Received 28 June 2017
Revised 17 April 2018
Accepted 23 April 2018

The curve of knowledge transfer: a theoretical model

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Abstract

Purpose – The knowledge transfer plays a key role in the firm's capability to develop and to maintain a strategic competitive advantage over time. The capability of the firm to develop an efficient and effective process of knowledge transfer increases the internal skills and then the capability to compete in the business with positive effects on the performance. In order to maximize the effectiveness and efficiency of the knowledge transfer process it must be consider two main variables: the amount of knowledge to be transferred and the speed of the process. In this contest, the purpose of this paper is to developed a theoretical model, defined the knowledge transfer curve, able to evaluate the knowledge transfer process on the basis of its speed.

Design/methodology/approach – The curve of the knowledge transfer is based on the methodology of the learning curve. The curve of the knowledge transfer process can be evaluated on the basis of two main variables: the first is the content of knowledge to be transferred. It refers to the quality and quantity of the information to be transferred within the firm; and the second is the speed of the knowledge transfer process. It refers to the time in which the knowledge transfer can be realized. The function of the knowledge transfer is defined using ordinary differential equation.

Findings – There is an inverse relationship between time t and the variation rate r. The higher the variable r, the faster the knowledge transfer toward the level K. Therefore, the variable r measures the efficiency and effectiveness of the knowledge transfer process. On the basis of these considerations, manager must evaluate their policies about the knowledge transfer on the basis of their effects on the variable r: only the policy that increases its value can be considered effective for the knowledge transfer process.

Originality/value – The originality resides in the development of a theoretical model that is able to capture and measure the effectiveness and efficiency of the knowledge transfer. It is possible to define a curve of knowledge transfer on the basis of these two variables: content of the knowledge to be transferred and the time of the transfer process, by using an ordinary differential equation.

Keywords Knowledge transfer

Paper type Research paper

1. Introduction

One of the most relevant sources of a firm's competitive advantage is knowledge (Chen *et al.*, 2006; Grant, 1996; Kang and Hau, 2014). It increases the skills of the firm's internal structure and its capability to compete in the business over time by developing and maintaining a strategic competitive resource.

In an increasingly dynamic context, firms need to seize signals from the market to remain competitive (Burgelman, 1991; Covin and Slevin, 1989; Floyd and Lane, 2000; De Clerq *et al.*, 2013).

Therefore, different layers of the market—on the one hand, the sectors that have direct transactions with the firm's organization, such as competitors, suppliers and customers; on the other hand, the layer that represents general relations affecting firms indirectly, such as legal, social and demographic sectors (Xu *et al.*, 2003)—define the external knowledge (Chen *et al.*, 2006). Understanding of the reference market and strong ties with it make knowledge exchanges easy by decreasing uncertainty during decision-making processes (Hansen, 1999; Hansen *et al.*, 2005; Monteiro *et al.*, 2008; Szulanski *et al.*, 2004; Tsai and Ghoshal, 1998; De Clerq *et al.*, 2013).

Business Process Management Journal
Vol. 25 No. 1, 2019
pp. 10-26

1463-7154
DOI 10.1108/BPMJ-06-2017-0161

The firm capability to create value depends also on the integration of external and internal knowledge (Wadhwa and Kotha, 2006; Grant, 1996). Therefore, knowledge can be created and developed within the firm through improvisation (Krylova *et al.*, 2015), innovation (Macdonald, 1995) and experience (Argote and Miron-Spektor, 2011). Internal knowledge promotes firm's survival and florid prospects in the future (Argote and Ingram, 2000; Szulanski *et al.*, 2004; Kang and Hau, 2014). It is widely recognized that the information available both inside and outside the firm is critical for the manager to understand different areas of action as well as for organizing internal structure to operate in those areas (Rulke *et al.*, 2000). Once it is acquired, it is crucial that knowledge is transferred to others within the firm; only in this way it can create value for the firm. Therefore, knowledge cannot remain available to only one individual, but it must be spread within the firm by strengthening common values and behaviors. A firm's capability to transfer knowledge is correlated with its performance (Argote, 2015; Krylova *et al.*, 2015; Argote and Ingram, 2000; Darr *et al.*, 1995; Epple *et al.*, 1996; Tukel *et al.*, 2008).

