ENTERPRENEURSHIP AND INNOVATION ACTIVITES IN THE SCHUMPETERIAN LINES

Abstract:
The importance of diffusion of technology for economic growth has been emphasised by economic literature. Much of the recent work on economic growth can be viewed as refining the basic economic insights of classical economists. The recent debate on the determinants of output growth has concentrated mainly on the role of knowledge, typically produced by a specific sector of the economy, and furthermore in the role of entrepreneurship and the implications on economic growth. This paper attempts to examine the role of entrepreneurship, and those of innovation activities (technical change, research and development and diffusion of technology) and the effects of output growth, according to the Schumpeterian lines. Following on the Schumpeterian tradition, this paper starts from the recognition that there are two main patterns of innovations: the first one is the creative destruction pattern and the second one is a creative accumulation pattern. Also, it emphasizes the role of entrepreneurship and the impact of the diffusion of technology in the inter-country and international economic contexts using some of the empirical implementation of epidemic, probit analysis and moreover from technological substitution models.

Key Words: Entrepreneurship, Innovation Activities, Diffusion, Modernization, Competitiveness, Schumperer.

Theme H: Entrepreneurship, networks and innovation

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1. Introduction

The term of *difussion of technology* is used to include both voluntary and involuntary spread of technology, whereas the term of *technology transfer* is defined as the voluntary dissemination, while the involuntary dissemination is labelled *imitation*. According to the definition given by Nasbeth and Ray (1974), *imitation* is the process by which an envious firm attempts to duplicate an imperfectly observed success. The first important point is to distinguish between diffusion and the adoption of technology. In the analysis of adoption one considers the decisions taken by agents to incorporate a new technology into their activities. A typical measure of adoption would be the proportion of eligible firms in an industry which use a given technology. By contrast, in the analysis of diffusion one is concerned with measuring the changing economic significance of a technology with the passage of time. In a sense, the analysis of diffusion is closely related to the analysis of *technological substitution* in which the displacement of one technology by another is the focus of attention. The spread of new technology occurs in a number of dimensions. The potential buyers of a technology can be public institutions, firms and households. The adoption by other users as well as more extensive use by the original innovator. More generally it encompasses all those actions at the level of the firm or organisation taken to exploit the economic benefits of the innovation", (OECD, 1992).

According to the Schumpeterian tradition, this paper starts from the recognition that there are two main patterns of innovations: the first one is the *creative destruction pattern* where innovations introduced by firms that did not innovate before and fundamental role played by entrepreneurs with new ideas and the new firms in innovative activities and in methods of production and also the second one is a *creative accumulation pattern* where innovations introduced by firms that innovated before with the large established forms and the accumulated stock of knowledge with the presence of relevant barriers to entry small firms. As a consequence, on cumulative pattern the current knowledge and the innovation activities form the base that building blocks on the future innovations.

Schumpeter states that the major long-term fluctuations in economic development cannot be explained by terms of conventional short and medium term business cycle theory but require an additional dimension of analysis. This involves the rise of new technologies, the rise and declined of entire industries, major infrastructural investments, changes in the international location of industry and technological leadership and other related structural changes, for instance, in the skills and composition of labour force and the management structure of enterprises.

Many studies (such as Abramovitz 1986, Fagerberg 1987, 1988, 1994) have suggested that there is a close correlation between technological development and the productivity level. Technological knowledge involves various degrees of specify, complexity and independence and many differ across technologies. Generic knowledge refers to a very broad knowledge nature, while specific knowledge refers to specialised knowledge and specific applications. Economists have analysed different possible views of why productivity growth has declined. These alternative explanations can be grouped into the following categories:

(a) the capital factor, for instance investment may have been inadequate to sustain the level of productivity growth;

(b) the technology factor which affects the productivity level, for instance a decline in innovation activities can affect productivity growth;

(c) the increased price of raw materials and energy;

(d) government regulations and demand policies that affect the productivity level;

(e) the skills and experience of labour force may have deteriorated or moreover workers may not work as hard as they used to;

(f) the products and services produced by the economy have become more diverse;

(g) productivity levels differ greatly across industries.

Technological gap models represent two conflicting forces, innovation which tends to increase the productivity differences between countries and diffusion which tends to reduce them. In the Schumpeterian theory, growth differences are seen as the combined results of these forces. We have applied a model for economic growth that based on the Schumpeterian logic. Essentially, the technological-gap theory of economic growth is an application of Schumpeter's dynamic theory of capitalist development, which was developed in a closed economy, to a world economy characterised by competing capitalist nations. Schumepter analyses economic development as a disequilibrium process characterised by an interplay by two conflicting forces: innovation which tends to increase technological and economic differences between countries and imitation or diffusion which tends to reduce them. The outcome of the international process of innovation and diffusion, with regard to the economic development of different countries, is uncertain.

