Organizational Productivity and Absorptive Capacity: A Conceptual Modeling

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Abstract:

This paper aims to design a mathematical model for organizational absorptive capacity, which is both deterministic and directional. Banking on maximization conditions, time duration needed for an organization to shift from exploration to exploitation and vice versa, has been determined. Using simultaneous differential equation matrix, effects of absorptive capacity constituents on marginal productivity of organization have been analyzed. The model depicts relationship of organizational memory, revenue stream, time taken for creating the knowledge base with their respective elasticities with organizational absorptive capacity, and respective productivities of organizational capital and capability alongside organizational absorptive capacity, considering knowledge exploration and exploitation phases.

Keywords: Organizational memory; Absorptive capacity; Optimization; Productivity

JEL Classification: C50, M12, M50

1. Introduction

While talking about organizational learning and effectiveness, absorptive capacity of the organization plays the major role. Various dimensions of organizational absorptive capacity add to the organizational productivity (Chen and Ching 2004). Organizational learning is a continuous process which works in spiral connectivity with organizational productivity (Carayannis 1999). The ups and downs in the history of organizational productivity add to organizational memory, which in turn adds to the absorptive capacity of the organization (Chou 2005). The process adds to the organizational learning as well. This learning process can occur in two ways depending on the environment: by exploiting the existing knowledge and by exploring new knowledge (Van Den Bosch, Volberda and De Boer 1999). At the nascent level, the organizational environment is turbulent and it goes for exploration. Once the practices are standardized and are in place, it goes for exploiting the existing knowledge. But in both the cases, organizational learning takes place. This will in turn affect the profitability and productivity of the organization.

It is not always possible for a firm to hold a monopoly position in industry. In order to sustain in the competition, the firms must continue innovation. Absorptive capacity provides firm with the capability to acquire, assimilate and transform new knowledge with a view to keep the innovation moving (Cohen and Levinthal 1990). Innovation drives the market power possessed by any firm (Kamien and Schwartz 1975). If we look at the existing body of literature, several studies have been done on the relationship between firm innovation and absorptive capacity. Tsai (2001) discussed about position of business unit in a network with a view to defining capability of a firm in terms of its absorptive capacity and innovation. Argote, McEvily and Reagans (2003) talk about the knowledge transactions for expansion of knowledge base. Exponential temporal growth of organizational memory was discussed by Michael and Palandjian (2004). Price elasticity of end product in driving innovation and absorptive capacity was discussed by Lane and Lubatkin (1998). Revenue generation by the way of innovation driving absorptive capacity was discussed by Stock, Greis and Fischer (2001).

The literature on organizational productivity and absorptive capacity also reflects upon some of the important factors. Girma (2005) discusses about exploitation driver of productivity and the role of absorptive capacity. The relationship between absorptive capacity and dynamic capability building via R&D was discussed by Zahra and George (2002). Participation in knowledge creation and transfer also drives to build up profitable absorptive capacity (Jansen, Van Den Bosch and Volberda 2005). Knowledge exploration and knowledge exploitation are used complementarily in any organization in order to build up capability (Lichtenthaler 2009). Hence for a profitable absorptive capacity building, both the processes must be used in cyclical order (Uotila *et al*. 2009).

In this paper, we are going to design a mathematical model for absorptive capacity on the basis of the parameters discussed so far. The model is two-fold in nature. In the deterministic part of the model, the absorptive capacity will be designed in terms of the various deterministic factors. On the other hand, directional part of the model will show the nature of absorptive capacity effect in three different scenarios: knowledge exploration, knowledge exploitation and combination of both. In the first part of the model development, analysis of the aforementioned factors will be discussed. In the second part of the model development, the directional analysis of these factors will be discussed

2. Model development

2.1. Deterministic model

Let us assume the following variables for model development.

R_{pt} = Revenue generated by exploitation
R_{pr} = Revenue generated by exploration
R_t = Total revenue generated by firm
P_t = Price of the end product
Q_t = Quantity of the end product
K_t = Capital investment by the firm
r_t = Cost of capital borne by the firm
AC = Absorptive capacity of firm
θ = Organizational memory
Є = Price elasticity of demand
N = Position of firm in business network
t = Time of shifting from exploration to exploitation and vice versa
a_0, a_1, a_2, a_3, a_4, a_5, b_0, b_1, b_2, b_3, b_4 = Design variables

In this section, we will be discussing the profit-based model for absorptive capacity. Zahra and George (2002) give an indication about the organizational profit as a proxy measure for absorptive capacity modelling. The revenue structures for knowledge exploration and exploitation will be formulated first. Then on the basis of these equations, further model will be developed.