If knowledge plays a key role in the firm's capability to generate value over time, therefore one of the most relevant problems is related to the process by which the knowledge can be transferred to each level of the organization.

Generally, knowledge transfer can be defined as a process of exchange of knowledge between different parties in which the acquired information can be used in several ways (Kumar and Ganesh, 2009, p. 163).

It is relevant to note that knowledge transfer must be considered as a process and not as a simple act (Szulanski, 2000). This approach facilitates an accurate comprehension of different learning activities within the firm (Argote, 2015). All the factors involved in the definition of knowledge transfer are predictors of this process (Argote and Miron- Spektor, 2011).

Specifically, the transfer knowledge process refers to the quality and quantity of information to be transferred; they define the content of knowledge. Therefore, it refers to the nature of knowledge and the ways of communication through which it occurs. The organizational structure of the firm plays a key role for the effectiveness and efficiency of the knowledge transfer process (McKenna, 1995). Generally, this process requires hard and soft skills capable to allow a high level of communication at each level of the organization. Therefore, the transfer process generates an incremental flow of information that increases the individuals' capabilities to do; thus, the characteristics of human capital such as the absorptive capacity (Cohen and Levinthal, 1990; Liao *et al.*, 2003), skills and expertise (Cross and Sproull, 2004) are the most important variable that must be handled. It is relevant to note that knowledge transfer can go beyond the individual level to higher levels, such as teams, groups, divisions or departments, generating common values and goals in order to enhance the entrepreneurial dimension.

In this context, we develop a theoretical model called knowledge transfer curve (KTC) that it can be used to evaluate the process of the knowledge transfer on the basis of its speed rather than the content of knowledge to be transferred.

The KTC can be defined on the basis of two main variables: the first variable is the content of knowledge to be transferred. It refers to the complexity, the quality and quantity of the information to be transferred within the firm. The second variable is the speed of the knowledge transfer process. It refers to the period-time in which the knowledge transfer can be realized.

The KTC is based on the methodology of the learning curve. The capability of the learning curve to capture the transfer of knowledge is well-known in the literature (Clark, 1991; Epple *et al.*, 1991; Mazur and Hastie, 1978; Zangwill and Kantor, 1998; Levin, 2000; Tukel *et al.*, 2008).

The KTC can be used to evaluate the efficiency and effectiveness of the knowledge transfer process at each level of the firm's structure. The baseline assumption is that

the higher the efficiency and effectiveness of the knowledge transfer process at each level of the organization, the higher the firm's performance. The higher the efficiency and effectiveness of the transfer knowledge process, the greater the skills at each level of the organization, the higher the capability to align the success factors of the business to the strategic resources of the firm, and thus the higher the firm's performance over time (Argote, 2015; Tukel *et al.*, 2008; Levin, 2000).

The paper is structured in four sections: Section 2 defines knowledge transfer in the literature; Section 3 defines the theoretical model and it draws the KTC; Section 4 shows the relevance of speed in the knowledge transfer process; and Section 5 contains brief conclusions and the main limitations and future research lines of this work. The paper as it was thought and developed responds to the special issue about evaluation methods for the assessment of knowledge transfer.

2. Knowledge transfer: literature review

By defining the transfer of knowledge as a process rather than a simple act, one of the most relevant problems is related to the definition and control of the main variables able to give effectiveness and efficiency to the entire process (Liyanage *et al.*, 2009).

The literature identifies two levels to describe how people can learn: first, lower-level learning which is focused on the repetition of past behaviors and is based on the routine activities formed in the short term; and second, higher-level learning which is focused on the development of new insights with effects in the long term, on the basis of the cognitive process that skilled personnel needs (Fiol and Lyles, 1985). These two different forms are classified in different ways in the literature: "surface" and "deep" learning, "adaptive" and "generative" learning (Gibb, 1995; Senge, 1990), "incremental" and "transformational" learning, "instrumental" and "transformative" learning (Mezirow, 1990). Higher-lever learning is at the core of the creation of knowledge. It enhances the performance of the firm by facilitating the acquisition and transmission of knowledge. The quality of intellectual capital is the key of a successful process (Cuozzo *et al.*, 2017; Trequattrini *et al.*, 2016).

