope driven by imitation and the downward slope by knowledge spillovers. Changes in the characteristics of innovation shift its peak across time. The relative advantage and compatibility shift the peak towards the left and the complexity shifts it to the right. The model is tested in a simulated environment and offers insights into the differences in temporal trajectories of the various adopter groups.

Keywords

Diffusion, assimilation gap, acquisition, deployment, network externality

INTRODUCTION

Organizations invest in innovations to improve their performance. However, the returns from investment may not materialize due to the lack of organizational ability or interest. The resulting gap between innovation adoption and its deployment increases with the number of firms adopting the innovation (Fichman and Kemerer 1999). The paper shows that the increase in population knowledge eventually decreases this gap. Changes in the characteristics of innovation modify the curvilinearity of the gap and shift it across time. The results extend our understanding of the temporal relationship between innovation and its effective usage.

An organizational innovation is "the first or early use of an idea by one of a set of organizations with similar goals" (Becker and Whisler 1967, 463). However, not all organizational innovations experience satisfactory usage. Firms may acquire innovations but fail to deploy them, creating an assimilation gap which is the "difference between the pattern of cumulative acquisitions and cumulative deployments of an innovation across a population of potential adopters . . . the longer the typical acquiring firm takes to deploy an innovation once acquired, the larger the assimilation gap will be" (Fichman and Kemerer 1999, 258).

The literature on innovation diffusion treats assimilation gap as a monotonic increase (or decrease) over time (Fichman and Kemerer 1999; Attewell 1992; Karahanna, Straub, and Chervany 1999). The unidimensional nature of the assimilation gap implies inefficient use of innovations and raises questions on managerial choices as well as the quality of innovations (Cohen, March, and Olsen 1972). The implication represents organizational decision making as a static process of strategizing that avoids a reevaluation of existing resources.

Changes in the environment impose upon the organization a continuous need to reevaluate existing and potential resources in order to identify combinations necessary to gain or sustain a competitive position (Teece, Pisano, and Shuen 1997; Kogut and Zander 1992). The literature on dynamic capabilities and knowledge-based perspective consider organizational decisions as a continuous interplay between resource evaluation and capability development (Nonaka 1994; Grant 1996). It is this very dynamic that identifies organizational innovations as a source of competitive advantage. The difference in perspective over organizational innovations experiencing a one-time evaluation instead of a continuous review arises from focusing on a single environment as the determining influence of the value of innovation. While this eases the empirical validation of arguments, it limits the possibility of evaluating dynamic shifts in resource utilization. We argue that the idiosyncrasy of innovation as a resource simultaneously affected by the population and firm environments produces a curvilinear change in the assimilation gap. The non-monotonic increase is driven by a combination of imitation and knowledge spillover.

The difficulty of separating the influence of various factors underlying this gap complicates its empirical validation. We use the framework of problem space developed by Newell and Simon (1972) in conceptualizing a simulated environment that

facilitates overcoming this limitation. The model allows for the treatment of innovations as a solution to organizational needs. The mapping between organizational problems and innovation is influenced by the presence of other firms that contribute to the total knowledge (Katz and Shapiro 1985). We find that the population experiences a dominant imitation effect in the early phases of the innovation which increases the assimilation gap. This is followed by the increased influence of knowledge spillovers that decrease the gap over time.

A change in the characteristics of innovation affects the assimilation gap by shifting the curve, specifically, by advancing or delaying its peak in time. The exploration of the combined influence of external and internal effects on organizational knowledge gives rich insights into the diffusion of innovations. The convexity of the assimilation gap advances our understanding of the literature on organizational diffusion and integrates the perspectives on resource utilization between the dynamic capabilities approach and the diffusion of innovations. This shifts the discussion of assimilation gap from a permanent feature of organizational processes to a transient characteristic of population-firm interaction.

The paper is organized in the following way. The next section discusses the effect of population-firm interaction on organizational innovations. This is followed by the development of hypotheses. The fourth section discusses the methodology and the fifth section shows the results. The final section discusses the conclusion, limitations and suggests directions for future research.