For exploration, the revenue structure is going to be U-shaped. According to Rothaermel and Alexandre (2009), assortment of technology and firm productivity are associated in terms of an inverted U-shaped curve. They considered the technology to be exploited throughout the entire period. They undermined the newly fangled technologies. Focusing more on those would have shifted their focus from exploitation to exploration, as well as the technology-firm performance association curve would have been U-shaped. The validation of this statement can be found in the works of Pindyck (1978), who has identified the same in domain of non-renewable resource economics.

$$R_{pr} = a_1 \left(t - a_2\right)^2 - P_t Q_t \tag{1}$$

For exploitation, the revenue structure is going to be linear. Lee, Liang and Liu (2010) derived the liner association between absorptive capacity, R&D investment and sales volume. The associations were significant in all the stages of the development. On the similar note, revenue structure has considered to be linear.

$$R_{pt} = P_t Q_t + a_3 t \tag{2}$$

Now the combined revenue structure of the firm will be given by:

$$R_t = a_4 R_{pr} + a_5 R_{pt} \tag{3}$$

Investment in innovation is dependent on income elasticity of consumers, network position of the firm and revenue growth of the firm (Lane, Koko and Pathak 2006). It can be shown in following manner:

$$K_t = b_1 R_t + b_2 C + b_3 N \tag{4}$$

Hence the profit generated by firm is given by:

$$\pi_t = R_t - r_t K_t \tag{5}$$

Combining Eq. (4) and (5), we get:

$$\pi_t = R_t\ (1 - r_t\ b_1) - r_t\ (b_2\ C + b_3\ N) \quad (6)$$

It is a continuous function with respect to time. Hence maximization of this profit will determine the time span or temporal cycle of shifting knowledge exploration and knowledge exploitation. This limiting condition can be achieved by determining first order differentiation of Eq. (6).

$$\frac{d\pi_t}{dt} = \frac{dR_t}{dt}\ (1 - r_t\ b_1) = 0$$

$$t = 2\,a_2 - (a_3\ a_5)\ /\ (a_1\ a_4) \quad (7)$$

We have already discussed that organizational memory holds an exponential relationship with graduating time. Michael and Palandjian (2004) describe this seeing that expected alternative of allocation for continued existence is distributed exponentially. The memory-less traits die out with graduation of time and the on the contrary the traits with memory experience a gradually rising exponential distribution.

$$\theta = b_4 \exp(b_5\ t) \quad (8)$$

Combining Eq. (7) and (8) we get:

$$\theta = b_4 \exp\left(2\,a_2\ b_5 - (a_3\ a_5\ b_5)\ /\ (a_1\ a_4)\right) \quad (9)$$

We have also discussed about spiral relationship that holds between absorptive capacity and organizational memory. Carayannis (1999) discusses about the "Organizational Cognition Spiral". It considers continuous revaluation of a particular state of affair from new perspectives. It is the foundation of the spiral model.

$$AC = a_0 \exp(b_0\ \theta) \quad (10)$$

Combining Eq. (9) and (10) we get:

$$\log(AC\ /\ a_0) = (b_0\ b_4) \exp\left(2\,a_2\ b_5 - (a_3\ a_5\ b_5)\ /\ (a_1\ a_4)\right) \quad (11)$$

In view of the relation depicted in Eq. (11), constants gain an importance in terms of their interpretation. These constants can be interpreted in the following manner, in line with literature:

a_0 = Inherent absorptive capacity (Cockburn and Henderson 1998)
a_1 = Time elasticity of revenue for knowledge exploration (Hauge 2006)
a_2 = Inherent time required to build up exploration capability (Keil 2004)
a_3 = Time elasticity of revenue for knowledge exploitation (Nash 1991)
a_4 = Proportion of revenue earned by knowledge exploration (Wils 2001)
a_5 = Proportion of revenue earned by knowledge exploitation (Brennan and Buchanan 1977)
b_0 = Absorptive capacity impact factor
b_4 = Inherent organizational memory (Walsh and Ungson 1991)
b_5 = Organizational memory impact factor

Eq. (11) shows a set of direct and inverse relationship between absorptive capacity and the aforementioned deterministic factors (not mentioning as constants or variables). Changes in one or some will change the value of absorptive capacity in accordance with the relationship depicted in Eq. (11). Those are recorded in Table 1.