The transfer of knowledge becomes necessary because people develop the ability to do things differently (Rae, 2005a, b) through a cognitive process that drives individuals to a full awareness of their learning. Usually the transfer can be realized by formal written information (such as books, hardcopy reading materials) or online materials that refer to technology intervention (Tangaraja *et al.*, 2016). The way in which the knowledge is transferred is not important, both modes of codification are relevant because they allow the conveyance of knowledge.

Moreover, the transfer of knowledge is essential, since the inability to do so becomes the reason why most firms fail (Argyris and Schon, 1996; Senge, 1990). The possession of knowledge alone is not able to guide the firm toward bright prospects of success, but it provides the firm with the capability and will to act (Liao *et al.*, 2003).

Specifically, the firm must identify the signals that come from the market and then it must translate this information to transmit it to the organization. The greater the knowledge collected by the firm in a given period of time, the greater its capability to transfer knowledge and to be more proactive, since the firm is able to take advantage from the environment by exploiting opportunities. Therefore, the firm can avoid obstacles and seize opportunities if it manages to understand and transmit the information within its organizational structure. The contribution of new knowledge inside the firm, coming from the outside market, allows it to achieve better performance, because the firm is perfectly aligned with the interests and demands of the surrounding environment. The acquisition of external knowledge and the transmission of knowledge intrafirm are two main components of the absorptive capacity. It "refers not only to the acquisition or assimilation of information by an organization but also the organization's ability to

exploit it. Therefore, an organization's absorptive capacity does not simply depend on he organization's direct interface with the external environment. It depends also on the transfers of knowledge across and within subunits" (Cohen and Levinthal, 1990). Thus, two types of relationships are created: a relationship between the firm and the external environment, the knowledge is required to understand the needs of the market, and an internal one between the various subunits of the corporate organization to align the internal structure with the required needs of the surrounding and external environment.

We focus our attention on the transfer of knowledge, and therefore, in general, once knowledge is acquired, it is translated and transmitted to the various individuals.

Indeed, knowledge transfer is a process in which the knowledge is transmitted from one person to another directly or indirectly. Thus, there is a dyadic relationship between the source (the owner of knowledge who sends it) and the recipient (the receiver of knowledge that is transmitted). In this interaction, a recipient's perception of a source's expertise plays a key role: if the recipient respects and believes in the source's competence, the former will accept the knowledge and allow the knowledge transfer (Kang and Hau, 2014). However, if the receiver does not trust and believe in the capabilities of the sender, the transmission of the knowledge will not happen. Trust between all individuals involved in the knowledge transfer process facilitates the conveyance of the flow of information. The trust that connects the sender of the knowledge and his/her recipient helps the knowledge transfer to be achieved, but this is also influenced by strong ties. Specifically, these strong ties are preferred because they outline the intensity of the relationship between the source and the receiver, increasing trust and favoring the transfer (Hansen, 1999; Ingram and Roberts, 2000; Kang and Hau, 2014; Ko *et al.*, 2005; Reagans and McEvily, 2003; Tsai, 2002; Uzzi and Lancaster, 2003). They enable the source to explain and transmit the information clearly and in a personalized way, so that the recipient can understand easily (Kang and Hau, 2014). Maintaining strong ties, rather than weak links, strengthens the sharing of common interests and collective goals in order to achieve the common entrepreneurial mission.

The nature of this relationship is based on direct or indirect contact, or differentiated in formal or informal (Tangaraja *et al.*, 2016; Sammarra and Biggiero, 2008), or it is also called relational and non-relational learning channel (Rulke *et al.*, 2000). Direct contact occurs when the individuals involved in the process of the transmission of the knowledge use face to face communication, such as meetings, training activities or when the transfer of knowledge simply occurs through observation. The second one refers to the flow of information that arises through technological means, such as e-mails, phone messages or the use of social networks.

