Chapter 3

THEORTICAL AND EMPERICAL LITERATURE ON DIFFUSION: AN OVERVIEW

In this chapter, a detailed introduction of concepts of technology, diffusion and adoption process along with theoretical framework of technology adoption and its diffusion process is discussed. This chapter begins with various views of diffusion and ends with some empirical evidences of the diffusion process.

3.1 Introduction

Technology is a fundamental component of production and the main driver of growth. Technology and technological changes also play a significant role in the socio-economic development of any country. Technology means the goods and services produced and the means by which they are produced in a firm, an industry or an economy. Technological change refers to the application of a new knowledge or previously ignored or rejected production methods of scientific, engineering, or agronomic principles to techniques of production across a broad spectrum of economic activity which enables the economy to obtain greater outputs from the same inputs, as time proceeds (Atkinson and Stiglitz, 1969; Strassmann, 1968). Concept of the technology in economics is a subject of increasing concern in the modern world; it is also a subject that remains controversial and speculative in nature (Pytlik et al., 1985; Mowery and Rosenberg, 1991). Meanwhile, technology, technological change, and technological diffusion play a central role in the theory of resource allocations in economics. A serious study of the process of technology change, diffusion and its adoption by economists began only in the 1950s (Ruttan, 1996).

In this chapter, Section 3.2 discusses the technological theory in economics which begins from Classicals, Neo-classicals, and the New growth theories. Section 3.3 presents the theoretical view of technological diffusion.
3.2 Perspectives of Technological Change

Technology and technological change are the main ingredient factors of economic growth and development. The Classical Theory is based on the works of three English economists of the early nineteenth century - Thomas R. Malthus, David Ricardo, and John Stuart Mill who were pessimistic about the possibility of a sustained economic growth. In the late-eighteenth century Classical economist Adam Smith, in his *Wealth of Nations*, emphasised that division of labour and capital accumulation are powerful factors in the organisation and efficiency of scientific progress (Antonelli, 2009). The exogenous growth model developed by Robert M. Solow observed that technological change is an exogenous phenomenon (Solow, 1957) and other Neo-classical economics largely did not try to explain what caused technology to improve over time. Contrary to the Neoclassical ideas, Kaldor (1957); Verdoorn (1949); Fabricant et al. (1942); Young (1928); Arrow (1962) and Uzawa (1965) introduced models of *learning by doing* as a source of technological progress and formulated full-fledged growth models with endogenous technological change (Paul M. Romer and Robert E. Lucas) in the late 1980s and early 1990s. The central notion of the endogenous theory is that increasing returns is associated with accumulation of new knowledge, human capital and technology (Lucas, 1988; Romer, 1994; Cortright, 2001) that serve as the engine of economic growth. The question of what kind of structure promotes rapid technological progress in an economy was answered by Joseph Schumpeter\(^1\) who opined that a large market with market power accelerate the rate of invention, innovation, and diffusion\(^2\) (Ruttan, 1959; Nicholas, 2003). It is a linear progression from invention to innovation and innovation to imitation/diffusion (Sarkar, 1998). In Schumpeter’s analysis, the invention phase or the basic innovation have less of an impact, while the diffusion and imitation process have a much greater influence on the state of an economy (Sledzik, 2013). Schumpeter (1934) observed that innovation or technological progress is the only determinant of economic growth. When the level of technology becomes constant the process of growth stops. Thus, it is the technological

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\(^1\) J. Schumpeter is considered as the father of the study of diffusion in Economics (Stoneman, 1995)

\(^2\) Invention means new concepts or products that derive from individual’s ideas or from scientific research. Innovation means an idea, practice, or objective that perceived as new by an individual or other unit of adoption. In simple, diffusion means a process by which an innovation is communicated through certain channels over time among the members of social system (Rogers Everett, 1995)
progress which keeps the economy moving. Inventions and innovations have been largely responsible for rapid economic growth in developed countries.

### 3.3 Technological Diffusion

Diffusion of innovation theory attempts to explain how new ideas and practices spread within and between communities. Diffusion of new technology takes time, often a considerable period of time (Stoneman, 1995). Diffusion theory is one of the most widely used theories of communication (Gatignon and Robertson, 1985). The theory emerged from various disciplines, anthropology, economics, geography, sociology, and marketing (Robertson, 1971; Brown, 1981) in the 1920s, 1930s and 1940s (Rogers Everett, 1995).

By the late 1950s and mid-1960s, more economists started to contribute the adoption and diffusion literature, and the most important among them were the works of Griliches (1957); Mansfield (1961); Hanel and Niosi (2007); Dixon (1980); Stoneman (2002). The adoption of technology depends on the characteristics of the potential adopters and its absorptive capacity (Cohen and Levinthal, 1990) in the system which focuses on the demand side of the technological diffusion. The theoretical approach of technology diffusion can be divided into supply and demand approaches.

