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An Approach on Spatial Integration and Diffusion Process

George M. KORRES[1,2]

[1] *University of Newcastle, Centre of Urban Regional & Development Studies, (CURDS), Newcastle, UNITED KINGDOM*

[2] *University of the Aegean, School of Social Sciences, Department of Geography, Mytilene, GREECE*

E-mail: gkorres@geo.aegean.gr

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ABSTRACT

The importance of diffusion of technology for economic growth has been considerably emphasised in economic literature. This paper investigates the role and the impact of the diffusion of technology in economic context. It also attempts to analyze the diffusion models through epidemic and probit analysis models.

1. INTRODUCTION

We can consider economic growth in different forms and within different geographical distribution patterns. There is a huge and extensive literature on the theory of macro-aspects of regional economic growth, however the specific spatial economic linkage pattern of open regions having received less attention. Spatial dynamics and techno-economic evolution are often two parallel phenomena. Stoneman (1983, 1995) has made a useful distinction between the generation of new technology, the adoption of new technology, the diffusion pattern of new technology and the socio-economic impact of these processes. In later studies, much attention has been devoted to the main critical factors that are favourable to diffusion and innovation processes, such as, knowledge intensity, capital intensity, accessibility to the market and suppliers, organizational and logistic structures.

This paper attempts to analyse the diffusion of technology within diffusion process. In addition, it also examines the probit analysis and the substitution diffusion models. The first type of the models focuses on the temporal aspects, while the other concentrates on the phenomenon of the spatial aspects.

2. MODELLING INNOVATION DIFFUSION IN A SPACE-TIME CONTEXT

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

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

The epidemic model is based on the idea that the spread of information about a new technology is the key towards explaining diffusion. Epidemic models hypothesize that some firms adopt later than others because they do not have sufficient information about the new technology. According to this theory, initially, potential adopters have little or no information about the new technology and are therefore unable or disinclined to adopt it. However, as diffusion proceeds, non-adopters collect technical information from adopters via their day-to-day interactions with them, just as one may contract a disease by casual contact with an infected person. As a result, as the number of adopters grows, the dissemination of information accelerates, and the speed of diffusion increases. However, as the number of adopters exceeds the number of non-adopters, the speed of diffusion decreases. Importantly, the probability of a non-adopter becoming "infected" by contact with an adopter is not the same for every technology; it depends on characteristics of the technology such as profitability, risk, and the size of the investment required to be adopted. Figure 1 illustrates the logistic form of three different innovations which may vary in their relative rate of adoption.

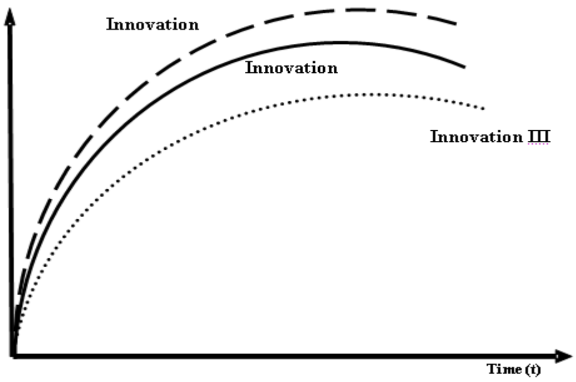

Fig. 1. Adoption curves.

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 mt number of firms in a fixed population of n which have adopted the new innovation at time t and to (n-mt) firms remaining as the potential adopters.

Let us assume the probability of an adoption is a constant term b. Then Dmt, 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 Dt).

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 rationalized by assuming that each uninfected individual has a constant and equal propensity to catch the disease, from the contact with 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: [mt(n-mt)]Dt.

It follows that Dmt is equal to:

$$mt+1-mt=b[(n-mt)mt/n], (b>0)$$

where, the parameter b is the speed of diffusion or the rate of diffusion.

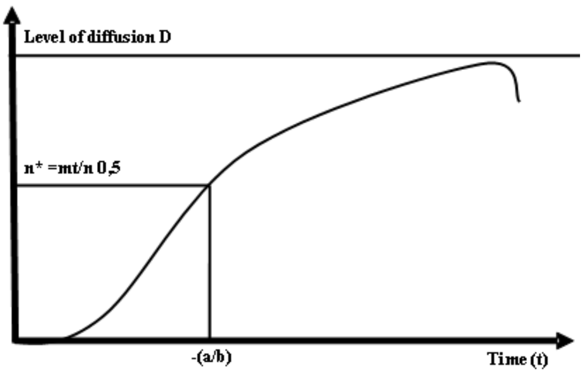

Fig. 2. The logistic epidemic curve.