Several empirical studies and research works (Rulke *et al.*, 2000; Galaskiewicz and Wasserman, 1989; Ghoshal and Bartlett, 1988) establish and express a preference among the different learning channels. In particular, some studies highlight the contribution of the relational and direct contact (Darr *et al.*, 1995; Baum and Ingram, 1998; Galaskiewicz and Wasserman, 1989; Huberman, 1983; Liebenz, 1982; Rulke *et al.*, 2000); on the opposite side, other studies (Burke and Bold, 1986) show the importance of indirect and non-relational learning channels to acquire knowledge. According to several authors, all interactions increase the transfer of knowledge (Tangaraja *et al.*, 2016; Fang *et al.*, 2013; Sammarra and Biggiero, 2008; Chen *et al.*, 2006). Therefore, the learning channels are relevant means of transmitting knowledge because they depend on the interactions that connect individuals within the firm. The different interactions between the subjects involved in the process of knowledge transfer tend to have a common entrepreneurial mission that strengthens conscience and membership in the same company.

Therefore, the firm needs managerial capability that inspires higher values and increase awareness of common interest among the individuals of the organization and leads them to

achieve their collective goals. It represents the style of leadership that can be defined as transformational leadership (Garcia-Morales *et al.*, 2012). This ability refers to the possession of skills and competence of communication and, specifically, it relates to the sender of the knowledge. Therefore, the sender of the knowledge, who has good communication skills acquired through experience, is able to explain and transmit the flow of information in a clear and a personalized way, so that the knowledge can be understood easily by the recipient.

Knowledge transfer does not only depend on communication competency but also on the organizational capacity and the decision-making process (Lombardi *et al.*, 2014). It refers to the ability of the manager to design efficient knowledge governance mechanisms that enhance the quality and the quantity of the transferred knowledge. It refers to the hard components of the organizational structure that define its "mechanical operating." Specifically, it defines the work model of a company which comprises the levels of hierarchy and the mechanism of relationships among all the parts of the organizational structure, both formal and informal. In the traditional structure, the decisions are taken by the top levels and they are communicated to the bottom levels. It describes the formal mechanism of reporting and it is defined as a vertical structure. The communication process usually starts from top levels and it finishes to bottom levels, following an up-down direction. When the vertical structure becomes high, full of many hierarchical levels, it takes a lot of time to acquire and transfer the knowledge from the higher to lower levels because it must overcome a large number of stages. Therefore, the greater the number of hierarchical levels, the greater the time of the transmission of knowledge in the process. Thus, the number of levels of the organizational structure affects knowledge transfer by slowing the speed of the transfer process. This speed represents the time in which the knowledge transfer can be realized. Generally, the lower the time that the process requires to be realized, the greater the speed of the transfer process of knowledge is. Therefore, the speed becomes a very important variable to define and describe the conveyance of the flow of information.

In particular, to reduce the transmission time, the knowledge must be clear in the expression, accurate and simple in the transmission. However, in the transfer process of knowledge, a certain level of ambiguity cannot be deleted (Szulanski, 1996). Regarding the vagueness of the transmission and of knowledge, this is the result of actions, behaviors, culture and traditions that are not available and accessible and that are not transferable. It is defined as tacit knowledge that derives from non-verbalization and non-codification of the transfer process (Inpen and Pien, 2006).

In an effort to avoid ambiguity and changes, the firm creates standard procedures that control the managerial and operating activities of the firm. The set of documented procedures and rules defines the formalization level. It is based on policies, procedures and plans, rather than informal processes (Dyer and Song, 1998; De Clerq *et al.*, 2013). On the positive side, high formalization leads to the increase in efficiency and predictability (Weber, 1924), offering guidelines on how to transfer knowledge into the firm among different individuals in diverse areas. It also restricts uncertainty through clarity about rules and, additionally, responsibilities decrease the managers' role conflict (Michaels *et al.*, 1988). It limits managerial behavior because it imposes the priority of business interest on individual desires and it eliminates divergent interpretations. Still, formalized systems increase commitment and job satisfaction (Snizek and Bullard, 1983), favoring collaboration within the firm. On the negative side, bureaucracy limits the scope of the decisions because it defines and governs individual behaviors (Burns and Stalker, 1966). In this way, formal procedures and rules reduce the depths of analysis, limiting the managers' capability of accessing the knowledge accumulated by other areas of the firm. Finally, the creativity and innovation of the individuals are repressed when

high formalization can "ritualize" the transmission of the knowledge (Dougherty and Heller, 1994; Hirst *et al.*, 2011; Miller, 1987). At low levels of formalization, the managers enjoy the flexibility and freedom to combine others' knowledge with their own (De Clerq *et al.*, 2013) favoring the acquisition and sharing of knowledge. Therefore, overall, the knowledge transfer is made difficult by bureaucracy when the formalized structure is too rigid and complicated. Thus, the greater the level of bureaucracy, the lower the level of learning becomes. It is necessary to have an array of minimal procedures and rules that create order and clarity, but at the same time to give managers the freedom to combine and transfer knowledge.