Most of the modelling frameworks of the diffusion process have considered only the demand side to explain diffusion process. However, the observed diffusion pattern is the result of interaction between the forces of both supply and demand approaches (Karshenas and Stoneman, 1993). The interaction of both the supply and demand approaches is discussed in the models like epidemic model, rank model, stock, and order model.

#### 3.3.1 Epidemic Model

Epidemic model is one of earliest model of technological diffusion process. The best examples of this model are studies by Griliches (1957) and Bain (1963). This model assumes that, the use of new technology is constrained by the number of the fishermen who know and who do not know about the existence of that technology. As time proceeds, users and non-users mix socially and make contact with each other, leading to further
spread of information. Over time, number of users increases and with constant mixing of the population, there is a greater chance of a non-user meeting a user and becoming a user. It could be assumed that all potential adopters know that the technology exists but knowledge of the performance characteristics of the technology is limited and epidemic model shows transferring of knowledge through social contact. This model is self perpetuating and once it starts, it will finish only when all potential members accessed the technology. The model also is a disequilibrium model, because along the diffusion the actual level of use of technology is always less than the equilibrium level of use.

### 3.3.2 Probit or Rank Approach

The Probit model or the rank model are the other important diffusion approaches (Karshenas and Stoneman, 1993; Davies, 1979). In the rank model, the population can be ranked in terms of the benefits derived from its adoption. Population of a society is assumed to be heterogeneous, and different members of the population would get different benefits from the technology. Thus, in this system, an individual considering acquisition of technology will compare its benefits against its cost. A new technology is adopted if the gross benefit of the technologies greater than the cost of acquisition i.e. \( B(t) \geq C(t) \). The costs of acquisition of new technology also depends on its R&D programmes and they are able to assimilate new technology more easily (Cohen and Levinthal, 1989) than others.

The stock model of diffusion is a similar work by Schumpeter (Stoneman, 2002). It shows that, the return to adoption depends on the number of uses at any point in time. It states that the innovation leads the entrepreneur to generate excess or entrepreneurial profits. These profits then act as a signal to other potential users of the technology who follow the lead of the entrepreneur in the search for profits.

### 3.3.3 Evolutionary Model

Evolutionary model of diffusion is based on a micro perspective of technology adoption and was mainly done by Nelson (1968); Nelson and Winter (2009); Hanel and Niosi (2007) & Stoneman (1995). Viewed from the point of view of an individual, firm or other
organization, models of this type estimate the factors (characteristics of firms, industries and technologies) that increase or decrease the probability of adoption of the new technology by the observed unit (Hanel and Niosi, 2007). Here, technological adoption takes place in a context of uncertainty and limited information. It states that diffusion of a technology to be a confrontation between the old and the new instead of considering that, at any time there are a variety of technologies available and that diffusion is the outcome of the process of competitive selection across these technologies (Metcalfe, 1987). A Rosenberg-type "learning by using" process occurs in the adopters, whereas a "learning by searching" progression takes places in the innovating firms together with an Arrow-type ‘learning by doing’ enhances the original adoption (Hanel and Niosi, 2007). This new strand of evolutionary models is based on complexity and systems dynamics inspired by the work of Jay Forrester and John Sterman at MIT and W. B. Arthur and David Lane at the Santa Fe Institute (Sterman, 2000; Lane et al., 2009).

### 3.4 Various Perspectives of Diffusion

The major concern of the diffusion of a new technology is that, all the members of the population of potential adopters do not adopt simultaneously and some never adopt. For better understanding of this complex situation, Brown (1981) classified four major diffusion perspectives. They are: (1) adoption perspective,(2) the market and infrastructure perspective, (3) the economical and historical perspective, and (4) the development perspective. Each of these perspectives addresses the diffusion aspect in various ways, but to some extent, they are considered as complimentary to each other, which provide a comprehensive view of the innovation-diffusion process.

#### 3.4.1 Adoption Perspective

Adoption Perspective is a traditional and more dominant approach to diffusion studies. Thus, primarily focusing on the process through which adoption occurs. It assumes that everybody has an equal opportunity to adopt and explains the differences in actual time of adoption with individual characteristics (Rogers and Shoemaker, 1971). The best tenet of
this conceptualization of the spread of innovation across the landscape is that the adoption of an innovation is primarily the outcome of learning process. The fundamental step in the process of diffusion is identification of factors and characteristics related to the effective flow of information, information reception and resistances to adoption (Brown, 1981).

3.4.2 Market and Infrastructure Perspective

Market and Infrastructure Perspective is a complimentary approach to adoption perspective and it holds the supply aspects of diffusion. Diffusion process is carried out by undertaking three activities (Brown, 1981); (1) establishment of diffusion agencies (2) strategy to implement, termed as establishment of innovation, and (3) adoption of the innovation. The establishment of diffusion agencies and the operating procedures of each agency are, more generally, aspects of marketing the innovation. This marketing involves both the creation of infrastructure and its utilization. Thus the characteristics of the relevant public and private infrastructures - such as service, delivery, information, transportation, electricity or water systems- also have an important influence upon the rate and spatial patterning of diffusion. In short, the market and infrastructure perspective emphasizes on the role of diffusion agencies instead of the adopter.