This *technological gap model* gives a good explanation for the differences among various countries. The empirical estimates suggest that the convergence hypothesis applies among industrialized countries. Research on *why growth rates differ* has a long history which goes well beyond growth accounting exercises.

The idea that the poorer countries should catch up on the richer ones was advanced already in the nineteenth century, in order to explain continental Europe's convergence with Britain. In the 1960s one of the most basic was the Marx-Lewis model of abundant labour supplies which explained the divergent growth experience in the Western European countries.

To achieve safe results, it is necessary to apply a cross country multi sectoral analysis, in order to be able to examine how technological activities affect the different sectors. According to our estimates there is a relationship between the level of economic growth and growth of technological activities.

The studies of Scmookler, Kendrick (1991), Abramovitz (1986), have recognised the interaction between technological change and productivity. In these studies, factor prices were used to weight the various inputs so as to get a measure of total input growth. The approach which was developed by Abramovitz (1986), Solow (1957), Denison (1962), refers to the common method for decomposition of output growth into its various sources, which can be defined as the *growth accounting and residual method*.

Growth accounting theories began with Kuznets and were developed by Abramovitz (1986). Growth accounting tries to explain changes in real product and TFP. These studies were mainly based on comparison between the growth of inputs (capital and labour) and the growth of output; one part of actual growth could not be explained and it has been classified as *unexplained total factor productivity growth* (or the so called *residual*).

Solow expanded the work of John Stuart Mill and developed the *neoclassical growth models*. The *neoclassical growth theory* as developed by Solow and his followers dominated in the literature of *long term or trend movements* in per capita income for more than three decades. The starting *neoclassical growth models* of Solow are important studies for economic growth and convergence. In these models, the rate of exogenous technical progress is the key parameter that determining the steady state growth rate of per capita income.

The recent debate on the determinants of output growth has concentrated mainly on the role of knowledge, typically produced by a specific sector of the economy. This approach considers the economy in a three sector framework (Romer 1990a, 1990b), where the Research and Development sector produces knowledge to be used as an input by firms producing capital goods. Output growth rate is indigenously determined by the allocation of human capital in the research and manufacturing sectors and is not affected by other crucial variable such as the unit cost of production of new capital goods. Furthermore, this approach does not take into account the possible effect of diffusion on the growth rate.

The use of capital goods in the consumer durable sector is taken at its equilibrium (or post diffusion) level. This implies a condition of stationary, as la the variables are at their equilibrium level. The aim of the present analysis is to relax this implication, which crucially affects the conclusion of previous models. Particularly, we are interested in considering the effect of diffusion on output growth. This paper analyses the diffusion of technology both of inter-country and the international approach; in addition, it examines the probit analysis and the substitution diffusion models.

2. Inter-country and international diffusion approach: the theoretical framework

2.1. *The inter-country approach diffusion approach*

Inter-country differences tend to be explained in terms of three groups of variables:

(a) the most popular are the measurement of proxies for *the profitability of innovation* in the different countries;

(b) *technological and institutional differences* which are mentioned in a number of cases;

(c) *economic industrial characteristics*, (such as the growth and the size of market, the size of firms and the age of existing equipment).

The literature in the diffusion of technology incorporates three different approaches. The most well-known is the *inter-industry innovation approach* pioneered by Mansfield (1969). They studied diffusion in one or more innovations in a number of industries and they attempted to explain empirically the variance of the speed of diffusion in terms of differences in the attributes of the industries and innovations concerned.

The *inter firm approach* also pioneered by Mansfield concentrates on individual innovations diffusing in single industries and attempts to explain the differences between firms in the time taken to adopt. Mansfield (1969) suggested that if other things were equal, then the length of the time that a firm waits before use of the new technique will be inversely related to its size. Large firms are more likely to have more units to replace and also the conditions usually are more favourable and better for a large firm, (such as financial resources, engineering and research departments).

For these reasons, large firms would be expected in general to use a new technique more quickly than small firms. According to the Mansfield's analysis, as the firm's size increases the length of time to introduce a new technology tends to decrease at an increasing rate; also the length of time that a firm makes to introduce a technology tends to be inversely related to the returns that obtain from the innovation. The most striking contribution in this area has been produced by an international consortium of economic research institutes who have studied the diffusion of ten major process innovations in six countries, Nasbeth and Ray present a final report. However, because each institute was responsible for a separate innovation, a number of quite different methodologies have been pursued and a brief summary of their conclusions cannot be comprehensive.

In the *inter-firm model*, at any point of the diffusion process the number of users acquiring the technology is related to risk attached to acquisition, the expected profitability of acquisition and the number of potential adopters. According to the inter-firm decision theories, the most important elements that contribute to determine the actual cost of entry can be considered to be the following:

(a) fixed investment costs;

(b) the cost of scientific and technical knowledge required to assimilate the innovation;

(c) the cost of acquiring the experience required to handle it and successfully bring it to the market;

(d) the cost of overcoming any locational disadvantages related to the general infrastructure and other economic and institutional conditions.