In conclusion, knowledge transfer is a complex process that is based on the quality and quantity of the knowledge and on the time the process requires to be realized. The first variable to be concerned about is the complexity of the relationship between the individuals involved in the process of the transfer of the acquired knowledge. The second one refers to the speed of the transmission of the knowledge with particular reference to all the procedures and rules that compose the bureaucracy of the firm.

3. The knowledge transfer curve

The curve of the knowledge transfer process can be evaluated on the basis of two main variables:

(1) First is the content of the knowledge to be transferred. It refers to the complexity, the quality and quantity of the information to be transferred within the firm.

(2) Second is the speed of the knowledge transfer process. It refers to the time in which the knowledge transfer can be realized.

In this context, we focused our attention on the speed of the process rather than the content of the knowledge to be transferred. The paradigm on which the theoretical model defining the KTC is built is the following: for a defined level of knowledge to be transferred, the higher the speed of the process is, the higher the efficiency and effectiveness of the entire knowledge transfer process will be. It can be formalized as following:

$$W_{KT} = f(I_{KT}; S_{KT})$$

where W_{KT}: it denotes the quality of the knowledge transfer process in terms of its effectiveness and efficiency; I_{KT}: it denotes the complexity, quality and quantity of the information to be transferred; it defines the content of the knowledge; S_{KT}: it denotes the speed of the knowledge transfer process; it is defined on the basis of the time that process requires to be realized.

We can define the KTC on the basis of these two variables: the content of knowledge to be transferred and the time of the transfer process as shown in Figure 1.

The level K defines the content of knowledge to be transferred and, thus, it refers to the complexity, quality and quantity of information to be transferred within the firm. Therefore, it refers to the intrinsic characteristics of the information flow that must be acquired or created, transferred and absorbed. In this context, it is assumed as known. Our aim in this paper is to measure the speed of the process rather than its content.

Based on the time variable, t, the slope of the curve measures the speed of the transfer knowledge process. Formally, the higher the slope, the faster the curve reaches the defined level of knowledge to be transferred (K).

It is worth noticing the assumption that the curve does not start from 0 as shown in Figure 1. It is reasonable to accept that in any time there is always a small part of knowledge transferred without any process and policy.

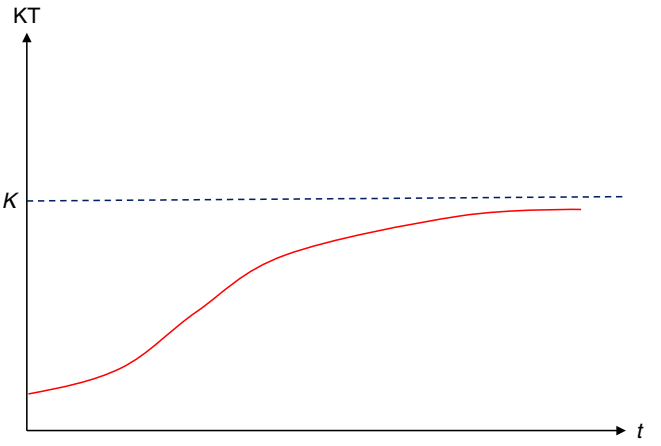

Figure 1.
The knowledge transfer function

Our aim is to define this curve and to measure its slope at any time. Therefore, it is necessary to define the function of the knowledge transfer. To this aim, it is possible to use the following ordinary differential equation that leads to this logistic function:

$$\dot{x}(t) = rx(t)\left(1 - \frac{x(t)}{K}\right) \tag{1}$$

where $x(t)$ is the function of the knowledge transfer (K), where $x(t) \neq 0$ in any given case; $\dot{x}(t)$ the first derivative in relation to the time t; K the content of knowledge to be transferred and r the relative variation rate that is equal to:

$$r = \frac{\dot{x}(t)}{x(t)}. \tag{2}$$

It is relevant to pinpoint that whenever the level of knowledge transfer is much lower than the level K defined, the ratio $(x(t)/K)$ becomes much lower until it gets:

$$\dot{x}(t) \approx rx(t) \tag{3}$$

and, thus, $x(t)$ increases in an approximately exponential way.

