SIMULATION OF ABSORPTIVE CAPACITY IMPACT ON THE PERFORMANCE OF PROJECT NETWORKS LEARNING

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Abstract

In this paper, a multi-agent simulation model is developed for inter-organizational learning to evaluate the impact of absorptive capacity on learning performance. One of the most important problems on project networks is to understand which innovation has the most benefit on learning and how much it could effect on learning in inter-organizational project networks. On the other hand, the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities. This capability called a firm's absorptive capacity and it is largely a function of the firm's level of prior related knowledge. It is evaluated which duration will be suitable to repeat innovation not to exceed the limit of absorptive capacity and demonstrate that the duration of innovation due to technological changes in project networks can result on relationally unstable network relationships and productive implementation of networks. These findings are critical to developing a comprehensive understanding of innovation on the learning process in inter-organizational project networks.

Keywords: Absorptive Capacity, Project Networks, Simulation

1. INTRODUCTION

The different aspects of project networks have been improved during the last decade. Economic origins(Coase 1937; and Williamson 1981), sociological origins (Eccles 1981; and Powell 1990), alignment (Jacobides et al. 2005; and Taylor et al. 2007), robustness (Ortiz et al. (2010); and Wong et al. (2010), virtual teams (Chinowsky et al. 2003; and Chen and Messner (2011), hold-up (Unsal and Taylor 2010) and learning (Taylor et al. 2008; and Villarroel et al. 2002) are various parts of project networks.

Learning is a social construction process (Brown and Duguid 1991). The degree to which firms learn about new opportunities is a function of the extent of their participation in such activities (Levinthal and March 1990). Modeling and simulation of the process of learning has been developed during this time. Hijazi and Abourizk (1992) present a simulation-based methodology for incorporating learning development in process simulation modeling and experimentation. They suggest that a stochastic learning model be adopted due to the random factors affecting learning in construction. Lutz and Halpin (1994) present the methodology used to model the learning development phenomenon in the Cyclone format using the Boeing learning curve. Hartman (2005) demonstrates that contemporary computer simulations in civil engineering are different to conventional simulations of the past. Especially, in the learning rate of project networks, Taylor and Levit develop a multi-agent simulation model to explore the impact of learning dynamics on the productive implementation of innovations in project networks comprised of designers and contractors.

In a competitive condition among architecture, engineering and construction industry, accomplishment of projects with the lowest cost, time and the best quality is one of the most important factor. Projects should be improved to succeed in the competition to win bid before getting the project or get bonus from client. Researchers describe systematic innovations as potentially leading to significant increases in productivity while being particularly difficult to implement in project networks. When a project network must adapt to a systemic innovation (i.e., an innovation that impacts more than one type of firm in the network), the network's ability to adapt to such change is critical (Taylor and Levitt 2004).

On the other hand, the ability to exploit external knowledge is thus a critical component of innovative capabilities. The ability to evaluate and utilize outside knowledge is largely a function of the level of prior related knowledge. The ability of recognition of the value of new information, assimilate and apply it to the commercial ends called absorptive capacity (Cohen and Levinthal 1990). Changing the qualitative factors of absorptive capacity to quantitative ones is very important part of our model. When adapting to the systemic changes, the innovation can occur in gaps of time between learning events among firms may impact adaptation performance of network.

2. BACKGROUND

2.1 Simulation of Innovation in the Process of Learning in Architecture, Engineering and Construction

Innovation in project networks has been evaluated in construction industry. Powel (1996) finds that the locus of innovation will be found in networks of learning, rather than individual firms, when the knowledge base of industry is both complex and expanding and the source of expertise are widely dispersed. Harty (2005) evaluates innovation in construction as a sociology technology approach. He suggests that system building contains outcomes that are not only transformation of practices, process and systems, but also the potential transformation of technologies themselves.