For any innovation, the costs of entry for the innovator can be represented as the sum of the following components: the fixed investment cost in plant and equipments, the cost incurred by innovator in acquiring the scientific and technical knowledge which was not possessed by the firm at the beginning of the innovation process, the cost incurred by the innovator in acquiring the relevant experience (know-how in organisation, management, marketing or other areas) required to carry the innovation through and the cost borne by the innovator to compensate for whatever relevant externalites are not provided by the environment in which the firm operates.

Imitators will compare the cost of buying the technology with the cost of developing it themselves, if they can. According to analysis of Perez, the imitator will know exactly where it stands and exactly where it is going. The imitator can purchase from the innovator all the required equipment, plant, knowledge, and knowhow. Whether the imitator has lower costs of entry than the innovator will depends on the relative starting positions of the innovator and imitator in terms of relevant knowledge, experience and location. The scientific and technical knowledge required for an innovation generally includes a fair amount which serves as a platform for generating the new or innovation-bound knowledge. The actual costs for the innovator will consequently include not only that of generating the new innovation-bound knowledge, but also the cost of acquiring that part of *freely available knowledge* which the innovator did not possess to begin with.

The capacity to absorb the new knowledge is greater the larger the amount of relevant knowledge already possessed. In terms of cost, this would imply that the closer to the required *frontier terms of knowledge*, the less costly it will be to acquire an additional unit of information. However, the imitator's knowledge related to the entry costs will depend crucially on his own initial scientific and technical knowledge base in the relevant areas, (consequently, his entry costs may be much higher or much lower than the innovator's, depending on their relative starting positions in the knowledge level of the firm). Moreover, government regulations, taxes, tariffs and other relevant policies will affect strongly the *environment* and the actual cost for an innovator. Specifically, the difficulty of *catching-up* for industries/firms in the developing countries is because scientific and technical knowledge, the practical experience and locational advantages may be lower than in the more advanced countries while of technology may be higher.

In the diffusion context, two factors are critical but each works in opposite directions; if the early adopters are large, medium or small firms will depend upon the importance of cost/risk considerations relative to innovativeness considerations and upon the way in which qualities vary with the firm size. This approach can be applied so as to investigate the diffusion of the same innovation in a number of different countries and to explain the observed differentials in the diffusion performance in the terms of the characteristics of the countries and industries concerned.

2.2. *The international diffusion approach*

The international diffusion of technology has been a major factor behind most industrial nations economic growth. Information and the particular characteristics of each country are the key points for the international diffusion of technologies through different countries. Moreover, the *international approach* attempts to explain international differences in the speed of diffusion of innovations in terms of the characteristics of the countries and industries concerned. An overall assessment of international differences in the rate of diffusion of new innovation technologies is extremely difficult to make for a variety of technical applications and for innovations that are continuously are introduced. *International diffusion* can be considered in connection with *international technology transfer*, (through multinationals and licensing); in addition included to various variables (such as profitability and transfer cost). An important factor which affects the level of diffusion is the nature of competition in the user's industry. It has also been argued that firms are more likely to experiment with new products and methods during a phase of increasing competition.

The framework of international diffusion can be considered through the following approaches:

(a) the *Schumpeterian approach* that tried to investigate and to explain long-waves in the economic activity (*the Kondratieff cycle*). The Schumpeterian hypothesis is concerned with the implications of new technology in the economy. In Schumpeterian theory, the entrepreneur introduces the innovations and the resulting profits that derived from the new innovations giving the signal and attribute to imitate that from other entrepreneurs. The introduction of new technologies would result in the reduction of factor and product prices. The change of prices will induce the non-adopters to use the new technology.

(b) The *vintage approach*; the great strength of the vintage model is that it is perfectly rational for the entrepreneurs to use the old technologies even when new best-practice techniques exist. Introduction of new technologies under perfect competition will depend on the age structure of the capital stock, the improvements in new technologies over time and movements in relative prices. The *old machines* can still yield a contribution to profits if price covers operating costs. One disadvantage of the vintage models is for instance that all investment in machines involves the latest type. Moreover, these models give us no guarantee that the diffusion will be sigmoid. The length of time between an initial innovation and an imitation in another country defines the *innovation lag*.

According to the classification analysis of Posner and Soete (1988), the *innovation-lag* can be viewed as a sum of the following components:

(a) the *foreign reaction lag*, as the product innovations are usually introduced into foreign markets through exports from the country in which the innovation initially occurred. The length of the foreign reaction lag depends on the magnitude of the threat to the foreign industry's market resulting from imports of the new innovated product, (the greater the competitiveness between domestic and foreign producers for the share of the market then the shorter will be the *foreign reaction-lag*).