In order to solve Equation (1), it can be useful to introduce the following function (Sydsaeter and Hammond, 2012):

$$u(t) = -1 + \frac{K}{x(t)}. \tag{4}$$

Therefore, the first derivative is equal to:

$$\dot{u}(t) = -\frac{K\dot{x}(t)}{[x(t)]^2}$$

and by considering Equation (1), it gets:

$$\dot{u}(t) = -\frac{K\left[rx(t)\left(1-\frac{x(t)}{K}\right)\right]}{[x(t)]^2}$$

and thus:

$$\dot{u}(t) = -\frac{K\left[rx(t)-\frac{r(x(t))^2}{K}\right]}{[x(t)]^2} = -\frac{Krx(t)-K\frac{r(x(t))^2}{K}}{[x(t)]^2} = -\frac{Krx(t)-r(x(t))^2}{[x(t)]^2}$$
$$= \frac{-rx(t)[K+x(t)]}{[x(t)]^2} = \frac{-r[K+x(t)]}{x(t)} = \frac{-rK}{x(t)}+\frac{rx(t)}{x(t)} = \frac{-rK}{x(t)}+r$$
$$= -r\left(\frac{K}{x(t)}-1\right) = -r\left(-1+\frac{K}{x(t)}\right)$$

and then by considering Equation (4), it gets:

$$\dot{u}(t) = -ru(t). \tag{5}$$

In order to solve Equation (5), it is essential to consider the ordinary differential equation:

$$\dot{u}(t) = ru(t). \tag{6}$$

Assume that the relative variation (r) is equal to 1. In this case, it gets:

$$\dot{u}(t) = u(t). \tag{7}$$

By considering that:

$$u(t) = e^t;\ \dot{u}(t) = e^t$$

and by generalizing, it achieves the following equation:

$$u(t) = Ae^t \tag{8}$$

which is able to satisfy Equation (7) for each real value of the parameter A.

On the basis of Equation (8), through procedures based on attempts and errors, it gets:

$$u(t) = Ae^{rt} \tag{9}$$

and Equation (9) is the solution of Equation (6). Indeed:

$$u(t) = Ae^{rt} \rightarrow \dot{u}(t) = Ae^{rt}r = rAe^{rt} = ru(t).$$

On the basis of Equation (9), the solution of Equation (5) is the following:

$$u(t) = Ae^{-rt} \tag{10}$$

By considering Equation (4) and Equation (10), it gets:

$$-1+\frac{K}{x(t)} = Ae^{-rt}$$

and thus:

$$x(t) = \frac{K}{1+Ae^{-rt}}. \tag{11}$$

Equation (11) is known in the literature as logistic function.

By assuming that the function is not equal to 0, as is our case $x(t) \neq 0$, for $t = 0$ it gets a positive value x_0, so that $x(0) = x_0$. In this case, Equation (11) becomes:

$$x_0 = \frac{K}{1+A}$$

and thus:

$$A = \frac{K-x_0}{x_0} \tag{12}$$

and by substituting it in Equation (11), it gets:

$$x(t) = \frac{K}{1+Ae^{-rt}} = \frac{K}{1+\left(\frac{K-x_0}{x_0}\right)e^{-rt}}. \tag{13}$$

Therefore, for $0 < x_0 < K$, where $t \to +\infty$ the function $x(t) \to K$ is as follows:

$$\lim_{t \to +\infty} x(t) = \lim_{t \to +\infty} \frac{K}{1+Ae^{-rt}} = \lim_{t \to +\infty} \frac{K}{1+\frac{A}{e^{rt}}} = \frac{K}{1} = K.$$

Note that the function $x(t)$ is strictly increasing. Indeed, the first derivative is always positive:

$$\dot{x}(t) > 0 \to rx(t)\left(1-\frac{x(t)}{K}\right) > 0 \to \begin{cases} rx(t) > 0 \to x(t) > 0 & \text{always} \\ 1-\frac{x(t)}{K} > 0 \to x(t) < K & \text{always} \end{cases}.$$