POPULATION-FIRM INTERACTION

When awareness of the innovation is not limited to a certain segment of the population, its initial adopters are the ones that have the most use of the innovation (Mansfield 1985) and may even pay a premium (Gandal 1995). While adoption is generally driven by the need to improve performance, it may be a consequence of imitative pressure (Zhu, Kraemer, and Xu 2006) which becomes more 'legitimate' as the number of adopters reaches a critical mass (Kimberly and Evanisko 1981; DiMaggio and Powell 1983). The focus of the paper is on this latter set of adopters, their adoption and eventual use (or non-use) of the innovation. We identify the firms driven towards acquisition of innovations due to imitative influences as its 'influence-based adopters' who experience limitations in its effective use. The paper uses the term deployment to represent effective use of the innovation.

The external and organizational environment plays a key role in determining the success of an innovation towards overcoming the gap between its acquisition and assimilation. The innovation undergoes a 're-invention' as it is integrated with the organizational fabric (Rice and Rogers 1980; Rogers 1983). For an off-the-shelf innovation that needs no customization to fit the organizational environment, acquisition can be immediately followed by deployment. However, most innovations require some customization. The need for learning disassociates the two stages and creates a gap between acquisition and deployment (Fichman and Kemerer 1999). Several factors limit acquirers from adequately deploying the innovation including the lack of technical know-how (Attewell 1992), lack of top management interest (Ginzberg 1981), underdeveloped organizing vision (Swanson and Ramiller 1997), lack of organizational receptiveness (Zmud 1984), lack of support services (Fichman 2000), perception of risk (Cooper and Zmud 1990), and the negative impact on current skills (Attewell and Rule 1984). These factors may vary with time creating the possibility that an influence-based adopter may be able to deploy the innovation and become an effective user. We identify the users of innovation, whether relying on internal or external sources of knowledge as its 'use-based adopters'. A satisfactory deployment of innovation can be experienced by firms new to the innovation as well as those that have acquired it sometime in the past and remained from developing an adequate usage. In the former case, new users increase total adoption, keeping the assimilation gap constant. In the latter case, the conversion of influence-based adopters to use-based adopters keeps the total adopters constant and increases the number of effective users. This decreases the assimilation gap as shown in figure 1.

The curvilinear nature of the assimilation gap reflects changes in firm attitude towards the innovation. This may come from three sources: First, changes in the external environment such as the pertinent laws or market competition (Grant 1996). Second, changes within the firm such as a new CEO or appointment of an innovation champion (Howell and Higgins 1990; Grover and Goslar 1993). While the first is an industry-level change that has a proportional effect on all firms at the same time, the second is a randomly occurring firm-level effect. Both of these eliminate the possibility of observing a time-varying systematic change in the population. The third source of change comes from the combined effect of the external and internal environment that neither takes place all at once, nor is particular to one or few actors in the market. This happens as one environment moderates the effect of innovation on the other, offering the possibility to observe an extant change across the population. We use this interaction to explore the dynamics of the assimilation gap (Yetton, Sharma, and Southon 1999).

The population-firm interaction increases the benefits of innovation with an increase in the number of users, creating a positive consumption externality. Using Katz, & Shapiro's terminology, we divide consumption externalities into direct and indirect effects (Katz and Shapiro 1985, 424). Direct effects arise when the consumption of a product by one or more firms in

the population directly influences the focal firm, such as the use of fax machine. Indirect effects arise when the consumption of the product by certain firms in the population affect some population characteristic that in turn influences the focal firm. An example is the number of suppliers and buyers joining an e-commerce portal. In certain cases, both the direct and indirect effects may be present at the same time.
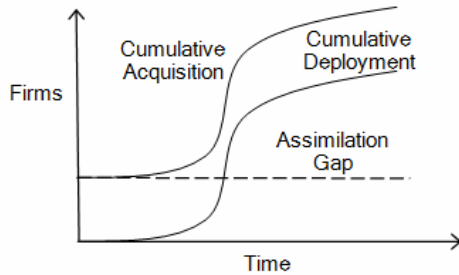