(b) The *domestic reaction lag* can be considered as the time elapsing between a positive *foreign reaction* to an innovation and the actual decision to imitate. The length of time that an industry waits before imitating tends to be inversely related to its size. Generally, large industries produce a wide range of products and usually have better facilities and technical skills for the improvement or introduction of products. (c) Finally, the *learning period*, where the international communications channels tend to accelerate the diffusion of innovations.

The most important determinants in the diffusion lag can be considered the following:

(a) The *size of the country*; according to Mansfield (1969), and Metcalfe (1981) size plays a positive role in the reduction of diffusion-lags. Small countries seems to have better opportunities than large ones to adopt earlier innovations that originate abroad and also they are more receptive to innovation that originates elsewhere.

(b) *Technological capability* of the country; many studies (Antonelli, 1986) have suggested that the R&D influence reduces diffusion-lags.

(c) The *origin of the technology* seems important in explaining diffusion lags. According to Metcalfe (1981), the diffusion process of an innovation is affected by the characteristics of supply and demand of technology. Firms are more able to capitalise on technological opportunities when the origin of the technology is internal. Moreover, as Benvignati (1982) has shown the domestic technologies diffuse much quicker than foreign ones.

(d) *Multinational firms*; according to Antonelli (1986), multinational firms have played an important role in the diffusion of technology. However, it seems that multinational firms can help spread product innovations rather than process innovations. In fact, product innovations are introduced in the imitating countries by multinational firms that have already benefited from capitalised know-how and research spending in the innovating country.

3. An overview of technological diffusion on economic analysis

The economic analysis of international diffusion patterns of technological innovations distinguishes four different aspects:

- (a) the *speed* with which a country initially tries a new product or the demand-lag;

- (b) how quickly the use of the product *spreads* among consumers after introduction into the domestic market, as indicated by the growth in the country's consumption;
- (c) the *speed* with which the country acquires the production technology from abroad or the *imitation lag rate*;
- (d) how quickly the domestic producers *adopt* the technology once it is transferred from abroad, as indicated by the growth of the country's output.

Diffusion models have a methodological similarity with some of the models of industrial and economic growth which were developed in the 1930s by Kuznets and Schumpeter. According to Schumpeter (1934) the diffusion process of major innovations is the driving force behind the trade cycle (the *long term Kondratieff cycle*), however the forces driving the diffusion process per se are not made explicit. The conception is that the entrepreneur innovates and the attractiveness of attaining a similarly increased profit and cost reductions encourages others to imitate, this imitation representing a diffusion process.

The diffusion of technology can be defined as the process by which the use of an innovation spreads and grows. Diffusion is very important in the process of technological change. On the one hand diffusion narrows the technological gap that exists between the economic units of an industry and thus the rate of diffusion determines to a large extent the rate of technological change measured as the effect of an innovation on productivity increase

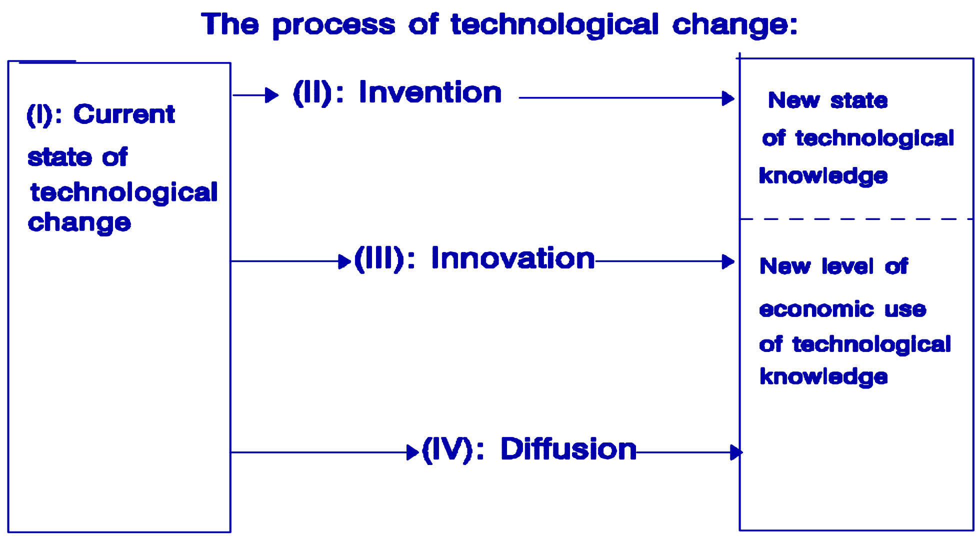

Figure 1, The process of technological change

in an industry. On the other hand, diffusion plays an important part in the competitive process in the sense that diffusion deteriorates the competitive edge which is maintained by the originator of successful innovations. Schumpeter had classified technological change in the following steps: (a) the invention; (b) the innovation and (c) the diffusion. Diffusion is the last step in the economic impact of a new product or process. Diffusion is the stage in which a new product or process comes into widespread use.