3.4.3 Economical and Historical Perspectives

Both the adoption and the market and infrastructure perspective present a static approach to innovation because they implicitly presume innovation to be same throughout the diffusion process. In contrast, the economic historians talk about the dynamic approach of innovation, by emphasizing upon both the preconditions of diffusion as well as continuity of innovation. The traditional interpretation of economic historians are more concerned with the invention than with the diffusion process. The reinterpretation of economic history conveys that innovation is a continuous process and this is characterized by innovation-diffusion interaction. This continuity of innovation affects the temporal and spatial pattern of diffusion in both supply and demand viewpoints. From supply point of view, market or potential adopters have significant bearing on the location and timing of
the supply of new technology (or innovation) and its adoption. The time of the diffusion process depends upon the nature of the new technology, its novelty and complexity, and its profitability. On the demand side, even if innovation is made available, some potential adopters (individual or firms) might prefer to delay their decision expecting further improvements in the innovation system. Specifically it can be said that, economic history perspectives examines three complementary aspects of innovation diffusion, namely, dynamism of innovation, process through which innovations are made available to potential adopters and the demand side factors (Brown, 1981).

3.4.4 Development Perspective

This approach is a logical extension of the market and infrastructure perspective. One of the major areas of research is the impact of innovation diffusion, such as its effects on economic development, social change and individual welfare. Development perspective represents a reaction to a discontinuity between belief and fact. It is concerned with two aspects (1) the ways in which the levels of development affects the diffusion process. (2) the outcome or impact of that process on development. The first aspect can be related to the availability of infrastructure and other public goods in the economy, which have a significant influence on the extent of diffusion and the types of innovation diffused. Good access facilities, well developed transport, easy availability of credit etc., are factors which have a significant promotional effect on potential adopters and thus stimulates innovation-diffusion.

3.5 Measuring Technological Diffusion

The study about the spread of use (as stated by epidemic model) and or ownership of new technology is known as technological diffusion. The diffusion of technology takes time and it improves over time. It is also shown that the diffusion rates differ across industries, regions or states and countries and also across technologies. Suppose there are $N$ potential users of a new technology and each one adopt the technology when they get information about it at time $t$. Under the assumption of homogeneous mix of population,
at time $t$, $y(t)$ firms have adopted and $N - y(t)$ have not, if the information passes from central sources, reaching $\alpha\%$ of the population each period. If $\alpha = 1$, then sources contact all $N$ potential users in the first period, and diffusion is instantaneous. On the other hand, if $\alpha < 1$, then the information spreads gradually, and so does the uses of the new technology. A transmitter that contacts $\alpha\%$ of the current population of non-users, $N - y(t)$, at time $t$ over the time interval $\Delta t$ increases awareness (usage) by an amount change $y(t) = \alpha N - y(t) \Delta t$, taking the limit as $\Delta t$ tends to zero and solving for the time path of usage provides the Equation 3.1. This expression is the standard logistic curve, often used to represent the sigmoid shape of the diffusion process. This illustrates that, a low initial rate of growth of ownership follows by faster rate of growth up to the point of inflexion, after which, although still positive rates of growth declines. The diffusion process and its various stage of adoption is presented in Figure 3.1 and Table 3.1.

$$y(t) = N(1 - e^{\alpha t})$$  \hspace{1cm} (3.1)

**Figure 3.1:** Theoretical ‘S’ shaped curve (compiled from Rogers Everett (1995) Rogers & Stoneman (2002))

A new technology is consumed in the beginning of the process by some innovator users, and later on by an increasing number of users (imitators) as shown in Figure 3.1.
At a certain point, adoption level starts to decrease (when most of the technology is used), and finally the marginal change in the amount of new adopters approaches zero where full penetration of a new technology is achieved (Jaakkola et al., 1998). This process of adoption gives sigmoid shape or S shape curve. The theoretical justification for this shape commonly used by economists is the hypothesis which is usually referred to as the demonstration or bandwagon effects (Jensen, 1983).

