3 Diffusion Of Innovations Into Technology-Based Firms

"Innovation is the specific instrument of entrepreneurship."

PETER DRUCKER (1909–2005)

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3.1 Introduction

Governments today regard technology diffusion as an important route to increased competitiveness, especially diffusion into Technology-Based Firms (TBFs) (La Rovere, 1998; Tran and Kocaoglu, 2009) with advantages of flexibility, dynamism and responsiveness. However, TBFs have disadvantages related to finite technological and financial resources which can lead not only to problems in their ability to source technology but also in their capability to absorb it into their organisation and diffuse it into their industrial sector (Jones-Evans, 1998).

The objectives of the chapter are threefold: first, to investigate technology diffusion (Brooksbank et al, 2001) in the form of new or improved technology through formal and informal networks enabling learning by interacting; second, to develop a model of technology diffusion including external sources, channels of technology transfer, and mechanisms involved in the transfer of technology into the innovative TBF; and third, to relate the model to "best practice" and to note situations where "low activity" can be improved. Finally, the implications for policy relevant to technology and entrepreneurship arising from the model of technology diffusion are investigated and conclusions drawn.

Since there is a time dimension involved in the study of the diffusion of technology into TBFs, similar to other investigations of innovation, theories based on these studies will tend to lag behind the "best" current practices. All models of technology diffusion, including refined models such as the Bass Norton model, are a simplification of reality (Islam and Meade, 1997) and, therefore, have a measured influence upon policy. One theoretical model that has informed policies is the Centre Periphery Model (Schon, 1971) which rests on three basic assumptions –

1) the technology to be diffused exists prior to its diffusion,
2) technology diffusion takes place from the source outwards to TBFs, and
3) the support of technology diffusion involves incentives, provision of resources and training.

This model is shown in Figure 3.1.

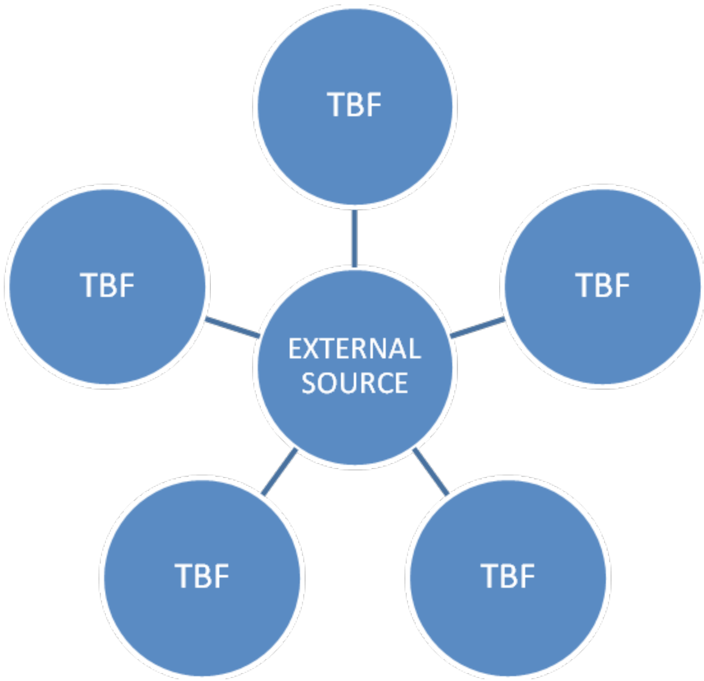

Figure 3.1 Centre-Periphery Model

By applying the Centre-Periphery Model to Technology Transfer Network Theory it is possible to construct what can be described as the "Hub and spoke" or "Star" network. This is a simple construct that can be used as a building block for more intricate networks. Diffusion will take place from the source of the technology through channels by a "diffuser", using a transfer mechanism, to the TBF. The effectiveness of the system will depend upon the resources available to the external source to enable the transfer, the efficiency of the diffuser and the mechanism involved, and the ability of the TBF to acquire technology. The scope of the system will vary directly with the level of technology and the flow of information.

3.2 Technology Diffusion

When a new technique has been adopted the speed at which other TBFs adopt may differ widely. This leads to what can be called the rate of diffusion (imitation). The rate of diffusion will be faster, the greater the improvement over existing technology and, the lower the cost of the technology in general (Roy and Cross, 1975). Using the definition of Bradley, et al, (Bradley, McErlean and Kirke, 1995) technology diffusion can be defined as the spread of a new technique from one TBF to another (`inter-firm diffusion') (Stoneman and Karshenas, 1993). The two principal types of technology diffusion are "disembodied" diffusion (the transmission of knowledge and technical expertise) and "embodied" diffusion (the introduction into production processes of machinery, equipment and components incorporating new technology) (Papaconstantinou, Sakurai and Wyckoff, 1995). Research spillovers are the means by which new knowledge or technology developed by one firm become potentially available to others and the absorptive capacity of the receiving firms will determine the extent to which the technology is incorporated.