Figure 1 indicates the importance of diffusion in the process of technological change, (Chen 1983). The *current state of technological knowledge* (stage I) gives rise to the second stage (II) of *invention*, however, sometimes it gives rise to *innovation* and to *diffusion*. At the second stage, the results of *invention* can give rise to a *new state of technical knowledge*, where in this case a new stage is created and the cycle begins again. Most of the diffusion literature is focused on the theoretical arguments that underlying the traditional, *S-shaped epidemic diffusion curve*.

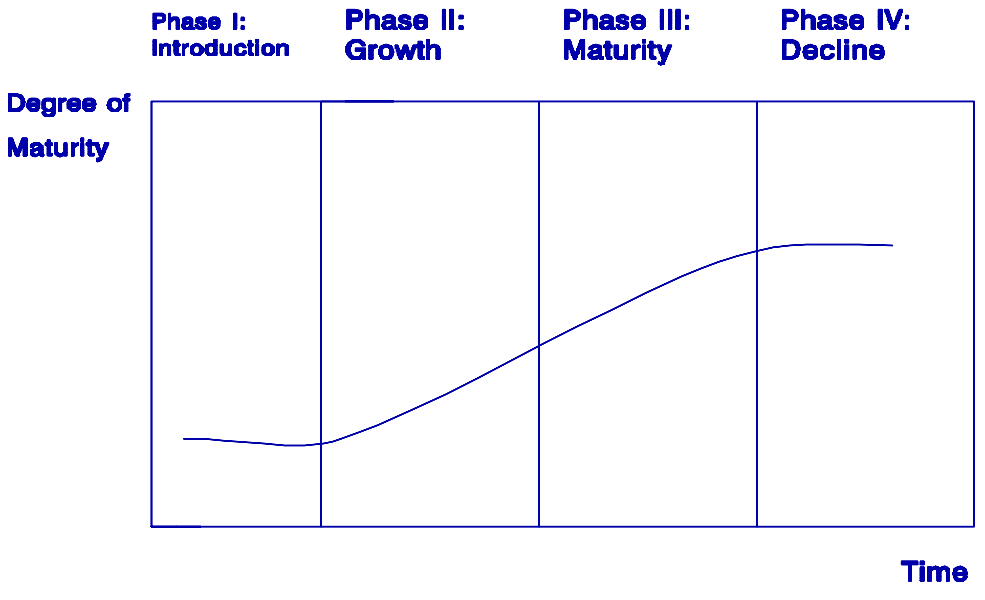

Figure 2, Stages of Growth

Figure 2 illustrates the different phases of the diffusion process, where improvements are achieved slowly in the first stage, then accelerate and finally slow down. Figure 2 (Malecki, 1991) shows diagrammatically the following diffusion phases:

- *(a) phase I is the period of first introduction*, where the innovation has to perform adequately and break successfully into the market;
- *(b) phase II is the period of rapid market growth*, once the product is basically defined and its market tested the focus shifts to the process of production;

- *(c) phase III of maturity*, where market size and rate of growth are well known and the relationship between product and process has been optimised;
- *(d) phase IV of decline*, where both the product and its process of production are standardised.

4. Epidemic and probit analysis and the technological substitution models

4.1 The epidemic approach & logistic curve in a diffusion context

Many diffusion models, (Davies 1979, and Stoneman 1987), are based on the approach of the theory of epidemics. Epidemic models can be used to explain how the innovation spreads from one unit to others, at what speed and what can stop it. The epidemic approach starts with assumption that a diffusion process is similar to the spread of a disease among a given population. The basic epidemic model was based on three assumptions:

- (a) the potential number of adopters may not be in each case the whole population under view;
- (b) the way in which information is spread may not be uniform and homogeneous;
- (c) the probability to optimise the innovation once informed, is not independent of economic considerations, such as profitability and market perspectives.

The spread of new technology among a fixed number of identical firms can be represented as follows: Let us assume that the level of diffusion is D which corresponds to m_t number of firms in a fixed population of n which have adopted the new innovation at time t and to (n-m_t) firms that remaining as the potential adopters. Let us assume the probability of an adoption is a constant term b. Then Dm_t, the expected number of new adopters between t and Dt, will be given by the product of this probability, (between one non-adopter and one adopter to lead to an adoption during the period of time D_t). The number of individuals contracting the disease between times t and t+1 is proportionate to the product of the number of uninfected individuals and the proportion of the population already infected, both at time t. The magnitude of b will depend on a number of factors, such as, the infectiousness of the disease and the frequency of social intercourse.