On the other hand, some attempts have been done on the modularity and innovation in complex systems. Ethiraj and levinthal (2004) try to identify what constitutes an appropriate modularization of a complex system. They develop a formal simulation model to examine the dynamics of innovation and performance in complex systems. Recently, researchers have developed simulation models to investigate the learning between task interdependent organizations on a project. Taylor and levit (2007) evaluate the innovation alignment and project network dynamics as an integrative model for change. They got whether an innovation is aligned with the allocation of work in a project network, then it will diffuse more than if it is misaligned with the allocation of work. In addition, they evaluate the relational instability in interorganizational networks. The project network dynamics simulation research demonstrates that relational stability in a project network increases the value of productivity in the learning process. However, this increase in productivity does not take impact of absorptive capacity on innovation in the learning rate which may be a significant factor in unstable networks. This paper extends previous simulation research on unstable network learning with considering an absorptive capacity theory based on its effect on innovation of project networks.

2.2 Absorptive Capacity and R&D Investments

Rooted in Cohen's and Levinthal's (1990) theory on absorptive capacity on learning and innovation specifies three classes of industry level determinants of R&D intensity: demand, appropriability, and technological opportunity conditions. There are two dimensions of technological opportunity. The first, refers simply to the quantity of extra-industry technological knowledge and the second dimension of technological opportunity is the degree to which a unit of new knowledge improves the technological performance of the firm's manufacturing processes or products and, in turn, the firm's profits. There are two factors that will affect a firm's incentives to learn, and, therefore, its incentives to invest in absorptive capacity via its R&D expenditures. First, there is the quantity of knowledge to be assimilated and exploited the more there is, the greater the incentive. Second, there is the difficulty of learning. Some types of information are more difficult to assimilate and use than others. As learning is more difficult, more prior knowledge has to have been accumulated via R&D for effective learning to occur. As a result, this is a more costly learning environment (Cohen's and Levinthal 1990). The basic model of how absorptive capacity affects the determination of R&D expenditures is represented diagrammatically in Figure 1.

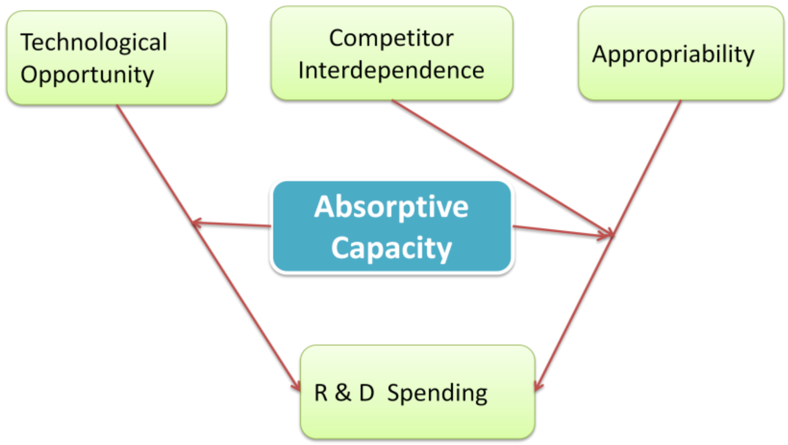

Figure 1. Model of Absorptive capacity and R&D incentives

We focus on the third factor of absorptive capacity and considered technological changes as an important factor of innovation in the model. Technological change occurs in two forms. When advances build on existing know-how, established firms reap the bulk of the benefits and when new discoveries create technological discontinuities, or radical breaks from previous dominant method, incumbents can be robbed of many of their advantages (Powell 1996). Moreover, technological change as a quantitative parameter has been considered. It is assumed that this qualitative factor can be changeable to quantitative factor in the model. Accordingly, the effect of technological changes on learning rate as an innovation factor has been evaluated.