Table 3.1

<table>
<thead>
<tr>
<th>Beal and Bohlen 1957</th>
<th>Rogers 1995</th>
<th>Manueli et al. 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovators</td>
<td>Innovators</td>
<td>No ICT adoption</td>
</tr>
<tr>
<td>Early adopters</td>
<td>Early adopters</td>
<td>Basic ICT adoption</td>
</tr>
<tr>
<td>Early majority</td>
<td>Early majority</td>
<td>Intermediate ICT adoption</td>
</tr>
<tr>
<td>Majority</td>
<td>Late majority</td>
<td>Advanced ICT adoption</td>
</tr>
<tr>
<td>Non-adopters</td>
<td>Laggards</td>
<td></td>
</tr>
</tbody>
</table>

Source: Compiled by the researcher, from Beal and Bohlen (1957); Rogers Everett (1995) and Manueli et al. (2007)

To apply and interpret the results of any diffusion model, we must understand its concepts and mathematical foundations. There are different models for finding out the diffusion pattern of the technology and predict the trend of adopters as shown in the Table 3.2. One of the fundamental diffusion models is expressed as in the following differential Equation 3.2.

\[
\frac{dnt}{dt} = (gt) = \left[ \bar{N} - N_t \right]
\] (3.2)

With the boundary condition \( N_{(t=0)} = N_0 \), \( N_{(t)} \) is the cumulative numbers of adopters at time \( t \), \( N(t) = \int_{t_0}^{t} d(t) \), \( n(t) \) being the non-cumulative number of adopters at time \( t \), \( \bar{N} \) is the total number of potential adopters in the social system at time \( t \), \( \frac{dnt}{dt} \) is the rate of diffusion at time \( t \). Diffusion of an innovation at any time \( t \) is a function of (i.e., is directly proportional to) the difference between the total number of possible adopters existing at that time and the total number of previous adopters at that time \( [\bar{N} - N(t)] \). The model shows that as the cumulative number of prior adopters, \( N(t) \), approaches the total number of possible adopters in the social system, \( \bar{N} \), the rate of diffusion decreases.

The nature of relationship between the rate of diffusion and the number of potential...
Table 3.2
Diffusion models and their application of a new technology

<table>
<thead>
<tr>
<th>No.</th>
<th>Diffusion models</th>
<th>Equation</th>
<th>Shape</th>
<th>Inflection point</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Logistics function</td>
<td>$y_t = \frac{a}{1 + e^{-(x-xc)/x}}$</td>
<td>S</td>
<td>0.5</td>
<td>Telecom innovation</td>
</tr>
<tr>
<td>2</td>
<td>Gompertz function</td>
<td>$y_t = ke^{-\alpha t}$</td>
<td>NS</td>
<td>0.37</td>
<td>Consumer durable goods (vcd, TV), agriculture, telecom innovation</td>
</tr>
<tr>
<td>3</td>
<td>Bass model</td>
<td>$y_t = N\left[1 - e^{-(p+q)t}\right]$</td>
<td>S</td>
<td>0.0-0.5</td>
<td>Consumer durable goods (vcd, TV), retail service agriculture, industrial process</td>
</tr>
<tr>
<td>4</td>
<td>Fisher Pry model</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Floyd model</td>
<td>$bF = (1 - F^2)$</td>
<td>NS</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Sharif - Kabir model</td>
<td>$(a + bF)(1 - F)^{(1+\theta)}$</td>
<td>S or NS</td>
<td>0.33-0.5</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Jeuland model</td>
<td>$(a + bF)(1 - F^2)$</td>
<td>S or NS</td>
<td>0.0-1.0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Non uniform influence</td>
<td>$(a + bF)^2(1 - F)$</td>
<td>S or NS</td>
<td>0.0-1.0</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Non symmetric responding</td>
<td>$(bF)^2(1 - F)$</td>
<td>S or NS</td>
<td>0.0-1.0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Von Bertalanffy model</td>
<td>$\frac{bF}{1-F^{1-\theta}}(1-F)$</td>
<td>S or NS</td>
<td>0.0-1.0</td>
<td></td>
</tr>
</tbody>
</table>

Source: (EASINGWOOD and MULLER, 1983)

adopters as shown existing at $t$, $[\bar{N} - N(t)]$, is controlled by $g(t)$, the coefficient of diffusion. The specific value of $g(t)$ depends on the characteristics of diffusion process such as the nature of the innovation, communication channels used, and attributes of social system. In addition, $g(t)$ can be interpreted as the probability of an adoption time $t$. If this interpretation is used, then $g(t)$, $[\bar{N} - N(t)]$ represents the expected number of adopters at time $t$, $n(t)$. Furthermore, if $n(t)$ is viewed as the number of members in social system transferred from potential adopter status to non potential adopter status at time $t$, then $g(t)$ can also be considered a transfer mechanism, a conductivity coefficient or a coefficient of conversion. Two distinct approaches have been used to represent $g(t)$, viz; as a function of time and as a function of the number of previous adopters.

### 3.6 Technology Acceptance Theories and Models

Understanding the influencing factors of adoption is important to the present study. Finding out the reason of adopting or rejecting any new technology by users has become one of the most important areas in the information communication technology (Momani and Jamous, 2017). Technology acceptance theories and models aim to convey the concept of how users may understand and accept the new technology and how they may use it (Fishbein and Ajzen, 1975). For any new technology, there are many variables affect the individual’s decision-making process about how and when they will use it.