This is rationalised by assuming that each uninfected individual has a constant and equal propensity to catch the disease (as reflected by b), from the contact by an infected individual and that the number of such contacts will be determined by the proportion of the population who is already infected (assuming homogeneous mixing). At each instant t, every individual can meet randomly with another member of population and then the expected number of encounters (between adopters and non-adopters) during the time Dt, is:

$$[m_t(n-m_t)]Dt, \qquad \textbf{(1),}$$

It follows that Dm_t is equal to:

$$m_{t+1}-m_t=b[(n-m_t)m_t/n], \quad (b>0) \qquad \textbf{(2)},$$

where, the parameter b (usually called the *speed of the diffusion* or the *rate of the diffusion*). This is rationalised by assuming that each uninfected individual has a constant and equal propensity to catch the disease (as given by b) from the contact with an infected individual and the number of such contacts will be determined the proportion of the population who are already infected. If the period, is very small then equation (2) can be rewritten, as:

$$dm_t/dt[1/(n-m_t)]=bm_t/n, \qquad \textbf{(3)},$$

This differential equation has the following solution (***logistic function***):

$$m_t/n=\{1+\exp(-a-bt)\}^{-1} \qquad \textbf{(4)},$$

where a is a constant of integration,

If one plots m_t against the time t, the profile will follow an *S-shaped curve* (or the *sigmoid curve*). The empirical tests are straightforward using the linear transformation:

$$\log[m_t/(n-m_t)]=a+bt, \qquad \textbf{(5),}$$

A huge literature exists on the *law of logistic growth,* which must be measured in appropriate units.[4] The growth process was supposed to be represented by a function of the

[4] In the literature, widely different models have been employed to generate the S-shaped trends. Such examples are the logistic function, the Gompertz function, the modified exponential function, the cumulative normal distribution function, the cumulative log-normal

form (3) with t to represent the time. Different studies for plants and animals were found to follow the *logistic law*, even though these two variables cannot be subject to the same distribution. Population theory relied on the logistic extrapolations. The only trouble with the theory is that not only the logistic distribution but also the normal, the Cauchy, and other distributions can be fitted to the same material with the same or better goodness of fit.

Examining the logistic curve, we can summarise the following disadvantages:

(a) the infectiousness of the disease must remain constant over time for all individuals, that means b must be constant, however, in the increasing resistance on the part of uninfected or a reduction in the contagiousness of the disease suppose that b falls over the time;

(b) all individuals must have an equal change of catching-up the disease. That means, b is the same for all groups within the population. There are a number of other assumptions which may prove unrealistic for the logistic solution, (for instance, constant population is required).

4.2 The Probit analysis

The probit analysis was already a well established technique in the study of diffusion of new products between the individuals. This approach concentrates on the characteristics of individuals in a sector and is suitable not only to generate a diffusion curve, but also gives some indications of which firms will be early adopters and which late.

Given the difficulties which are associated with the linear probability model, it is natural to transform the original model in such a way that predictions will lie between (0,1)

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distribution function. Chow has introduced the following logistic curve, (the *Chow logistic curve* of equation a):

$$dn/dt = g(t)n_t(n^*-n_t) \qquad \textbf{(a)}$$

This differs from sigmoid logistic curve by: $1-(n_t/n^*)=(n^*-n_t)/n^*$. Of course, the sigmoid curve need not be logistic. Another curve which has been used is *Gompertz curve* deriving from the following equation (b):

$$dn_t/dt = k(t)n_t(\log n^*-\log n_t)$$

(b)

Where k(t) is the speed of diffusion and in the case where k(t) is a constant then the curve has an infection point at $n_t=0.37n^*$. However, the logistic and Gompertz curves are just two of a whole class of curves that may be labelled sigmoid. The logistic curve is no more that the cumulative density curve derived from a *chi-squared or (logistic) frequency distribution*. For each bell-shaped distribution there will be exist an S-shaped curve which can be used in a diffusion study. For a more detailed analysis see Stoneman, (1983).

interval for all X.[5] These requirements suggest the use of a *cumulative probability function* (F) in order to be able to explain a dichotomous dependent variable, (the range of the *cumulative probability function* is the (0,1) interval, since all probabilities lie between 0 and 1. The resulting probability distribution might be represented as:

$$P_i=F(a+bX_i)=F(Z_i) \quad \textbf{(6)}$$

Under the assumption that we transform the model using a *cumulative distribution function* (CDF), we can get the constrained version of the linear probability model:

$$P_i=a+bX_i \quad \textbf{(7)}$$

There are numerous alternative cumulative probability functions, but we will consider only two, the *normal* and the *logistic*. The probit probability model is associated with the cumulative normal probability function. To understand this model, we can assume that there exists a theoretical continuous index Z_i which is determined as an explanatory variable X. Thus, we can write:

$$Z_i=a+bX_i \quad \textbf{(8)}$$

The probit model assumes that there is a probability Z^*_i that is less or equal to Z_i, which can be computed from the *cumulative normal probability function*. The standardised cumulative normal function is written by the expression (8), (that is a random variable which is normally distributed with mean zero and a unit variance). By construction, the variable P_i will lie in the (0,1) interval, (P_i represents the probability that an event occurs). Since this probability is measured by the area under the standard normal curve, the event will be more likely to occur the larger the value of the index Z_i. In order to be able to obtain an estimate of the index Z_i, we should apply in (8) the inverse of the cumulative normal function of:

$$Z_i=F^{-1}(P_i)=a+bX_i \quad \textbf{(8')}$$

In the language of probit analysis the unobservable index Z_i is simply know as the *normal equivalent deviate* (n.e.d.) or simply as *normit*.