3. PROJECT NETWORK DYNAMICS ADAPTATION PERFORMANCE MODEL

3.1 The baseline project network dynamics model (Base Model)

The model borrows from the general form of the learning curve described in Wright (1936). The impact of learning rate on innovation process was determined in this form. The simulation model examines both organizational learning rates and interorganizational learning rates across interdependent tasks to examine the impact of an innovation on firm level and project network level productivity. (Tayler et al. 2007). With this assumption, given a firm i, its individual productivity is

$$\pi_i = \pi_0 (n_i)^{L_i} \tag{1}$$

Where π_0 is the initial productivity factor for individual work; n_i is the number of individual tasks executed by firm i ; and $L_i = Log_2^{\lambda_i}$ is the characteristic learning index for firm i; and λ_i is learning rate.

The learning rate for construction networks is generally defined in ranges 0.7 to 0.9 (Oglesby et al. 1988). Average industry learning rate has been considered 0.8 in the simulation. The model consists of N firms and M roles. Firms can implement a specialized role R_i and one role can be done by several firms. The actual execution time is given by:

$$T_i = \pi_i (T_{Ri}) \quad (2)$$

Where T_{Ri} is the execution duration of the first independent task by firm i in role R_i

In addition, 2 firms (i, j) may have task interdependent inter-organizational learning. As an example, the degree of task interdependence has been considered as $X_{i,j}$. Also the collaborative interdependent work has been developed with a dyadic learning curve between two firms:

$$\pi_{ij} = \pi_{00}(n_{ij})^{L_{ij}} \quad (3)$$

Where π_{00} is the initial productivity factor for collaborative work; n_{ij} is the number of interdependent tasks executed by firms (i, j); $L_i = Log_2^{\lambda_{ij}}$ is learning index between firms (i, j); and λ_{ij} is the learning rate between firms (i, j).

Similar to the single firm case, given a level of collaborative interdependent work for the firm dyad (i, j), defined as a percentage of firm i's characteristic execution time T_{Ri}, the actual one-sided execution time of this collaborative portion of the work is given by:

$$T_{ij} = \pi_{ij} X_{ij} (T_{Ri}) \quad (4)$$

Where X_{ij} is the degree of task interdependence.

The total execution time for the project of the network is T_P which is the sum of all independent tasks executed by each individual firm and all the collaborative interdependent tasks executed by all firms of the project is given by:

$$T_P = \sum_{i=1}^{M} T_i + \sum_{i=1}^{M} \sum_{j \neq i}^{M} T_{ij} \quad (5)$$

In order to plot and compare the performance of the different models, a normalization function and the normalizing factor are defined as:

$$T_N = \sum_{i=1}^{M} T_{Ri} + \sum_{i=1}^{M}\sum_{j\neq i}^{M} X_{ij} T_{Ri} \quad (6)$$

Therefore, the normalized performance of any given project is given by:

$$\overline{T}_P = \frac{T_P}{T_N} \quad (7)$$

To keep the average number of project executed per firm, it is necessary to adjust the number of projects executed by dividing the total number of projects to adjust the scale number of projects. Accordingly, the performance rate of all cases can be compared for relative differences.

3.2 Modeling Absorptive capacity

In the process of technological change, learning rate could affect from innovation. It always makes the capabilities of firms improve. In the model, the impact of innovation has been considered on the wright's learning curve. As indicated in the research of Villarroel and Taylor about the performance implications of open sourcing and knowledge brokering, the impact of absorptive capacity has been considered as following:

For given a firm i, its individual productivity is :

$$\pi_i = \pi_0((1+\alpha_i)n_i)^{L_i} \quad (8)$$

Where α_i is an absorptive capacity of firm i and $0 < \alpha_i < 1$

For the collaborative interdependent work with a dyadic learning curve between two firms:

$$\pi_{ij} = \pi_{00}((1+\alpha_{ij})n_{ij})^{L_{ij}} \quad (9)$$

Where α_{ij} is an absorptive capacity of firm (i, j) and $0 < \alpha_{ij} < 1$

It is important to note that these functions are used only when innovation happened in the simulation.