The time pattern of adoption and the speed at which it takes place are distinct happenings. The exploration time period when implementing an innovation can provide imitators with a "window of opportunity" to proliferate (Jayanthi, 1998). Empirical studies suggest that the adoption of a new technology follows a bell-shaped, or normal, distribution curve (Norris and Vaizey, 1973). By plotting cumulatively this shows the number of TBFs who have adopted a new technology in any given year, and the distribution will give an `S'- shaped curve. (It was Gabriel Tarde who in the Laws of Imitations, 1903, proposed that adoptions plotted against time assume a normal distribution, or if plotted cumulatively assume the `S'-shaped curve.) (Baker, 1976; Pijpers et al, 2002; UoT, 2004) An `S'-shaped distribution, not necessarily derived from a normal distribution, shows the spread of most new technology. There are two general reasons for the occurrence of this distribution.

(i) The diffusion process for TBFs is a learning process.

TBFs who are potential users have to become aware of the technology and then attempt to evaluate it. Consequently they may use the technology on a trial basis. The learning process takes place at this stage. Information about the technology has to be disseminated, and as it is adopted by other TBFs, or by the TBF on an experimental basis the information becomes more reliable. The importance of accumulated knowledge and expertise is an important factor determining whether firms are likely to adopt new technology or to act as sources of innovation (Gurisatti, Soli and Tattara, 1997). `Bugs' will be overcome, which will in turn reduce the risk of adopting the technology. The concept of the individual TBF learning curve can be extended to a network group of TBFs where experience with a new technology increases as each successive TBF adopts the new technology. As a result, the distribution of TBFs adopting a technology might be expected to yield a normal curve.

(ii) An interaction effect occurs for TBFs.

When only a small number of TBFs have adopted a technology, there are a small number of diffusers who can generate information on the technology and from whom the technological idea can spread. Diffusion rates at this point are low. When the number of TBFs using the technology increases the "information base" broadens and because there is still a considerable number of TBFs who have not adopted the new technology the rate of diffusion increases. When there is a large proportion of TBFs using the technology the number of potential TBFs still remaining becomes small. The remaining TBFs will be resistant to change and there will be a slow down in the cumulative number of TBFs using the new technology. This will yield an `S'-shaped curve. The first formal study of diffusion was the spread of hybrid corn (Grilliches, 1960). The adoption rate in different states in the USA was studied and it was found that there were significant differences between states in the rate of hybrid corn adoption. Logistic growth curves were fitted by Grilliches to his data and the parameters found from the curves for the different states showed wide variations.

Another formal study of the rate of diffusion was carried out by Mansfield who studied the rate of diffusion of twelve innovations in four industries – coal, iron and steel, brewing and rail (Mansfield, 1961, 1968). Although small firms were not included in the analysis, for medium-sized and large firms in most cases, the spread of innovations over time approximated the `S'-shaped curve. According to Mansfield the spread of innovations is best described by a logistic curve.

Despite the shape of the curve for technology diffusion appearing `S'-shaped, there will be differences in the speed at which technology is diffused and the length of the diffusion process. Both within and between industries there will be considerable variations in the rate of the diffusion of technology between TBFs.

Important factors which appear to affect the rate of diffusion (speed at which a new technology is accepted) are the characteristics of the TBF and the characteristics of the technology itself. Early work on the categories of adopters found that further to adoption following a normal distribution curve the distribution could be used to show the categories of adopters (Rogers, 1962). Table 3.1 shows the categories of adopters with the majority of adopters lying between the mean and the mean minus/plus the standard deviation on the normal distribution curve.

Table 3.1
The Categories of Adopters

Categories	Innovators	Early Adopters	Early Majority	Late Majority	Laggards
Number of Adopters	2.5%	13.5%	34%	34%	16%
	x – 2σ	x – σ	x	x + σ	

Years

The categories of adopters can be described as follows:

Innovative TBFs are those who want to explore new technologies. They will have relationships with other TBFs in their network, and with suppliers and customers.

Early adopters will be TBFs who will adopt new technology if it is to their advantage. Since they will act as 'opinion leaders' their influence will be greater than innovative TBFs.

The *early majority* will be intentional while the *late majority* will be sceptical and will adopt when the technology has diffused.

Last, the *laggards* will be so late adopting a new technology that it will have been superseded.