[5] The requirement for such a process is that it translates the value of the attribute X, which may range the value over the entire real line, to a probability which ranges in value from 0 to 1. We should also like the transformation to maintain the property that increases in X are associated with increases (or decreases) in the dependent variable for all values of X. The probit model is more appealing that the linear probability model, however, it involves the nonlinear maximum-likelihood estimation. For a more detailed analysis see Pindyck and Rundinfield (1991), pp:254-256.

The central assumption underlying the probit model is that an individual consumer (or a firm/country) will be found to own the new product (or to adopt the new innovation) at a particular time when the income (or the size) exceeds some critical level. Let us assume, that the potential adopters of technology differ according to some specified characteristic, z, that distributed across the population as f(z) with a cumulative distribution F(z). The advantage of the probit diffusion models is that relate the possibility of introducing behavioural assumptions concerning the individual firms (firms). Also, the probit model offers interesting insights into the slowness of the technological diffusion process. Let us consider, that we have two set of innovations, the first group concerns the innovation A which follow a *cumulative lognormal diffusion curve* (this can be considered as the simple and the relative cheap innovation), while the second group concerns the innovation B which follow a *cumulative normal diffusion curve* (this can be considered as the more complex and expensive innovation):

$P_t=N(\log t/m_D,s^2_D)$ **(9),**

$P_t=N(t/m_D,s^2_D)$ **(9$'$)**

For estimation purposes both equations can be linearized by the following transformation:

$P_t=N(Z_t/0,1)$, **(10)**

where: z_t may be defined as the *normal equivalent deviate or normit* of
P_t, where given values for P_t, Z_t can be read off from the standard normal Tables).

Re-arranging the equations (9) and (9$'$) in terms of the standard normal function, it follows that:

$Z_t=(\log t-m_D)/s_D)$ **(11)**,

$Z_t=(t-m_D)/s_D)$ **(11$'$)**

for group (11), and for group (11$'$), respectively.

For empirical purposes, it must be remembered that P_t refers to a probability that a randomly selected firm has adopted the innovation at time t. This can only be measured by the proportion of firms having adopted m_t/n. However, to employ the variable Z_t as dependent variable in the regression equation, we will violate one of the assumptions of the standard linear regression model, (which is the dependent variable and thus the disturbance term is not homoskedastic).

In fact, this problem is always encountered when use the *probit analysis*. In the past, two alternative estimators have been advocated under these circumstances: the first concern the *maximum likelihood* and the second concerns the *minimum normit* x^2 *method*. In this context, the *minimum normit* X^2 *method* amounts the following weighted regressions

$$Z_t = a_1 + b_1 \log t \qquad \textbf{(12),}$$

(for group A which corresponding to the *cumulative lognormal*),

$$Z_t = a_2 + b_2 t \qquad \textbf{(13),}$$

(for group B which corresponding to the *cumulative normal*),

where: Z_i refers to the normal equivalent deviate of the level of diffusion (m_t/n) in year t where diffusion is defined by the proportion of firms in the relevant industry who have adopted.

4.3 Technological substitution models

A number of economists (such as Mansfield 1969, Sahal 1977a) consider diffusion as a disequilibrium phenomenon. Usually, when a new technology or a new method is introduced, it is less developed than the older with which it is competing. Therefore, it is likely to have greater potential for improvement and for reduction in cost. The introduction of a new product or process broadens the range of choice of producers and consumers and the equilibrium is altered. In the real world, there is only a *gradual adjustment* over the course of time to the new equilibrium level. A simple formulation of this adjustment process would be to assume that the percentage adjustment in any one period is proportional to the percentage difference between the actual level of adoption of innovation and the level which corresponds to the new equilibrium. The essence of the technological substitution hypothesis lies on the disequilibrium characteristic of the diffusion process. We can assume that the system-wide disequilibrium caused by the gap in the use of two techniques. The equilibrium levels of the use of two techniques can be indicated by K_1 and K_2, while the intra-equilibrium gaps can be denoted by:

$$(K_1 - Y)/Y \text{ and } (K_2 - Y)/X. \qquad \textbf{(14a)}$$

Particularly, we can assume that the use of one technique as a percentage of the other is some fixed proportion g of the percentage of intra-equilibrium gaps, that is:

$$\log f(t)-\log f^{'}(t)=g[\log(X)-\log(Y)] \qquad \textbf{(14b)}$$

or otherwise using the differential equation of the well-known logistic function, we can find that:

$$\log f(t)-\log f^{'}(t)=g[\log(K_2-X)/X-\log(K_1-Y)/Y] \qquad \textbf{(15)}$$

where, $\log(K_2-X)/X=a_2-b_2t$ and $\log(K_1-Y)/Y=a_1-b_1t$ and a is the constant depending on the initial conditions, K is the equilibrium level of growth and b is the rate of growth parameter.