The second derivative of Equation (1) is the following:

$$\ddot{x}(t) = r\dot{x}(t)\left(1-\frac{x(t)}{K}\right) + rx(t)\left(-\frac{\dot{x}(t)}{K}\right) = r\dot{x}(t)\left[\left(1-\frac{x(t)}{K}\right) - \frac{x(t)}{K}\right]$$

and thus:

$$\ddot{x}(t) = r\dot{x}(t)\left[1-\frac{2x(t)}{K}\right]. \tag{14}$$

For $\ddot{x}(t) = 0$, it gets:

$$r\dot{x}(t)\left[1-\frac{2x(t)}{K}\right] = 0$$

and by considering that $r > 0$ and $\dot{x}(t) > 0$, it gets:

$$1-\frac{2x(t)}{K} = 0$$

and thus:

$$x(t) = \frac{K}{2}. \tag{15}$$

Equation (15) defines a point in which the curve changes from convex to concave.

On the basis of these analyses, Equation (13) draws a curve as in Figure 1.

4. Managerial implication

By using the KTC it is possible to measure the effectiveness and efficiency of the entire knowledge transfer process based on its speed for a defined level of knowledge to be transferred (K).

The application of Equation (13) requires the definition of the following variables:

- K: it is the content of the knowledge to be transferred within the company. It can be defined in terms of information to be transferred. The higher the complexity, quality and quantity of the information to be transferred, the higher K. In this context, the level of K is defined.
- x_0: it is the content part of knowledge that can be transferred per "unit of block." Therefore, it can be considered as a standard unit of block and it must be defined in the same unit measure of K.
- t: it is the time required for the knowledge transfer process.
- r: it is the speed of the knowledge transfer process.

It is worth noticing that the main problem we have to face is the inverse relationship between the time (t) and the speed (r) of the knowledge transfer process. Specifically, the higher the r, the lower the time to reach the level K. In other words, the higher r, the faster the knowledge transfer toward the level K.

The trade-off between the time and the speed can be defined by solving Equation (13) for r or t as follows:

$$x(t) = \frac{K}{1+Ae^{-rt}} \rightarrow rt = -\ln\left(\frac{K}{Ax(t)} - \frac{1}{A}\right) \rightarrow \begin{matrix} r = \frac{-\ln\left(\frac{K}{Ax(t)} - \frac{1}{A}\right)}{t} \\ t = \frac{-\ln\left(\frac{K}{Ax(t)} - \frac{1}{A}\right)}{r} \end{matrix}. \tag{16}$$

Therefore, by defining the level of knowledge to be transferred (K) and the total part of the knowledge to be transferred (x_ε) as a part of $K(\varepsilon = \alpha K)$, it gets:

$$x(t) \equiv x_\varepsilon = \alpha K$$

On the basis of this relation, r and t as defined by Equation (16) can be defined in operating terms as the following:

$$r = \frac{-\ln\left[\frac{1}{A}\left(\frac{1}{\alpha} - 1\right)\right]}{t} \leftrightarrow t = \frac{-\ln\left[\frac{1}{A}\left(\frac{1}{\alpha} - 1\right)\right]}{r} \text{ under condition: } x_\varepsilon = \alpha K < K\,. \tag{17}$$

Therefore, by defining a time-period t and the part of knowledge ($x_\varepsilon = \alpha K$) to be transferred in this time-period, the variable r measures the speed of the knowledge transfer process and then its efficiency and effectiveness. By its construction model, the lower the value of r the higher the speed of the transfer process.

Specifically, by defining a content of knowledge to be transferred (K) and the content part of knowledge ($x_\varepsilon = \alpha K$) to be transmitted in the defined period ($t = t_n$), the speed of the process r is a function of the part of knowledge per unit of block (x_0): the higher the level of x_0, the higher the speed and thus the lower the value of r.

To better understand the matter, we assume that:

- the total content of knowledge to be transferred can be translated in a numerical measure and assumed that it is equal to 100 ($K = 100$);
- the time reference is two years ($t = 2$); and
- the part of knowledge to be transferred at the end of the time-period must be equal to 99 percent ($x_\varepsilon = \alpha K = 99\%$).

The speed of the transfer process (r) is a function of the amount of block per unit of knowledge that a firm is able to transfer (x_0).