The categories of adopters show that TBFs which adopt an innovation independently are innovators (Tassopoulos and Papachroni, 1998). Early research studies aimed at defining the characteristics of adopters found that early adopters relied to a greater extent on impersonal sources of information from wider and more sources (Rogers, 1962). They used sources in close contact with the origin of new ideas including technical journals. TBFs that are early adopters will tend to be "technically progressive" and will be close to the best that can be achieved in the practice of applying technology (Carter and Williams, 1957). On this assumption a progressive TBF will take a wide range of authoritative technical journals, will have a variety of contacts with sources of technology including similar TBFs, and will assess ideas from these sources. It is expected that communication within the TBF will be well organised and co-ordinated and there will be a willingness to share knowledge with other TBFs in its network. A progressive TBF will set its standards by reference to best practice in other TBFs.

The speed of diffusion will also be faster the greater the awareness of TBFs to the advantages of adopting a new technology. The process of communication will be important here as well as the ability of TBFs to assess the merits of the technological advance. A TBF is more likely to adopt a new technology as it diffuses due to being under increasing competitive pressure to do so, through the technology becoming more attractive, and as a result of information about the technology being broadcast from an increasing base (Green and Morphet, 1975).

3.3 Technology Transfer Networks

Technology transfer networks are of particular importance to TBFs with finite in-house resources to explore the potential of new technologies. Two basic mechanisms available to TBFs are technology exchange (technology passed from one TBF to another) and technology exploitation (technology transferred to a TBF from an external source).

Technology transfer networks enable TBFs to reach a common understanding regarding new technologies quickly. Important aspects of TBF technology transfer networks are the type and size of the network. Whereas, small networks appear more efficient, since communications are easy and network dynamics controllable, large networks benefit from a greater pool of resources. There are four principal types of networks. The "star" network has already been reported. A "nodal linkage" network involves TBFs on an equal footing and is not suitable for those businesses with different levels of experience. "Ad hoc" or "informal" networks are those without a formal structure where TBFs intimately know each other concentrating communication where required. These tend to be mature networks, but are not well suited for heterogeneous groupings, or those with little commonality between TBFs. "Regional" networks are the most complex type consisting of multi-tiered structures linking local networks. These are suitable for heterogeneous TBFs. The descriptions of these four types of network are exemplars in their purist form. Networks adapt to changing internal and external factors and evolve from one (centre-periphery) to another (multi-tiered). Although co-operation with other technology transfer networks provides the possibility of accessing a wider contact base it carries with it some competitive risk.

3.4 A Model of Technology Diffusion

A model of the diffusion of technology into TBFs can be described as innovation (supply) from the source of technology (origins) and diffusion (demand) to the TBF (destination). The model can be expressed concisely in algebraic form:

Origins	$i = 1, 2, \ldots m$
Destinations	$j = 1, 2, \ldots n$
Supply at each origin	a_i
Demand at each destination	b_j
Constraint; supply = demand	$\Sigma a_i = \Sigma b_j$

In order to find a solution we must specify the variable x_{ij} as the unit(s) of technology transferred from origin i to destination j over time t.

All supply $\sum_{j} x_{ij} = a_i \qquad j = 1, 2 \ldots n$

All demand $\sum_{i} x_{ij} = b_j \qquad i = 1, 2 \ldots m$

The diffusion of technology D can be expressed:

$$D = \left[\sum_{i=1}^{m} \sum_{j=1}^{n}\right] x_{ij}$$

where i = 1, 2, … m and j = 1, 2, … n

The rate of diffusion of a new technology to TBFs can be likened to waves of adoption involving distinct time packages.

The rate of diffusion (R) can be calculated according to time (t) (number of years) as follows:

$$R = \frac{\left[\sum_{i=1}^{m} \sum_{j=1}^{n}\right] x_{ij}}{t}$$

where i = 1, 2, … m and j = 1, 2, … n

This equation is a temporal model (Thomas et al, 2001) of technology diffusion which measures the speeds of diffusion (or rates of technology transfer) (Bradley, McErlean, Kirke, 1995).

Technology transfer is an active process whereby technology is carried across the border of two or more social entities (the external source and the TBF), and technology transfer channels are the link between the entities (in which various technology transfer mechanisms are activated) (Autio and Laamanen, 1995). A technology transfer mechanism is defined as any specific form of interaction between entities during which technology is transferred (Autio and Laamanen, 1995). The ability to establish external linkages is of critical importance to TBFs and a critical mass of TBF users will spread the usage and acceptance of the technology (Jain, 1997). The success or uptake of technology depends on how successful the performed community of (implied or ideal) users match the characteristics of actual users (Woolgar, Vaux, Gomes, Ezingeard and Grieve, 1998). Success can be achieved by "configuring the user". Further to this Malecki has stated that "as new technology and products are learned, acquired, evaluated, and improved upon, a firm or region comes to know about best-practice technology…" (Malecki, 1991, p. 122). Laranja calls these "cumulative processes of learning" (Laranja, 1994, p. 173).