3.3 Input of innovation in learning dynamics of project network

In the model, the affects of absorptive capacity has been evaluated on innovation of learning in project network. It is clear that after technological change, innovation makes the productivity improve and because of learning, productivity values will decrease again. Figure 2 illustrates the form of the innovation curve over time. If the value of productivity increases continuously after each innovation, it will be exceeded from absorptive capacity and if it will decrease continuously after each innovation it will be below of absorptive capacity line. In this figure, the level of absorptive capacity is considered as an initial productivity and λ_i is the duration between two innovations.

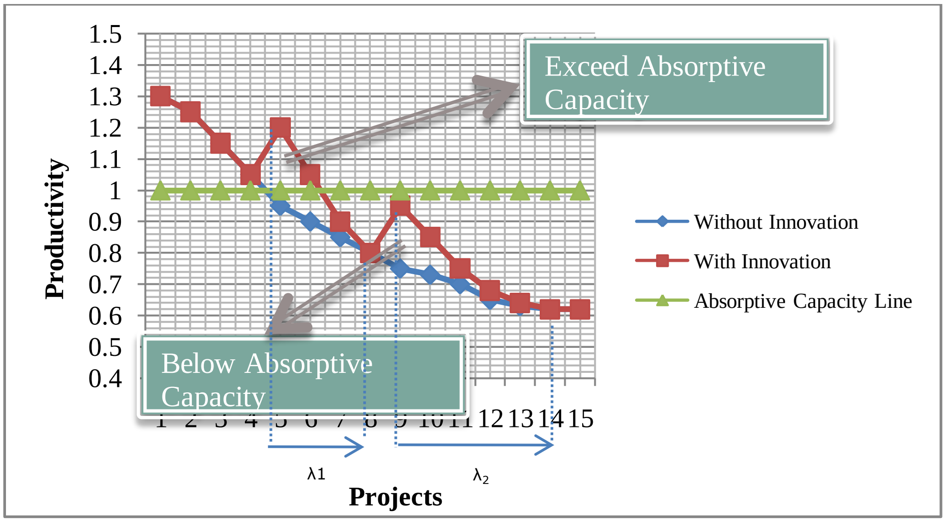

Figure 2. Learning Curve with two Periods of Innovation

4. Simulation Experimental Design

To examine the impact of innovation on learning rate, these assumptions has been considered. With considering the effect of innovation on each firm and also the concept of absorptive capacity, two projects can be executed during of innovation in simulation simultaneously. In other words, firms are working on a simulated project have opportunity to learn on the other project. This idea comes from this theory that technological changes improve the capabilities of the firms. In other words, simulation allows the possibility of simultaneous project execution. This is the impact of absorptive capacity on the learning of project network in this model.

By considering the impact of innovation on a project network, it is observed that the adaptation rate is impacted by the innovation period. Figure 3 contains a comparison of the individual firm learning without innovation and with innovation. Only one innovation occurred on project 8. It affects on productivity until project 16.

4.1 Results

In the model, it is assumed that first innovation has happened on the 5th project. In addition, we assume that next innovation could be happened when the value of productivity is equal to the value of productivity in case of without innovation. We want to understand how many innovations can be happened during 25 projects and also what the number of optimized value of λ is when different relational instability among firms in the network has happened. We call $\lambda_{capacity}$ as an average value of λ's during projects in the network. In addition, the surface of below the absorptive capacity line has the direct relation with relational instability. When three firms could get per role, the surface has the most value. Table 2 illustrates the results of simulation runs.