Specifically, the higher the block per unit of knowledge transferred (x_0), the higher the speed of transfer process and thus the lower the value of r, as it is summarized in Table I.

In order to show the relationship between the speed of the knowledge transfer process (r), the period-time in which the transfer must be realized (t) and the block per unit of knowledge transferred (x_0), it is possible to change the second and the third variables whereas all the other variables are kept equal.

Specifically, we assume a constant speed of the transfer process, where the time decreases when there is an increase of the level of the block per unit of knowledge transferred (x_0) as Table II shows.

Table II shows that for a defined level of speed (r), the increase of the level of the block per unit of knowledge to be transferred (x_0) decreases the period-time of the knowledge transfer process (t).

Similarly, for a defined level of the block per unit of knowledge to be transferred (x_0), the increase of the speed of the process (r) decreases the period-time of the knowledge transfer process (t) as it is shown in Table III.

Tables I-III show how the speed of the knowledge transfer process is a key variable in order to evaluate the effectiveness and efficiency of the entire process.

5. Conclusion

The evaluation of the knowledge transfer process is usually focused on the content of the knowledge to be transferred.

K	t	x_0	$x_\varepsilon = \alpha K$	$r = -\ln\left[\frac{1}{A}\left(\frac{1}{\alpha}-1\right)\right]/t$
100	2	10	0.99	3.396
100	2	20	0.99	2.991
100	2	30	0.99	2.721
100	2	40	0.99	2.500
100	2	50	0.99	2.298
100	2	60	0.99	2.095
100	2	70	0.99	1.874
100	2	80	0.99	1.604
100	2	90	0.99	1.199
100	2	99	0.99	0.000

Source: Own elaboration

Table I.
Relationship between the content part of knowledge and the speed of knowledge transfer

Our theoretical model, which is defined as KTC, shows that the content of knowledge to be transferred is as relevant as the speed of the transfer process. Specifically, the model shows that for a defined level of content of knowledge to be transferred, the higher the speed, the higher the effectiveness and efficiency of the process and thus the higher its value.

It has relevant implications for management. When the content of knowledge to be transferred is defined, and the block per unit of this knowledge and the time-period of the transfer process are determined, managers must monitor the process on the basis of its speed: the higher the speed, the lower the time of the transfer process; the higher the efficiency and effectiveness of the knowledge transfer process, the higher the value of the process.

Hence, managers, after defining the content of knowledge to be transferred, can evaluate their policies on knowledge transfer on the basis of their effects on the process's speed, so that only those policies that increase the speed of the process can be considered effective for the knowledge transfer process.

The limitations of the model are strictly related to its assumption. Specifically, in order to easily apply the model, it is necessary to define: first, the content of knowledge to be transferred in the process; and second the content part of knowledge that can be transferred per unit of block. Therefore, the right application of the model requires the definition of the measurement of its variables. This will be the argument of a future paper.

K	r	x_0	$x_e = \alpha K$	$t = -\ln\left[\frac{1}{A}\left(\frac{1}{\alpha}-1\right)\right]/r$
100	3.5	10	0.99	1.941
100	3.5	20	0.99	1.709
100	3.5	30	0.99	1.555
100	3.5	40	0.99	1.429
100	3.5	50	0.99	1.313
100	3.5	60	0.99	1.197
100	3.5	70	0.99	1.071
100	3.5	80	0.99	0.917
100	3.5	90	0.99	0.685
100	3.5	99	0.99	0.000

Source: Own elaboration

Table II. Relationship between the content part of knowledge and the increases of the block per unit of knowledge when the speed of knowledge transfer is constant

K	r	x_0	$x_e = \alpha K$	$t = -\ln\left[\frac{1}{A}\left(\frac{1}{\alpha}-1\right)\right]/r$
100	1	10	0.99	6.792
100	2	10	0.99	3.396
100	3	10	0.99	2.264
100	4	10	0.99	1.698
100	5	10	0.99	1.358
100	6	10	0.99	1.132
100	7	10	0.99	0.970
100	8	10	0.99	0.849
100	9	10	0.99	0.755
100	10	10	0.99	0.679

Table III. Relationship between the content part of knowledge and the speed of knowledge transfer when the block per unit of knowledge is constant

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