Figure 1a. New use-based adopters increase the total adoption without affecting the assimilation gap
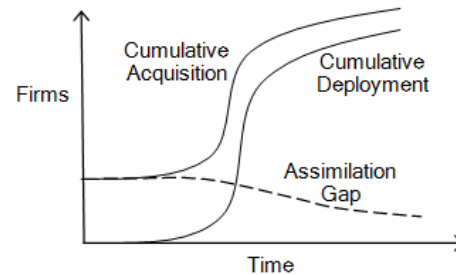
Figure 1b. Conversion of influence-based adopters to use-based adopters decrease the assimilation gap

The influence of firms on others as been considered as interfirm linkages (Pennings and Harianto 1992), Kodak effect (Loh and Venkatraman 1992), interorganizational networks (Kraatz 1998), or the social network and the bandwagon effect (Abrahamson and Rosenkopf 1997). The growing presence of the 'network good' comes from the contribution of each new adopter that adds to the value of the innovation (Kauffman, McAndrews, and Wang 2000). For organizational innovations affecting and being affected by population knowledge, imitation is an example of the direct effect and knowledge spillovers of an indirect effect (Katz and Shapiro 1985; Pennings and Harianto 1992). To explore the knowledge-based network externalities that affect innovation (Fichman and Kemerer 1999; Attewell 1992; Swanson and Ramiller 1997) we focus on three characteristics of innovation that have been consistently found to affect its diffusion. These include its relative advantage, complexity and compatibility (Rogers 1983; Tornatzky and Klein 1982).

In the presence of population-firm interaction, it is difficult to separate the innovation or imitation effects as the primary factor in an adoption decision. The factor driving the decision may even change once the innovation is acquired. The causal path of network influence through the direct or indirect effects is indistinguishable in the absence of a controlled environment, lacking which it may not be possible to separate acquirers from deployers. This limits our ability to understand the underlying changes in the assimilation gap. The use of a simulated model is instrumental in separating these effects and identifying the conversion of influence-based adopters towards their deployment.

HYPOTHESES DEVELOPMENT

An increase in diffusion heightens the legitimacy associated with its adoption and positively affects the proportion of users replaced by imitators (Rogers 1983; Abrahamson and Rosenkopf 1997). The resulting widening of the assimilation gap becomes obvious with the increase in the knowledge and organizational 'will' demanded by the process of deployment (Attewell 1992; O'Neill, Pouder, and Buchholtz 1998).

Over time, increases in diffusion widen the pool of knowledge contributors (including mediators) that ease the burden of knowledge integration (Attewell 1992; Ravichandran 2005). This may happen even though early users may attempt to restrict the flow of knowledge across their boundaries (Bell and Zaheer 2007). Late adopters experience a smaller gap between acquisition and deployment. Similarly, early imitators that have failed to assimilate the innovation subsequently benefit from the increase in external knowledge as well as the extended period of time available to advance their understanding and skills relevant to its effective use. This reduces the assimilation gap and changes the number of adopters successfully deploying the innovation with knowledge spillover manifesting as a network good (Kauffman, McAndrews, and Wang 2000)1.

A similar phenomenon is observed when organizational commitment is the cause of its limited deployment. A growing population of successful users increases the social pressure towards deployment. Organizational inability to withstand the bandwagon effect during acquisition increases the possibility of it being pressured into deployment if the innovation persists to be of value to the population (O'Neill, Pouder, and Buchholtz 1998). Thus, during the diffusion of innovation, the imitation

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[1] The population may also experience a lack of increase in population knowledge. This may happen due to a discontinuation in knowledge sharing, no further increase in adopters or technological obsolescence. The result is a stationary assimilation gap that identifies maximal market penetration of the innovation.

effect drives the initial growth in the assimilation gap, followed by knowledge spillover that reduces this gap. The assimilation gap forms an inverted-U shaped relationship with time that can be hypothesized as:

H1: The assimilation gap has a curvilinear relationship with time. The upward slope of the curve is driven by imitation and the downward slope by knowledge spillover.

Relative Advantage

An innovation offering a superior solution to user needs positively affects their competitiveness (Bowman 1974). This can be described as its relative advantage which is "the degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers 1983, 213). The early adopters translate this into first mover advantage (Mansfield 1986; Lieberman and Montgomery 1988) and/or resolution of problems limiting organizational performance (Greve 2003). The association between the adoption of innovation and increased firm performance sends a positive signal to the market, creating a network effect that increases the demand for innovation its rapid imitation.