This is rationalized 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 short, then the above equation can be rewritten, as:

$$dmt/dt[1/(n-mt)]=bmt/n$$

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

$$mt/n=\{1+exp(-a-bt)\}-1$$

New product variants enter into the market; products produced above average efficiency extend their market shares and below average products lose market shares and sometimes exit from the market. The epidemic model of technology diffusion is applied to depict this evolutionary process through which economic selection proceeds. The diffusion process is described by a complex equation, which is illustrated by the following simple logistic function (Gunnarsson Jan, Torsten Wallin, 2008), where a is a constant of integration.

If one plots mt against the time (t), the profile will follow an S-shaped curve (sigmoid curve). This is the well known logistic time curve. As we can see,

Figure 2 predicts that the proportion of the population having contacted the disease will increase at an accelerating rate until 50%, when infection is attained at time t=-(a/b). Thereafter, infection increases at a decelerating rate and 100% infection is approached asymptotically.

The upper limit of the curve will be (which itself has a maximum of 1, when t increases infinitely which follows from the assumption that all firms were potential adopters). The logistic curve has an infection point at mt=1/2, where the adoption process accelerates up to a point where the half of the population of firms have adopted and decelerates beyond. Empirical tests are straightforward using the linear transformation:

$$\log[mt/(n-mt)]=a+bt$$

There is a huge literature on the law of logistic growth, which must be measured in appropriate units. Growth process is supposed to be represented by a function of the form of the above third equation with t to represent the time. Population theory relies on logistic extrapolations. The only trouble with this 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 summarize the following disadvantages:

- 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;
- all individuals must have an n equal change of catching-up the disease.

That means, b is the same for all groups within the population. Moreover, there are a number of other assumptions which may prove unrealistic for the logistic solution, (for instance, constant population is required).

3. MODELLING GROWTH AND DIFFUSION PROCESSES: THE APPROACH OF PROBIT MODELS

Spatial growth processes may assume a variety of different forms. We will commence the analysis of spatial dynamics in the context of diffusion models of probit analysis.

The probit analysis has already been a well-established technique in the study of diffusion of new products between 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) interval for all X. 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 may be represented as:

$$Pi=F(a+bXi)=F(Zi)$$

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:

$$Pi=a+bXi$$

There are numerous alternative cumulative probability functions, but we will consider only two, the normal and the logistic ones. 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 Zi which is determined as an explanatory variable X. Thus, we can write:

$$Zi=a+bXi$$

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

$$Zi=F\text{-}1(Pi)=a+bXi$$

In the language of probit analysis, the unobservable index Zi is simply known as normal equivalent deviate (n.e.d.) or simply as normit.

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 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 is distributed across the population as f(z) with a cumulative distribution F(z), as the Figure 3 illustrates. The advantage of the probit diffusion models is that it relates the possibility of introducing behavioral assumptions concerning the individual firms (firms). The probit model also offers interesting insights into the slowness of technological diffusion process.

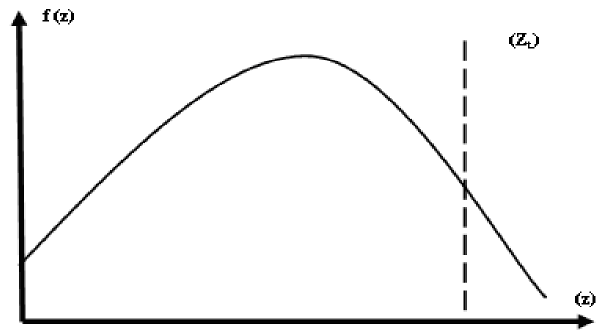

Fig. 3. The cumulative distribution.

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):

$$Pt=N(logt/mD,s2D)$$

$$Pt=N(t/mD,s2D)$$

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

$$Pt=N(Zt/0,1),$$

where: Zt may be defined as the normal equivalent deviate or normit of Pt, where given values for Pt, Zt can be read off from the standard normal Tables.

Re-arranging the equations the last two equations in terms of the standard normal function, it follows that:

$$Zt=(logt-mD)/sD)$$

$$Zt=(t-mD)/sD)$$

For empirical purposes, it must be remembered that Pt 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 mt/n.

However, to employ the variable Zt 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 is used 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 x2 method. In this context, the minimum normit X2 method amounts the following weighted regressions:

Zt=a1+b1logt (for group A which corresponding to cumulative lognormal),

Zt=a2+b2t (for group B which corresponding to cumulative normal),

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

4. CONCLUSIONS

Diffusion is the spread of a technology through an economy or industry. The diffusion of a technology generally follows an S-shaped curve, with early version of technology being rather unsuccessful, followed by a period of successful innovation with high levels of adoption, and finally a dropping off in adoption as a technology reaches its maximum potential in a market. Innovation and diffusion are virtually synonymous with long-run economic growth.

Diffusion is the process by which innovations (by the new products or new processes) are spread within and across economies. 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. Innovation and diffusion in a long-run way and should be expected to explain medium-run variations in the growth of GDP and productivity. 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:

- the cumulative lognormal curve and;
- the cumulative normal curve.

The exact forms of these curves can be varying according to the diffusion technologies and the diffusion period.

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