Another interesting result is that the coefficient g is a *measure of the speed* with which movement from an equilibrium to the other takes place. According to the previous analysis, the greater the disparity in the use of two techniques, the faster the speed the substitution will be. Using one technique as a proportion of the other, this can be indicated by $f/f^{'}$, we can reach in the following equation:[6]

$$\log(f/(1-f))=a_1+b_1t \qquad \textbf{(16)}$$

Moreover, assuming that X(t) is the adoption of new technique at the time t and Y(t) is the old technique at time t, then the fractional adoption of the new technique at time t is given by:

$$f(t)=X(t)/(X(t)+Y(t)) \qquad \textbf{(17)}$$

and

$$f^{'}(t)=Y(t)/(X(t)+Y(t)), \qquad \textbf{(17')}$$

so that $f(t)+f^{'}(t)=1$.

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[6] It also can be verified that the logistic curve is a symmetrical S-shaped curve with a point of infection at 0.5K. The higher the coefficient g, the less the difference between the rates of the adoption of the two techniques will be: $b=g(b_1-b_2)$, where:$a_1=g(a_2-a_1)$, and $b_1=g(b_1-b_2)$. For a more detailed analysis see Sahal and Nelson, (1981), and Sahal (1980).

Both X and Y can follow an S-shaped pattern of growth, Sahal and Nelson (1981), and Sahal (1982). The simplicity of the model is that it contains only two parameters. Any substitution that has gained a few percent of the available market has shown economic viability and hence the substitution will proceed to 100 percent. The substitutions tend to proceed exponentially in the early years (as for instance, with a constant percentage annual growth increment) and to follow an S-shaped curve. The simplest curve is characterised by two constants: the early growth rate and the time at which the substitution is half-complete.

According to this analysis, the substituted fraction can be given by the relationship:

$$f=(1/2)[1+\tanh a(t-t_0)], \qquad \textbf{(18)}$$

where: a is the half annual fractional growth in the early years and where t_0 is the time at which f=1/2. A more convenient form of the substitution expression can be given as:

$$f/(1-f)=\exp\,[2\,a(t-t_0)] \qquad \textbf{(19)}$$

5. Conclusions

The international diffusion of technology is undoubtedly a historical well-recognised factor in the industrialisation of both Europe and the United States in the nineteenth century, and even more strikingly of Japan in the twentieth century. Technological diffusion is the process by which innovations (by the new products or new processes) spread within and across economies. The various factors which might influence the incidence of innovation and the speed of its diffusion are the following: (a) the *technical applicability*; (b) *profitability*; (c) *finance*, (lack of financial resources might delay the diffusion of new processes); (d) *size, structure and organisation*; (e) *management attitudes*, (which is the most difficult to assess or to quantify, but nevertheless they may be as important as economic factors in influencing the rate of adoption of new methods); (f) *other factors*, such as research and development activities, access to information, the labour market availability of certain skills, licensing policy, the market situation and more precisely the growth of demand for the product as well as the competitive position with special regard to the import competition.

A vast literature exists on the diffusion of innovations. Most of this literature has developed along two separate paths:

- (a) the diffusion adopted by household or individuals;
- (b) the diffusion of innovations adopted by firms. Both of them have in common a heavy reliance on the mathematical theory of epidemic models.

Many studies explain the diffusion patterns by focusing mainly on the way that information spreads, the influence of expected profitability and the size of firms. Diffusion is the core of the process of modernisation. The diffusion analysis of new process can split into three parts:

- (a) in the *intra firm diffusion* and the *inter-firm diffusion* and
- (b) in the *economy-wide (inter country and international) diffusion*.

Standard diffusion models seem readily able to account for the situations which are open to empirical investigations. Both the epidemic approach and the probit approach are defined in positioning the place of firms relative to others.

The diffusion path can be interpreted by two theoretical forms:

- (a) the *cumulative lognormal curve* and
- (b) the *cumulative normal curve*.

According to Schumepter there are two conflicting forces: innovation which tends to increase technological and economic differences between countries and imitation or diffusion which tends to reduce them. The process may generate a pattern where countries follow diverging trends, as well as a pattern where countries converge towards a common mean.

In this paper proposed that the specific pattern of innovative activity can be explained as the outcome of different technological regimes (learning and knowledge) that are implied by the nature of technology. The theory which analysed in this paper concerns the form of the two models of technological substitution. The first of the model focus on the temporal aspects while the other concentrates on the phenomenon of the spatial aspects. We can considered that the two models are complementary in this respect.

6. References

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