An innovation with higher relative advantage also experiences an increased attention from its acquirers for its successful deployment. The attention may take the form of top management support or increased organization-wide emphasis on its deployment, decreasing the factors that inhibit its effective use (Davis 1989). The individuals responsible for deployment experience more attention as well as a higher risk of negative consequences in the event of a failure. This increases the intensity of search and the exploration of sources of knowledge that may be instrumental in deployment including capitalization of knowledge based network externalities. The relative advantage increases both the direct effect of imitation as well as the indirect effect of knowledge spillover.

We define 'time-to-peak' as the time taken by the assimilation curve to reach the maximum difference between its influence-based and use-based adoption. In the presence of a higher relative advantage, a larger proportion of firms are attracted to the innovation generating a significant influence early during the life of the innovation. We can therefore expect that innovation offering a higher relative advantage will shift the assimilation peak to the left, leading to the hypothesis:

H2: The time-to-peak for the assimilation gap has a negative relationship to the relative advantage of the innovation.

Complexity

Some innovations are easy to deploy following an acquisition, such as cell-phones for the field-level staff. Others require extensive knowledge for their proper usage. While Rogers defines complexity as "the degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers 1983, 230), Beach and Mitchell capture its nuances by identifying complexity as the 'number of different components of the decision problem; number of alternatives to be considered and amount of relevant information to be considered' (Beach and Mitchell 1978, 444). An increase in complexity changes the pattern of diffusion, requiring multiple decisions beyond individual's 'cognitive power' (Eveland and Tornatzky 1990). The decision to adopt and the decision to use become even more disconnected (Attewell 1992).

Firms vary in their ability to extract rents from the innovation as they attempt to develop new 'competences' (McGrath et al. 1996). The cause and effect relationship is made ambiguous by the complexity of the innovation and the need for learning associated with its effective usage (Dierickx and Cool 1989). The resulting variability in the effect of adoption on performance dilutes the direct effect of network influence, reducing imitation.

A firm's 'provisional' acceptance of an innovation increases its need for information, both in-house as well as from external contacts (Swanson and Ramiller 1997). The acquisition of complex innovations increases reliance on external sources and acquiring firms experience a stronger influence of knowledge spillovers.

The increased complexity decreases the direct effect of imitation on adoption and increases the indirect effect of knowledge spillover such that the ex-ante effect of externalities is minimized while the ex-post influence is increased. The resulting assimilation gap experiences a shift in its peak towards the right, leading to the hypothesis:

H3: The time-to-peak for the assimilation gap has a positive relationship to the complexity of the innovation.

Compatibility

An innovation is expected to be compatible both along the organizational level in terms of its beliefs, norms and values as well as the technical level (Schultz and Slevin 1975). Rogers defines compatibility as "degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of the potential adopter" (Rogers 1983, 223). The external influences affect organizational decisions through the cognitive virtues of its key members. The process of

imitation reinforces these values and beliefs which appear as the vehicle for legitimacy (Stinchcombe 1965; DiMaggio and Powell 1983). A well-aligned innovation experiences smaller influence from the factors that inhibit its use (Davis 1989).

Incompatibility may have limited meaning as firms observe the success of early adopters and are influenced into imitation. The bounds of rationality limit organizational clarity towards the extent of incompatibilities which reveal as firms enter the process of acquisition (March, Simon, and Guetzkow 1958). The desire to increase firm value increases managerial risk propensity when new innovations are considered to be critical towards a competitive position (Greve 2003). As acquisitions unfold during the process of integration, the misalignment creates a formidable barrier in their in-house acceptance (Ramiller 1994).

In the presence of incompatibilities the process of deployment encounters difficulty (Forrell and Solaner 1986; Ramiller 1994). While organizational incompatibility negatively affects firm acceptance due to violation of values necessary for its successful promulgation, the technical incompatibility raises the cost necessary for its deployment. This includes changes in existing technical infrastructure as well as the training necessary for its staff to comprehend and adjust to the scope of innovation. The process of mix-and-match between innovation and the organization raises the search and implementation costs, reducing the number of firms successful in its deployment (Matutes and Regibeau 1988).