Thus, the most important eleven theories are reviewed as follows: the Theory of Rea-
soned Action (TRA) (Fishbein and Ajzen, 1975), the Theory of Planned Behaviour (TPB) (Ajzen, 1985), the Decomposed Theory of Planned Behaviour (DTPB) (Taylor and Todd, 1995), the Technology Acceptance Model (TAM) (Davis, 1985), Extended Technology Acceptance Model (TAM2) (Venkatesh and Davis, 2000), the Combined TAM and TPB (C-TAM-TPB) (Taylor and Todd, 1995), The Model of PC Utilization (MPCU) (Triandis, 1979), the Innovation Diffusion Theory (IDT) (Rogers, 2003), the Motivational Model (MM) (Deci and Ryan, 1985), the Social Cognitive Theory (SCT) (Compeau et al., 1999), and The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) are developed in several scientific and social fields and are reviewed as well.

3.6.1 Theory of Reasoned Action (TRA)

TRA is one of the earliest technology acceptance theories. It was developed in the field of social psychology by Ajzen and Fishbein in 1967 (Vallerand et al., 1992). It is one of the most fundamental theories of human behaviour (Wang et al., 2009). In this model, any human behaviour is predicted and explained through three main cognitive components including attitudes (unfavourableness or favourableness of person’s feeling for a behaviour), social norms (social influence), and intentions (individual’s decision do or do not do a behaviour) (Taherdoost, 2018). Their aim was to develop a theory that could predict, explain, and influence human behaviour. They considered that this theory is moderated by two main constructs; attitude toward behaviour and subjective norm.

3.6.2 Theory of Planned Behavior (TPB)

TPB is an extension of TRA, developed by Ajzen (Ajzen, 1985). It was extended by adding a new construct which was perceived behavioural control (Armitage and Conner, 2001). It is theorized to be an additional determinant of intention and behaviour. TPB has been successfully applied to the understanding of individual acceptance and usage of many different technologies. Ajzen (1985) considered that this theory is moderated by three main constructs; attitude toward behaviour and subjective norm of TRA, with the new one, the perceived behavioural control.
3.6.3 Decomposed Theory of Planned Behavior (DTPB)

The DTPB has been discussed two times in separate studies by Taylor and Todd (Taylor and Todd, 1995). It decomposes attitude toward behavior, subjective norm, and perceived behavioral control into multi-dimensional belief constructs within technology adoption contexts. As an extension to TPB, which was an enhancement of TRA, the DTPB expanded the TPB by including three factors from the Innovation Diffusion Theory (IDT). IDT includes relative advantage, compatibility, and complexity. The relative advantage and compatibility were joined together in order to make some effect on perceived behavioral control (Taylor and Todd, 1995). According to Taylor and Todd (Taylor and Todd, 1995) examination to TRA, TPB, and DTPB, they found that TRA and TPB are good in pre-dating the behaviour, but DTPB proved effective in explaining the behaviour.

3.6.4 Technology Acceptance Model (TAM)

TAM is an adaptation of TRA done by Davis (Davis Jr, 1986). It replaced TRA’s attitude toward behavior with two technology acceptance measures. They are perceived usefulness and perceived ease of use (Davis et al., 1989). TAM did not include the TRA’s subjective norms in its structure. It is developed in information technology field while TRA and TPB developed in the psychology field, so that it is less general than TRA and TPB (Venkatesh et al., 2003). The development for TAM comes through three phases: adoption, validation, and extension.

3.6.5 Extended Technology Acceptance Model (TAM2)

TAM2 was extended model of TAM by Venkatesh and Davis (Venkatesh and Davis, 2000). It explains perceived usefulness and perceived ease of use from the social influence and cognitive instrumental processes’ viewpoints. Social influence processes refer to: subjective norm, voluntariness, and image, while cognitive instrumental processes refer to: job relevance, output quality, result demonstrability, and perceived ease of use. Unlike TAM, Venkatesh and Davis inserted subjective norm as an additional construct by adopting from TRA and TPB models. Subjective norm has direct relations with perceived usefulness and
intention of use. Its relation with perceived usefulness is moderated by the user experience, while its relation with intention of use is moderated by the user experience and voluntariness of use. Extending TAM to TAM2 by including some constructs from older theories in addition to some moderators to perceived usefulness and perceived ease of use will enhance the performance to the model. As an example, the existence of experience moderator will show the increase in the level of users’ experience in technology over the time, and this will cause a tangible change in technology acceptance to them.