3.5 "Best practice"

Technology transfer networks are one of the best forums for TBFs to learn from each other, to exchange experiences, and to diffuse technology. The typical areas where the benefits of "best practice" can be found are technology transfer skills (determining a TBFs' needs by auditing and drawing-up agreements and contracts), technological expertise and know-how (including standards and regulatory issues), service provision (assembling the provision of services), and management and organisation (public relations) (Commission of the European Communities, 1998).

Networks are usually segmented by geographical region, industry sector or by technology and they can work with a mixed sector-technology focus. The danger with specialisation is that it carries the disadvantage that eventually the potential market will be exhausted. It is possible to overcome this by anticipating and looking for opportunities in complementary technology areas.

"Best practice" procedures for the diffusion of technology within networks usually include minimum standards for the TBFs, external funding apportionment, expected performance, and confidentiality. Procedures will usually become less formal over time due to ideal size attainment and growth realisation. Good practice for the successful operation of a network is the realisation by TBFs that it is not only an alliance of enterprises but also a partnership of entrepreneurs. (Entrepreneurs will act as technological gatekeepers and will have an important role to play in the operation of networks.) (Thomas, 1999) This needs to be reflected in network communications and good relationships between the TBFs will form the basis of good practice for the operation of the network.

Success in the diffusion of technology within networks is often the result of TBFs following "best practice" and this usually involves performance management. This is not easy to attain since the process of technology transfer can be long and without success, the results of the network are difficult to define and there may be discrepancies between the TBFs. "Low" activity may arise due to conflicts in a network. When these are efficiently managed and resolved they provide opportunities for the TBFs to broaden their experience and widen their understanding of other TBFs' views. When they are not conflict may lead to "low" activity. Conflict management and identification will form part of the "best practice" of successful technology diffusion. Typical examples of "low" activity are misunderstanding between TBFs, different objectives and motives and under-performance of a TBF.

3.6 Implications for Policy

The implications for policy of a model of the diffusion of technology into TBFs, and the technology processes involved, necessitates the need to formulate technology transfer related action. This includes raising TBFs' awareness of the potential of technology transfer to help solve problems and the existence of networks to provide practical support. Once TBFs comprehend the possible benefits of technology transfer they will need more help to realise the benefits. Two further types of action to achieve this are specific support provided to individual TBFs (assistance during the establishment of network relationships) and technology transfer support to TBFs in general (to foster technological knowledge and establish network links from external sources such as universities and research providers for the dissemination of know-how into TBFs).

Coupled to the three forms of policy action described above the three main types of external sources involved in the diffusion of technology to TBFs are public and non-profit organisations (regional and national development organisations (RDOs/NDOs), regional technology advice centres (RTACS) and chambers of commerce), private consultants (technology brokers, management consultants, patent attorneys), and Research and Technology Organisations (RTOs) (contract research firms, science parks and technology centres). Technology transfer networks may comprise all three types although homogeneous networks are usually easier to form and develop. Amongst the three types public bodies are best placed to undertake policy programmes, private companies concentrate on providing focused assistance and RTOs provide technology knowledge and know-how. For TBFs involved in technology transfer networks key mechanisms include information transfer (newsletters and databases), technology transfer (R&D audits), skills transfer (training) and specialist support (financial guidance). Value for money of the mechanisms will be a key policy measure. There will need to be care that changes in policy will not make a TBF withdraw from technology transfer activities and that policy reacts to difficult situations by providing TBFs with incentives.

3.7 Conclusions

Although the variables involved in the model appear to be the most important influences on technology diffusion into TBFs there will also be a multiplicity of influences that accelerate or alleviate the rate of diffusion. This spectrum of influences on diffusion rates broadens when considering technology transfer among the various different TBFs in multi-tiered networks. An extension of the hypothetical example of diffusion is the diffusion of technology into TBFs through multi-tiered networks. In these TBFs' sociological forces will have an important role to play. The rate of adoption of a new technology will be faster if it is compatible with the previous experience and present normative values of TBFs. Other influences on the speed of diffusion include the complexity of the new technology and random influences.

The model illustrates that the successful diffusion of a new technology involves considerably more than technical competence. Many complementary factors will be prominent and a TBF may be retarded in its acquisition of technology by other firms who are slow to adopt. `Laggards' can have a deleterious effect on the diffusion of technology by other TBFs. The rapid diffusion of a technology will be facilitated by a willingness of TBFs to make adjustments.

Recommended Reading

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