While innovation incompatibility reduces the strength of imitation, it has a stronger (negative) effect on the in-house drivers that encourage knowledge spillovers. Stated differently, innovation compatibility shifts the peak of the assimilation gap to the left. This leads to the hypothesis:

H4: The time-to-peak for the assimilation gap has a negative relation to the compatibility of the innovation.

Hypothesis	Assimilation Gap	Direct Effect	Indirect Effect
H1: Assimilation Gap over time	Curvilinear	-	-
H2: Relative Advantage	Left-shifted	Strong	Strong
H3: Complexity	Right-shifted	Weak	Strong
H4: Compatibility	Left-shifted	Strong	Weak

Table 1. Summary of hypotheses

METHODS

We use the Newell and Simon's (1972) conceptualization of 'problem space' as the background in which a population of firms with differences in knowledge and unique sets of problems pursue innovation as a solution to their needs. Innovation provides the firms with the opportunity to reduce impediments to their performance and improve their competitive position (Greve 2003; March, Simon, and Guetzkow 1958). The problem space characterization allows for the development of relationship between firm knowledge and their problems while the agent-based modeling facilitates the exchange of information between firms that help identify solutions to their problems.

We identify firms as agents with unique knowledge and problems. Firm knowledge is extracted from a universal set representing industry knowledge and varies for each firm. Innovation comprises of a smaller subset that is independently extracted from the same universal set and remains the same for all firms. Each firm experiences a problem represented as a subset of their knowledge. A complete overlap between the problem and the innovation allows the innovation to serve as a solution to organizational problem. Firm knowledge is critical and lower knowledge decreases the probability of overlap between the problem and the innovation. Firm interactions offer the only way to increase knowledge that may lead to a match between their problem and the innovation.

Model

The problem-innovation pairs are created in an environment called the problem space. This is a set that includes all elements of knowledge as "objects . . . represented by symbols; sets of objects . . . as lists" (Newell and Simon 1972, 67). Objects are represented by random numbers and their lists as a set. Firm knowledge is represented by a list and their problem as its subset akin to Kuhn's 'paradigm' of scientific knowledge (Kuhn 1970, 11). These lists are randomly generated to allow for heterogeneity between firm knowledge and their problems (Rumelt 1991; Wernerfelt 1984). Organizational innovation is identified by a single list of random numbers that is common to all firms in the population. The innovation serves as a

solution if a firm finds a match between all objects that are part of their problem and the available innovation. Such a match turns the firm into a successful user that has completely deployed the innovation. As the simulation begins, heterogeneity of firm knowledge allows some firms to have substantial overlap between their problem and the innovation while others may experience none (Abrahamson and Rosenkopf 1997; see also Hayward 2002). This results into a normal distribution of firm tendencies towards innovation deployment.

The acquisition of innovation by firms is made possible in two ways. First when firms find the innovation to completely match with their problem as discussed above. This leads to simultaneous adoption as well as deployment turning the firm into a use-based adopter. In the second case, firms that find majority of their peers adopting the innovation acquire it but remain unable to deploy it until their knowledge provides them a way to match their problem with the innovation. This turns them into an influence-based adopter until the match is in place, creating an assimilation gap.

The objects forming knowledge are 'associated' to each other (Newell and Simon 1972, 67). Since firm knowledge is a subset of industry knowledge, only some of the relevant associations are available to them. Firms learn by identifying knowledge possessed by their peers to bridge the missing associative links. This is represented in figure 2. The process of learning not only takes place by focusing on peers, identified as 1st order associations, but also from firms associated to their first order relation, termed as the 2nd order associations. This forms the basis of the 'direct' and 'indirect experiences' of firms (Karahanna, Straub, and Chervany 1999).
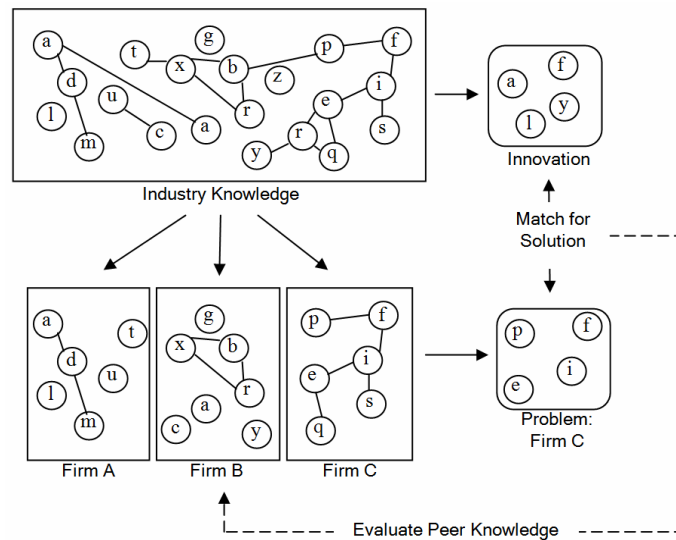