Table 1 - Relationship between Deterministic Factors and Absorptive capacity

Deterministic Factor	Relationship with Absorptive Capacity
a_0 = Inherent absorptive capacity	**Direct**
a_1 = Time elasticity of revenue for knowledge exploration	**Direct**
a_2 = Inherent time required to build up exploration capability	**Direct**
a_3 = Time elasticity of revenue for knowledge exploitation	**Inverse**
a_4 = Proportion or revenue earned in terms of knowledge exploration	**Direct**
a_5 = Proportion or revenue earned in terms of knowledge exploitation	**Inverse**
b_0 = Absorptive capacity impact factor	**Direct**
b_4 = Inherent organizational memory	**Direct**

b_5 = Organizational memory impact factor	**Inverse**

Source: Author's own calculations

This model provides with insights about the drivers of organizational productivity linked with absorptive capacity. But specifically this model doesn't provide any insight about the combinational aspects of knowledge exploitation and exploration. This also doesn't provide any insight about marginal temporal productivity of firm and its relation with absorptive capacity. This relationship can be depicted in directional format in the next model.

2.2. Directional model

Let us use the previous notations for this model as well. For designing this model, it is imperative to initiate from Eq. (3) seeing that it symbolizes the complete revenue structure incorporating exploration and exploitation perspectives.

For designing this model, it is needed to modify Eq. (5). A new variable is needed to be introduced in terms of cost component. This component is having certain characteristics. For the exploration and exploitation phase, this component will be time independent (Pindyck 1993). While considering the entire cycle of exploration and exploitation, time dependence of this component will come into picture. In view of this phenomenon, three profit functions emerge considering three scenarios mentioned, along with the cost components C_1, C_2 and C_3. In this case C_3 is only time variant.

$$\pi_1 = R_{pr} - r_t K_t - C_1 \tag{12}$$

$$\pi_2 = R_{pt} - r_t K_t - C_2 \tag{13}$$

$$\pi_3 = R_t - r_t K_t - C_3 \tag{14}$$

Where, π_1, π_2 and π_3 are profit functions for exploration, exploitation and entire cycle respectively.

The equilibrium point of these three equations will be achieved by fully differentiating them with respect to time. Solution of them on an individual basis is not a viable method. Hence a simultaneous equation method has been adopted. A matrix is formed by these equations in the form of AX =Z. The simultaneous differential equation matrix is shown in Eq. (15).

$$\begin{pmatrix} 0 & \frac{\delta\pi_1}{\delta R_{pr}} & \frac{\delta\pi_1}{\delta K_t} \\ \frac{\delta\pi_2}{\delta R_{pt}} & 0 & \frac{\delta\pi_2}{\delta K_t} \\ \frac{\delta\pi_3}{\delta R_{pt}} & \frac{\delta\pi_3}{\delta R_{pr}} & \frac{\delta\pi_3}{\delta K_t} \end{pmatrix} \begin{pmatrix} \frac{dR_{pt}}{dt} \\ \frac{dR_{pr}}{dt} \\ \frac{dK_t}{dt} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ C_3 \end{pmatrix} \tag{15}$$

Marginal productivity in terms of revenue growth can be expressed via the Eq. (15). The signs of $\frac{dR_{pt}}{dt}$, $\frac{dR_{pr}}{dt}$ and $\frac{dK_t}{dt}$ will derive the directional relationships between marginal productivity and absorptive capacity. Signs of these terms can be derived by solving the matrix in Eq. (15).

$$\frac{dR_{pt}}{dt} = (1/|\pi|) \cdot \left(C_3 \frac{\delta\pi_3}{\delta R_{pt}}\right) / \left(\frac{\delta\pi_1}{\delta R_{pr}} \cdot \frac{\delta\pi_2}{\delta K_t}\right) \tag{16}$$

$$\frac{dR_{pr}}{dt} = (1/|\pi|) \cdot \left(C_3 \frac{\delta\pi_3}{\delta R_{pr}}\right) / \left(\frac{\delta\pi_2}{\delta R_{pt}} \cdot \frac{\delta\pi_1}{\delta K_t}\right) \tag{17}$$

$$\frac{dK_t}{dt} = (1/|\pi|) \cdot \left(-C_3 \frac{\delta\pi_3}{\delta K_t}\right) / \left(\frac{\delta\pi_2}{\delta R_{pt}} \cdot \frac{\delta\pi_1}{\delta R_{pr}}\right) \tag{18}$$