### 3.6.6 Combined TAM and TPB (C-TAM-TPB)

Taylor and Todd developed this combined model in 1995 by combining the TPB model from social psychology field with TAM from information technology field to achieve a better use of TPB in technology acceptance (Wang et al., 2009). This model combines the predictors of TPB with perceived usefulness from TAM to provide a hybrid model (Taylor and Todd, 1995). TAM and TPB theories supposed that behaviour is determined by the intention to perform the behaviour. Intention itself is determined by the attitude towards behaviour. The constructs of TAM do not fully reflect the specific influences of technological and usage-context factor that may change user’s acceptance (Taylor and Todd, 1995). Davis Jr (1986) noted that the future technology acceptance researches need to address how other variables affect usefulness, ease of use, and acceptance. It is applied in many fields (Pynoo et al., 2012).

### 3.6.7 Model of PC Utilization (MPCU)

Some technology acceptance theories such as TPB and TAM developed over the TAR concept in order to explain the individual usage behaviours (Triandis, 1979; Ajzen, 1985; Fishbein and Ajzen, 1975). TPB and TAM adopted TRA with the majority of its advantages and limitations. The research work of Triandis (1979) resulted a framework that described how the behaviour happened, and what are the variables that encourage the individual to do the behaviour while using the personal computer (PC).
3.6.8 Innovation Diffusion Theory (IDT)

IDT developed by Rogers in 1962 (Rogers Everett, 1995). This theory was a result of several diffusion studies which had been done in 1950s and focused on individuals’ differences in innovativeness. Rogers Everett (1995) proposed four major factors for determining the behaviour: innovation, communication channels, time and social systems. Diffusion: is the process in which an innovation is communicated through certain channels over time among members of a social system. Innovation: is an idea, practice, or object that is perceived by an individual. Communication: is a process that leads to create and share information with others in order to get a common understanding. Rogers stated that there are five innovation attributes which effect on individuals’ behaviours and explain the rate of innovation adoption. These attributes are: relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003). He suggested five stages of adoption process of a new technology. They are: innovators, early adopters, early majority, late majority and laggards (see the section 3.3 for more details).

3.6.9 The Motivational Model (MM)

Since 1940’s, many theories have been resulted from motivation research. Self-Determination Theory (SDT) developed by Deci and Ryan (1985) is one of them. SDT proposed that self-determination is a human quality that involves the experience of choice, having choices and making choices (Deci and Ryan, 1985). Deci et al. (1991) mentioned that the regulatory process is choice when behaviour is self-determined, but when it is controlled, the regulatory process is compliance, or defiance in some cases.

3.6.10 Social Cognitive Theory (SCT)

SCT idea started in 1941 by Miller and Dollard with the name of Social Learning Theory (SLT) for the purpose of introducing the modelling into the principle of learning. In 1986, Bandura had developed SCT as a result of his continued work started in 1960s to expand SLT to become one of the most powerful theories of human behaviour (Bandura, 2001). The major feature of SCT is the social influence and its effect on external and in-
ternal social reinforcement. SCT also cares about the previous experiences of individuals. These previous experiences are influencing reinforcements and expectancies with no matter if the individual engages in a specific behaviour or not, and exposing the reasons why the individual engages in that behaviour. SCT believes that previous experiences create expectations of outcomes related to performing certain behaviour.

### 3.6.11 Unified theory of acceptance and use of technology (UTAUT)

The Unified Theory of Acceptance and Use of Technology integrates constructs across the eight models/theories (Zhou et al., 2010; Wang et al., 2009). The eight models/theories include TAM, TRA, TPB, C-TAM-TPB, IDT, SCT, MM, and MPCU. Although UTAUT has not been as widely used as TAM, it has gradually drawn researchers’ attentions and has been recently applied to exploring user acceptance of mobile technologies (Carlsson, Carlsson, Hyvonen, Puhakainen, & Walden, 2006; Min, Ji, & Qu, 2008; Park, Yang, & Lehto, 2007).

UTAUT model is one of the most important models to understand the usage of ICT. It was strengthened from Technology Acceptance Model (TAM) (Muhammed Shaffril, 2012). It is a technology acceptance model formulated by Venkatesh and others in ‘User acceptance of information technology: Toward a unified view’ (Venkatesh et al., 2003). This model has four main variables. They are; performance expectancy, efficiency expectancy, social influence and facilitating condition. The performance expectancy and efficiency expectancy are used to integrate perceived usefulness and perceived ease of use in the original TAM model (Muhammed Shaffril, 2012). Apart from this, demographic factors (gender, age and experience) and voluntariness of use are included to mediate the impact of the main variables on usage intention (Venkatesh et al., 2003).

### 3.7 ICT: A General Purpose Technology

The term general-purpose technology (GPT) has been used extensively in recent literature which confirms about the role of technology in economic growth. It is usually reserved for showing the changes that transform both household and business life (Jo-
vanovic and Rousseau, 2005). Some technologies are more important in the process of economic growth, while others and some new technologies may have only a small impact on the production process. Some technologies have only a very limited area of application. Thus, the term general purposive technologies has been coined to encompass these widely applicable technologies (Stoneman, 2002). GPT is a term coined to describe a new method of production and invention that is important enough to have a protracted aggregate impact. Electricity and information technology (IT) are the two most important GPTs (Jovanovic and Rousseau, 2005).