Figure 2. Modeling firm interactions in problem space

The matching process attempts to find association between the objects in the problem to those in the innovation where order is not important. At the basic level, it compares objects to see if they are the same. When they are different, the process evaluates if the objects in the problem are associated with objects in the solution. This is done by evaluating if (a) any object in peer knowledge is associated to the innovation, and, (b) if the matching object also matches the problem. If both of these conditions are true, the firm increases its knowledge by copying that object in its knowledge set given the constraints of its absorptive capacity.

Peer relationships are represented as firm-level associations (Abrahamson and Rosenkopf 1997). This is accomplished through the creation of a square matrix with the set of firms as rows and columns. The value in each cell is a random number between 0 and 1 with 0 representing no relation and 1 as a strong association. The diagonal elements have no meaning and are ignored. Firms connected with each other through a strong association are considered peers and experience the pressures for imitation when 25% or more of their peers have adopted the innovation, either as influence-based or use-based adoption. The association between firms allows them to influence (and be influenced) by each other as well as experience knowledge sharing.

The simulation is modeled for 50 cycles with each cycle representing a unit of time. In the cycles following the first, firms try to find a match between their problem and the innovation. This is similar to the search period used in NK simulations (Siggelkow and Rivkin 2006). The influence-based adopters keep exploring sources of knowledge in an effort to completely map their problems with the innovation (Kraatz 1998; Kauffman, McAndrews, and Wang 2000). Non adopters on the other hand remain unaffected until their peers pressure them into acquisition. It is possible that a firm may not be associated to any

other firm and the only way for it to adopt the innovation is the presence of a complete overlap between their problem and the innovation and therefore there is no change in their status following the first cycle.

We generated a total of 100 simulations to account for variations in the distribution of knowledge between firms and for variations in the nature of innovation. The 50 cycles ensure the emergence of a stable pattern of diffusion, adoption and deployment and the 100 runs averaged the effect of knowledge distribution. It was found that by the 30th cycle the population stabilized to a configuration with no additional changes in the following periods. We display all results until this time. The results have been found to be robust in their convergence across variations in the underlying model as well as across time. The mean value of changes in the number of firms measured after every five successive time intervals are statistically significant at the 0.05 level. Due to limitations of space, we do not discuss sensitivity analysis and the checks of robustness that validate the domain and integrity of the model.

Variables

The total knowledge possessed by the industry is represented as the width of the problem space set at 1,000 and each firm is allocated 500 random objects that represent firm knowledge within this space. While firm knowledge is unique, there are substantial overlaps between firms in the industry (Rumelt 1991). Innovation is a composed of a set of 25 random numbers universal to all firms. Firm knowledge includes a subset of 25 random numbers that form their problem (Greve 2003). The number of objects forming the total knowledge, firm knowledge and innovation was found to have no effect on the results and these values are kept constant across all runs.

The number of users or the use-based adopters is represented by a count of the firms that have been able to find a complete match between their problem and the innovation. Influence-based adopters are represented by counting the firms that have been influenced into adoption but remain from completing the match (Kauffman, McAndrews, and Wang 2000). The total adopters are a sum of the use-based and influence-based adopters. The minimum number of associations with other acquirers necessary for the focal firm to turn into an influence-based adopter was tested for values between 1 and 50 across successive trials. This number is found to influence the critical mass necessary for the adoption curve to accelerate upwards. A higher value decreases the acceleration of the curve while a smaller value initiates high growth in the presence of fewer users. We found that a value of 6 (approximately 25% of the average number of peers possessed by a firm) for a population of 100 firms gave a pace of adoption in line with previous research (Mahajan and Peterson 1985).