As this solution is locally stable, $|\pi|$ will be negative. From Eq. (8) and (10), we get that $\frac{d(\mathrm{AC})}{dt} > 0$. Assuming $\frac{d(\mathrm{AC})}{dt} = Y$, aforementioned three equations can be rewritten.

$$\frac{d\mathrm{R}_{pt}}{d(AC)} = (1 \ / Y|\pi|) \ . \ (\mathrm{C}_3 \ \frac{\delta\pi_3}{\delta\mathrm{R}_{pt}}) \ / \ (\frac{\delta\pi_1}{\delta\mathrm{R}_{pr}} \ . \ \frac{\delta\pi_2}{\delta\mathrm{K}_t}) \tag{19}$$

$$\frac{d\mathrm{R}_{pr}}{d(AC)} = (1 \ / Y|\pi|) \ . \ (\mathrm{C}_3 \ \frac{\delta\pi_3}{\delta\mathrm{R}_{pr}}) \ / \ (\frac{\delta\pi_2}{\delta\mathrm{R}_{pt}} \ . \ \frac{\delta\pi_1}{\delta\mathrm{K}_t}) \tag{20}$$

$$\frac{d\mathrm{K}_t}{d(AC)} = (1 \ / Y|\pi|) \ . \ (-\mathrm{C}_3 \ \frac{\delta\pi_3}{\delta\mathrm{K}_t}) \ / \ (\frac{\delta\pi_2}{\delta\mathrm{R}_{pt}} \ . \ \frac{\delta\pi_1}{\delta\mathrm{R}_{pr}}) \tag{21}$$

Now looking at Eq. (19), (20) and (21), the signs of $\frac{d\mathrm{R}_{pt}}{d(AC)}$, $\frac{d\mathrm{R}_{pr}}{d(AC)}$ and $\frac{d\mathrm{K}_t}{d(AC)}$ can be derived.

a. Sign of $\frac{d\mathrm{R}_{pt}}{d(AC)}$: There are three components in Eq. (19). Firstly, $\frac{\delta\pi_3}{\delta\mathrm{R}_{pt}} > 0$ under any given circumstances. For the case of knowledge exploitation, the linear revenue structure will assure $\frac{\delta\pi_2}{\delta\mathrm{K}_t} > 0$. Therefore the U-shaped nature of knowledge exploration will determine the sign of $\frac{\delta\pi_1}{\delta\mathrm{R}_{pr}}$, therefore, the sign of $\frac{d\mathrm{R}_{pt}}{d(AC)}$.

When $\frac{\delta\pi_1}{\delta\mathrm{R}_{pr}} > 0$, $\frac{d\mathrm{R}_{pt}}{d(AC)} < 0$

When $\frac{\delta\pi_1}{\delta\mathrm{R}_{pr}} < 0$, $\frac{d\mathrm{R}_{pt}}{d(AC)} > 0$

b. Sign of $\frac{d\mathrm{R}_{pr}}{d(AC)}$: There are three components in Eq. (20). Firstly, $\frac{\delta\pi_1}{\delta\mathrm{K}_t} > 0$ and $\frac{\delta\pi_2}{\delta\mathrm{R}_{pt}} > 0$ under any given circumstances. Therefore the U-shaped nature of knowledge exploration will determine the sign of $\frac{\delta\pi_3}{\delta\mathrm{R}_{pr}}$, therefore, the sign of $\frac{d\mathrm{R}_{pr}}{d(AC)}$.

When $\frac{\delta\pi_3}{\delta\mathrm{R}_{pr}} > 0$, $\frac{d\mathrm{R}_{pr}}{d(AC)} < 0$

When $\frac{\delta\pi_3}{\delta\mathrm{R}_{pr}} < 0$, $\frac{d\mathrm{R}_{pr}}{d(AC)} > 0$

c. Sign of $\frac{d\mathrm{K_t}}{d(AC)}$: There are three components in Eq. (21). Firstly, $\frac{\delta\pi_3}{\delta\mathrm{K_t}} > 0$ and $\frac{\delta\pi_2}{\delta\mathrm{R_{pt}}} > 0$ under any given circumstances. Therefore the U-shaped nature of knowledge exploration will determine the sign of $\frac{\delta\pi_1}{\delta\mathrm{R_{pr}}}$, therefore, the sign of $\frac{d\mathrm{K_t}}{d(AC)}$.