The concept of GPT was introduced by Bresnahan and Trajtenberg (1995), along with three key characteristics of such technologies, which are pervasiveness (should spread all sectors), technological dynamism (should get better over time) and innovational complementaries (make it easier to invent and produce new product or process).

ICT can be one of the best examples of GPT in this aspect. ICT revolution has contributed significantly to the whole economy by raising productivity. Many economists consider ICT as a general-purpose technology due to its pervasive character. It has already become an indispensable part of production of goods and services, irrespective of the industry (Erdil et al., 2009). Pohjola (2001) stated that ICT would need the development of complimentary inputs, infrastructure such as education, skills, telephones, and electricity connectivity etc., in order to reap the maximum benefit from the GPT. The literature has identified two important channels by which ICT applications have the effects
on real economy which are production of ICT and the use of ICT (by other industries).

### 3.8 ICT and Diffusion Models

Researchers such as, Griliches (1957); Mansfield (1961); Ryan and Gross (1943) and Beal and Bohlen (1957) have observed the continuous process of a new technology adoption based on several depending factors over a period of time which provides ‘S’ shaped or sigmoid curve in the agriculture sector. Rogers Everett (1995); Stoneman (2002) and Geroski (2000) developed several diffusion theories of technology adoption to explain the characteristics of the S-shape applying any field of study. Hall and Khan (2003); Stoneman (2002) gave an empirical analysis of ‘S’ shape curve where they stated that the rank and the epidemic models are the dominant factors explaining the adoption of a new technology. Rank model depends on inter firm differences of adoption time, intensity, and profit, whereas epidemic model depends on the spread of information from users to non-users. Mahajan and Peterson (1985) provides major diffusion models such as; Gompertz, logistics and cumulative normal growth functions for mathematical optimization and prediction of the adoption processes of new technologies. Normally, any technology diffusion process is empirically tested with the help these models in any sectors. Following are some important studies of application of Gompertz, logistics and Bass model of ICT tools application in selected areas.

The following models; Gompertz, Logistic and Bass models are commonly used to investigate mobile telephony diffusion (Wu and Chu, 2010b).

**Gompertz model**

The Gompertz model is one of the most frequently used sigmoid models fitted to growth data and other data, perhaps only second to the logistic model. Researchers have fitted the Gompertz model to everything from plant growth, bird growth, fish growth, and growth of other animals, to tumour growth and bacterial growth (Tjørve and Tjørve, 2017). The
Gompertz model is expressed as

\[ \frac{dN}{dt} = rN \ln \frac{K}{N} \]  

(3.3)

where \( N \) is the number of adopters at time \( t \), \( r \) is the intrinsic growth rate, and \( K \) is the maximum (equilibrium) number of adopters. The solution for this first-order differential equation is

\[ N(t) = Ke^{-e^{-r(t-m)}} \]  

(3.4)

**Logistic model**

The logistic growth function is very similar to the exponential growth function, except that it levels off once it reaches a certain point. Model shows for a quantity that increases quickly at first and then more slowly as the quantity approaches an upper limit. This model is used for such phenomena as the increasing use of a new technology, spread of a disease, or saturation of a market (sales)(Mahajan and Peterson, 1985) (see 1.7.2 more details).

\[ \frac{dN}{dt} = rN \left(1 - \frac{N}{K}\right) \]  

(3.5)

where \( N \) is the number of adopters at time \( t \), \( r \) is the intrinsic growth rate, and \( K \) is the maximum (equilibrium) number of adopters. The solution of this first-order differential equation is

\[ N(t) = \frac{K}{1 + e^{-r(t-m)}} \]  

(3.6)

**Bass model**

The Bass diffusion model was developed by Frank Bass and describes the process of how new products get adopted as an interaction between users and potential users. The model is widely used in forecasting, especially product forecasting and technology forecasting.
Mathematically, the basic Bass diffusion is a Riccati equation with constant coefficients (Dowling, 1980). The Bass model classifies adopters into two categories, innovators and imitators, which are expressed as

\[
\frac{f(t)}{1 - F(t)} = p + qF(t)
\]

(3.7)

where \(f(t)\) is the likelihood of adoption at time \(t\); \(F(t)\) is the fraction of the ultimate potential adopted by time \(t\), \(p\) is the innovation coefficient, and \(q\) is the imitation coefficient. Eq.3.9 can be rewritten as

\[
\frac{dN}{dt} K - N = p + q N
\]

(3.8)

where \(K\) is maximum (equilibrium) adoption potential, and \(N\), which equals \(KF(t)\), is the total number of adopters in the interval \((0, t)\). The solution for \(N\) is

\[
N(t) = K \frac{1 - e^{(p+q)t}}{1 + \frac{q}{p} e^{-(p+q)t}}
\]

(3.9)

Gupta and Jain (2012) used three important epidemic models of diffusion to study the spread of mobile phone in India. The Bass, Logistics, and Gompertz are the three models that they used to test its spread and for predicting the diffusion. They found the exact fit of Gompertz diffusion curve rather than logistic, bass model in the Indian mobile phone dissemination and the fitted curve traced ‘S’ shape. The study also found that tariff, fixed line telephony and communication with other people are the three major determining factors of adoption of mobile phone in India. Completion among service providers and government intervention are the major factors for spread of diffusion of mobile phones in India.