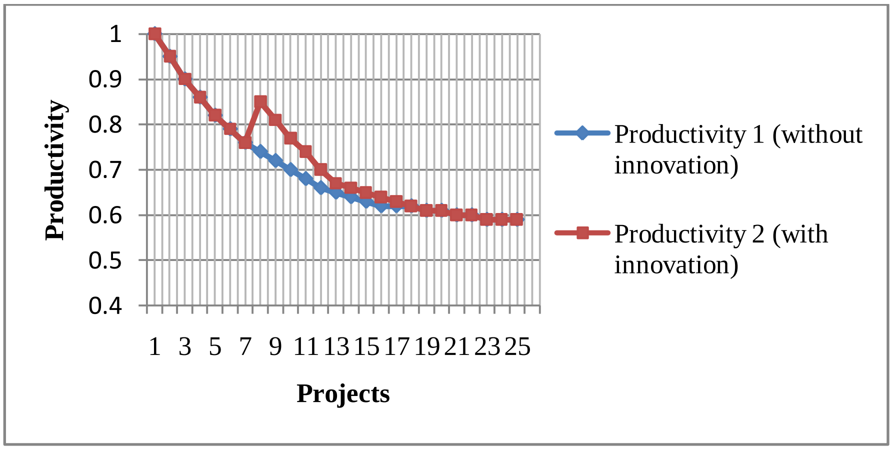

Figure 3. The comparison of Individual Firm Adaptation Performance With innovation and without innovation

Table 2. Comparison of Productivity at the 25th project

Number of Firms per Role	Degree of Task Interdependence	Productivity of 25th Project		Increase of Productivity	Rate of Increase	The number of innovation	The value of $\lambda^*_{capacity}$
		Without Innovation	With Innovation				
1 firm per role	0%	0.447	0.447	0	0%	3	(4+5+6)/ 3=5
2 firms per role	0%	0.552	0.562	0.01	2%	2	(7+8)/2= 7.5
3 firms per role	0%	0.692	0.721	0.029	4%	1	-
1 firm per role	50%	0.447	0.447	0	0%	3	(4+5+6)/ 3=5
2 firms per role	50%	0.669	0.685	0.016	2%	2	(5+11)/2 =8
3 firms per role	50%	0.721	0.817	0.096	13%	1	-

*$\lambda_{capacity}$: Average value of λ's during projects in the network

From the above table, in the situation where there is only 1 firm per role, no impact of innovation on the last project hasn't been observed. Three innovations happened during 25 projects. The value of productivity does not vary between two cases of task interdependence. It shows that innovation does not have impact on learning rate of project network, due to the fact that on each project the same firm would participate. In addition, in this case the value of productivity converges faster to the value of productivity in case of without innovation. Two innovations happened during 25 projects when two firms get one role. The value of productivity increases a little in two cases of task interdependence. The rate of productivity convergence is slower than case of 1 firm. It shows that relational instability has negative impact on innovation of networks. When three firms get per role, the rate of increase of the productivity value with innovation is more than two previous cases. Especially, when the degree of task interdependent is 50% innovation has the most impact on learning. Moreover, when innovation occurs, the value of productivity does not reach to the case of without innovation. As a result, there in not have $\lambda_{capacity}$ in this case. It confirms that relational instability has negative impact on innovation of networks. Accordingly, we put forward the following propositions:

Proposition 1: *The greater relational instability among firms in a network increases impact of innovation and decreases convergence rate of productivity.*

Proposition 2: *Increasing degree of task interdependence especially in greater relational instability among firms in a network increases the impact of innovation on the variation of productivity.*

5. Conclusion

The purpose of this simulation is to implement project network learning theory by using several controllable input parameters. Previous computational simulation modeling research on project network learning dynamics is extended by evaluation of the qualitative factors of absorptive capacity. The most important factor of innovation as technological changes has been considered. Also, it is assumed that one of the impacts of technological changes in the learning of project network is improving the firm capability during projects. In other word, two projects can be executed at same duration during the process of innovation. Then its effect has been considered on the productivity of networks. Also the first time of innovation on the model is assumed and number of innovations happened on duration of 25 projects are calculated. In total, six cases with different relational instability and task interdependences and evaluate the concept of absorptive capacity on learning dynamics of project networks. It is demonstrated that relational instability and degree of task interdependence of project networks can effect on innovation due to technological changes which is one of the most important factor of absorptive capacity.

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