Firms vary in their absorptive capacity, which is divided into the capacity towards identifying the number of relevant objects possessed by other firms in each run as well as the capacity to reconfigure their knowledge once an external object is acquired (Cohen and Levinthal 1990). The value for each firm is based on identifying an element from a uniform random distribution and the results have been found to be robust.

The relative advantage of the innovation is represented by assigning a performance value ranging from 1 to 10 for the innovation. A higher value represents greater advantage rendered from the use of the innovation. This is operationalized as a decrease in the threshold necessary for adoption and reduces the need for a complete match between the problem and the innovation before its acquisition. This emphasizes firm eagerness to use innovations that offer a higher potential to improve performance (Rogers 1983). Innovation complexity is operationalized as the increase in the objects forming the problem. This is ranged between 1 to 10 where 1 represents 20% of the objects available in the innovation set, 5 as 100% and 10 as 200%. Compatibility is evaluated as the sum of the objects forming the problem with the sum of objects forming the solution. A close match, given by 1, between the sums represents a higher probability that the absorptive capacity will facilitate the mapping between the problem and the innovation. A lower match, given by 0, indicates firm reliance on external knowledge for the solution of the problem. The intermediate values of the match offer a continuum of the compatibility scale. The absolute values of relative advantage, complexity and compatibility do not have any meaning and it is the relative increase that forms the basis of our argument. The increases are therefore normalized to ensure a cardinal scale with equal spacing of intervals.

RESULTS

We first tested the pattern of adoption and the resulting assimilation gap in the presence of the direct and indirect network externalities; the imitation and knowledge spillover effects. The result as shown in figure 3 identifies that as the process of adoption follows the S-shaped diffusion curve, the assimilation gap increases until a certain point after which it starts decreasing. Its peak identifies the maximal number of influence-based adopters. The decrease in the gap results from the conversion of imitators to use-based adopters. This supports hypothesis 1. It is interesting to see that the peak of the assimilation gap arrives earlier than the peak of the cumulative acquisitions. The knowledge effect overcomes imitation during the period when the population experiences a rapid increase in its diffusion.
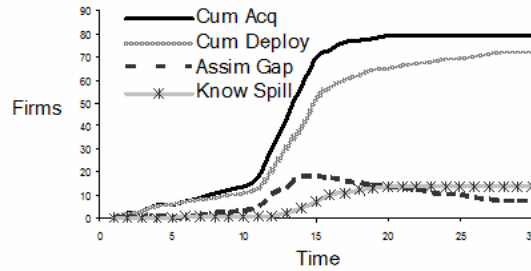
Figure 3. Adoption curve and the curvilinear assimilation gap

We then tested for the effect of changes in the relative advantage of the innovation. This was done by running 10 models each with a different value of the relative advantage starting from 1 and going up to 10. Figure 4 combines five of those graphs with even numbered values omitted. It shows that an increase in the relative advantage shifts the peak of the assimilation gap towards the left as argued in hypothesis 2. However, it can be seen that a lower advantage also decreases the height of the assimilation gap. The decrease in innovative advantage diminishes the impact of the bandwagon effect.
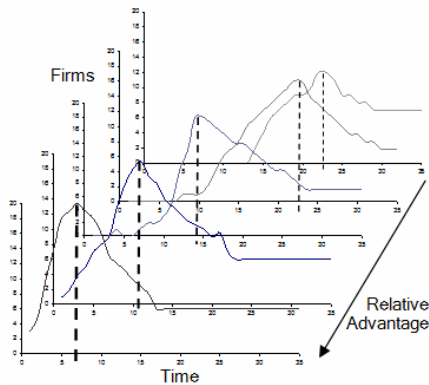

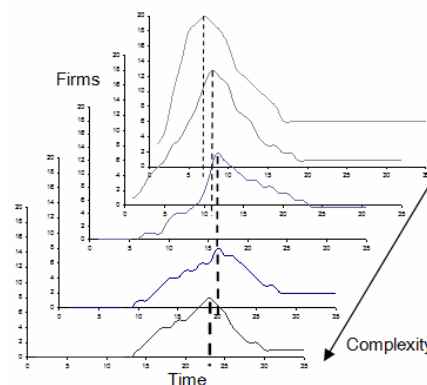**Figure 4. Relative advantage and the assimilation gap**