Singh (2008) estimated future trends with the help of Gompertz diffusion model and analysed the pattern and rate of adoption of mobile phones among the fishermen in India. For that, he used the ‘S’ shaped growth curve model. He found that mobile density in India would be 71% in 2015-16 and mobile subscribers would be 900 million. The reasons cited low tariff as result of competition of mobile companies, and increase in average income.
of people led to demand more mobile phones in India.

Botelho and Pinto (2004) estimated the rate of adoption of mobile phones in Portugal. They used ‘S’ shaped logistics function model to predict the number of cellular phones subscribers and found that it was growing at the rate of 18% per quarter. They also used the Gompertz model to describe a sigmoid diffusion curve. But logistic function fitted only adequately for mobile phone diffusion in Portugal.

Michalakelis et al. (2008) studied about diffusion models such as, logistics, Gompertz, bass, and fish pry models for data fitting and forecasting performance of 2G mobile telephone subscribers in Greece. All models of diffusion was well applied on mobile phone subscribers and forecasted their logistic shape. The study found that a saturation level of adoption of mobile phone was greater than 100% due to interaction between the groups and non-adopters.

Kwon and Stoneman (1995) theoretically and empirically tested the impact of technology adoption on firm output and productivity with the help of Cobb Douglas production function. Three versions of the model with varying degrees of endogenous was applied and then tested upon a data set relating to the adoption of five different process of technologies by 217 firms in the UK engineering industry over a period from 1981 to 1990. They found that technology adoption has a positive impact on output and productivity.

Many studies applied all the models of diffusion for measuring the level and characteristics of the diffusion curve in many field including agriculture and industry. Very limited studies have been conducted in the Indian communication industry and yet fewer studied the diffusion level of a technology (Mobile phone). But, no studies were conducted in Kerala for measuring the diffusion level of any new technologies, especially in agriculture sector. A systematic measurement of ICT tools by any basic growth models reveals economic and social development of the state. The present study measures the diffusion level of ICT tools in fisheries sector of Kerala with the help of logistic growth function. The following Table 3.3 shows the logistic growth model fits well (denoted as ✓) for measuring the Information Communication and Technology.
### Table 3.3
Studies of diffusion models of ICTs and their application

<table>
<thead>
<tr>
<th>Author</th>
<th>Area &amp; Region</th>
<th>Logistics</th>
<th>Gompertz</th>
<th>Bass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gruber and Verboven (2001)</td>
<td>Telecommunication in European union</td>
<td>✓</td>
<td>×</td>
<td>-</td>
</tr>
<tr>
<td>Botelho and Pinto (2004)</td>
<td>Cellular phone in Portugal</td>
<td>✓</td>
<td>×</td>
<td>-</td>
</tr>
<tr>
<td>Frank (2004)</td>
<td>Wireless communication in Finland</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lee and Cho (2007)</td>
<td>Mobile telecommunication - Korea</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Michalakelis et al. (2008)</td>
<td>Mobile communication - Greece</td>
<td>✓</td>
<td>✓</td>
<td>✕</td>
</tr>
<tr>
<td>Singh (2008)</td>
<td>Mobile phone - India</td>
<td>✓</td>
<td>✕</td>
<td>-</td>
</tr>
<tr>
<td>Gamboa and Otero (2009)</td>
<td>Mobile communication - Colombia</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wu and Chu (2010a)</td>
<td>Mobile telephone - Taiwan</td>
<td>✓</td>
<td>✕</td>
<td>✕</td>
</tr>
</tbody>
</table>

Source: Compiled by researcher

### 3.9 Summary

Technology innovation and diffusion are the main factors of economic development and growth. Diffusion is an essential part in the process of technological change. Economic theories concentrated on various approaches of diffusion, explains the process of diffusion and individual adoption decision. The theoretical analyses suggest that, technology diffusion is based on both the supply and demand factors. Some firms tend to adopt innovations earlier than the others, since spreading information is important for them. Diffusion takes place in different ways for different technologies and industries. The speed of diffusion and the shape of the diffusion curve depends both on the distribution of benefits and on the rate at which its dissemination takes place. However, the Logistic growth model is analogous to the Epidemic model which gives S shape for the adoption of a new technology and fitted successfully its shape in the sector, than other models.