When $\frac{\delta\pi_1}{\delta\mathrm{R_{pr}}} > 0$, $\frac{d\mathrm{K_t}}{d(AC)} > 0$

When $\frac{\delta\pi_1}{\delta\mathrm{R_{pr}}} < 0$, $\frac{d\mathrm{K_t}}{d(AC)} < 0$

Hence combination of the two models provides a deterministic and directional approach towards the profitability of organization, driven by its absorptive capacity. First half of the model provides the factor-based analysis of absorptive capacity, whereas the second half of the model provides a directional analysis of those factors.

3. Findings

Two approaches towards modelling the organizational absorptive capacity provide with a significant sum of insights. The findings will be discussed in accordance with the models.

Looking at the deterministic part of the model, a lot of subject matters gain significance. First, the inherent organizational absorptive capacity is directly proportional with the existential organizational absorptive capacity. It signifies that if any organization has a certain amount of latent absorptive capacity, then it helps the organization to boost up its existential form of absorptive capacity. It helps in building up the spiral knowledge formation in a much faster way. Second, whenever the firm goes for knowledge exploration, the revenue moves proportionately with the time for exploration along the U-shaped curve. The time elasticity of revenue is directly proportional to organizational absorptive capacity. Hence the revenue structure will follow the changes proportionately. Third, it is a critical task for an organization to build up its absorptive capacity. It is carried out with an ample amount of time. In the due course of the time taken for exploration, organization is enriched with higher amount of capabilities, which adds to the absorptive capacity of the organization. In this regard, the absorptive capacity impact factor symbolizes the impact of absorptive capacity on organizational memory. The direct relationship signifies that the rise in absorptive capacity will have a positive impact on organizational memory. Fourth, contrary to knowledge exploration, in the course of knowledge exploitation, organizational absorptive capacity is utilized, not enhanced. Hence the steady linear flow of revenue stream restricts the organization to look beyond obvious and therefore, the organizational absorptive capacity remains constant or goes down. Fifth, in revenue terms, knowledge exploration and exploitation brings forth two divergent dimensions. Enhanced knowledge base allows the organization to generate superior revenue stream, whereas exploiting the existing knowledge only will in turn make it obsolete and trim down the revenue stream. Hence, relationship of revenue stream generated with absorptive capacity is direct in case of knowledge exploration and inverse for knowledge exploitation. Six, while talking about the impact of organizational memory on absorptive capacity, the results are quite contradicting. At the very beginning stage of an organization, its inherent memory assists in building up its absorptive capacity. But with the graduation of time, when the memory grows bigger and become mature, it is tough to change it. At that point of time, the organizational absorptive capacity declines. At the very beginning stage organization tries to gather knowledge by means of exploration. That results in high absorptive capacity. But as the time graduates, organization tries to exploit the existing knowledge, which results in decline of absorptive capacity.

Subsequently if directional part of the model is looked at, the finding reinstates the findings of the deterministic part of the model. First, when everything goes right, organization is not concerned about investigating the rationale behind that. The escalating profit margin with the same revenue stream makes organization not to break the status quo and exploit the existing knowledge only. As a result of this, organizational absorptive capacity goes down. It is revisited when the same revenue stream generates less amount of profit. When the organization observes that there are possibilities of loopholes in the process or obsolescence of the organizational knowledge, only then they go for exploring fresh and innovative knowledge based processes. This leads to augmentation of organizational absorptive capacity. Similar results emerge when organization goes

through a cycle of exploration and exploitation. The cyclic nature of profit decides the extent of the absorptive capacity. Second, the productivity of the capital employed also plays an imperative role in deciding the extent of organizational absorptive capacity. During the knowledge exploration phase, when the revenue stream is able to generate more profit, then it can be stated that the employed capital is productive enough to build up a productive knowledge base for organization, and in turn augmenting organizational absorptive capacity. On the contrary, when the same revenue stream is not able to generate the expected amount of profit, the productivity of the capital can be duly questioned. It is knowledge base and organizational productivity that generates profit. This process is catalyzed by the productivity of the employed capital.

Conclusion

So far the model for absorptive capacity and organizational productivity is developed. Since this kind of model development is new and innovative in the existing body of literature, it has its own implication over existing empirical and qualitative researches on this area. In terms of quantitative conceptual model development, it is reliable and valid, as it incorporates the predefined parameters which were well discussed by previous researchers. However, this model has some limitations, which in turn poses the scope for future research:

1. Probabilistic modelling of knowledge exploration,
2. Incorporating time value of money by enabling inflation factor,
3. Considering discrete time analysis, and
4. Considering real life organizational data with a view to testing the model.

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