Figure 5. Innovation complexity and the assimilation gap

Testing for hypothesis 3, we find it to be supported as innovation complexity shifts the peak of the assimilation gap to the right as shown in figure 5. In this case, weak imitation significantly reduces the peak compared to other models while the knowledge spillover has a larger impact towards the reduction of the gap across time.
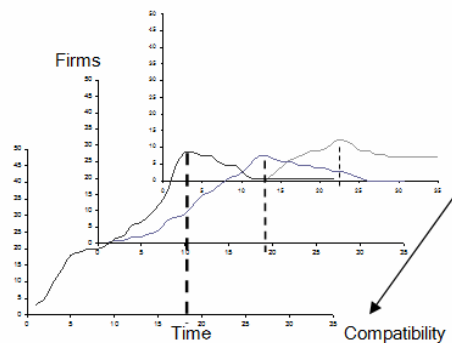

Figure 6. Innovation compatibility and the assimilation gap

The results for hypothesis 4 are also found to be supported. Compatibility of the innovation shifts the peak towards the left as it is increased from 0.1 to 1. The weakness of imitation and the subsequent weakness in knowledge spillover limit organizational ability to identify and capitalize relevant sources of knowledge in the internal or external environment. It can be seen that even for smaller values of incompatibility, it is has a much stronger indirect effect on knowledge development than the direct effect on imitation. For higher values, the comparative differences remain even though the imitative effects become marginal. This is shown in figure 6 (to retain readability only three curves are displayed with compatibility of 0.2, 0.6 and 0.8).

DISCUSSION AND CONCLUSION

The paper identifies the differences in the direct or indirect effects on the changes in assimilation gap as innovation diffuses across the industry (Becker and Whisler 1967). The increase in diffusion makes it difficult for the remaining firms to ignore its acquisition and the imitative influences result into assimilation gap (Kimberly and Evanisko 1981). In the presence of network externalities, the environmental impact at any time is perceived differently by each firm depending upon their perception of the value of the innovation (Hickson et al. 1971). As the availability of the innovation changes the behavior of the early adopters, they amplify or reduce this impact such that the innovation influence experienced by the subsequent firms is modified from its original value. The new users accentuate this effect and the positive externality modifies the current market equilibrium towards a new one at the rate of a few firms at a time (Kauffman, McAndrews, and Wang 2000; Arthur 1996). While it may be difficult to observe the threshold for each firm, sooner or later the network externality manifests into a systematically increasing (or decreasing) change across the population. As the number of influenced firms increase, the impact gains a higher momentum and increases the rate of adoption for the remaining players (Rogers 1983).

The nature of innovation varies the assimilation gap. Relative advantage and compatibility increase the rate of deployment and complexity delays its effective use. Each characteristic offers a unique combination of the effects of imitation and knowledge spillover. The study extends the diffusion literature by revealing the underlying structure of its various constituent factors and identifies the conditions that affect them individually. We demonstrate that the assimilation gap changes with the information available to acquirers experiencing the effects of imitation and helps in their conversion into successful users. The resulting curvilinear pattern reflects that organizational innovations are exposed to multiple cycles of evaluation and decision as they are adopted. This is in line with the perspective advanced by the resource based view in a dynamic environment (Grant 1996). The curvilinear path followed by the assimilation gap makes the phenomenon a transient characteristic of innovation diffusion. Further research along these lines can identify the factors that can moderate the intensity and duration of the assimilation gap to improve the impact of innovations on organizational performance.

While it may be possible for the initial adopters to experience a delay between their adoption and deployment, it is assumed that their inability to use the innovation in-house will lead to a reduction in their influence in convincing other firms to do so. The diffusion of the innovation will not gain from their experience and those exceptions are not considered. Furthermore, it is assumed that every innovation has a primary purpose, either to solve a problem or improve the quality of an available solution. Innovations that offer a reduction in organizational performance or the simultaneous availability of two or more competing innovations are not considered. These are interesting phenomena and may offer avenues of further research.

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