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INNOVATION DIFFUSION: CONTEMPORARY GEOGRAPHICAL APPROACHES G. Clark

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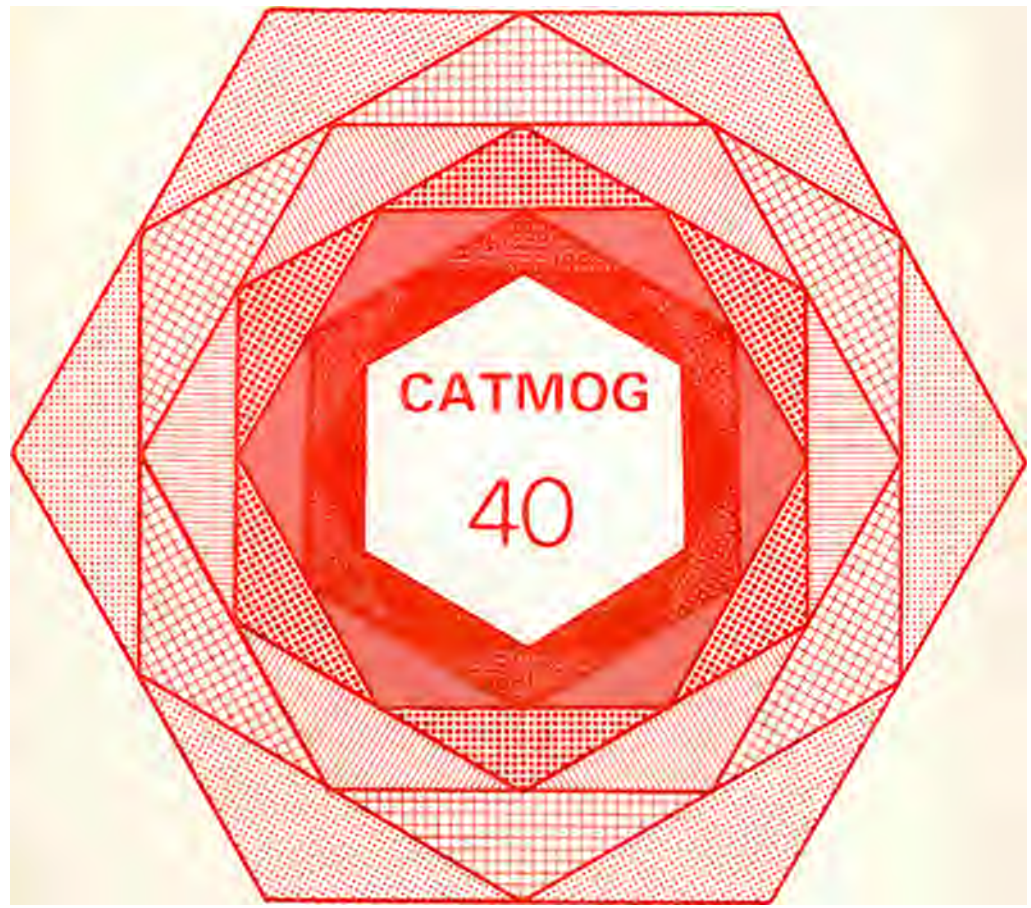
G. CLARK



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CONCEPTS AND TECHNIQUES IN MODERN GEOGRAPHY No.40

INNOVATION DIFFUSION: CONTEMPORARY GEOGRAPHICAL APPROACHES

by

G. Clark
(University of Lancaster)

CONTENTS

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I should like to acknowledge the helpful suggestions of Tony Gatrell and the referees, the assistance of Mrs. Jean Burford and Miss Maxine Young who typed this volume and the skill of Mrs. Anne Jackson (Cartographic Unit) who drew Figures 2, 3 and 5.

Dedication

To AHK and EFK

I INTRODUCTION

The new is always fascinating. Change is a major concern whether at a personal level or an intellectual one; it is with change that this monograph deals. New ideas and inventions are never accepted simultaneously by everyone; change is progressive and uneven. Equally, it is not a random process but one with a structure which may be predicted on the basis of earlier developments. This structure is at the heart of innovation diffusion studies.

The field is a large one; in 1982 the *Social Science Citation Index* listed 301 new publications during that year which contained within their title the key word 'innovation(s)', 'innovator(s)', 'innovative' or 'innovativeness'. Every social science was represented, which is readily understandable since we are studying the role of innovations in the changing relationships between society and economy. This may imply that we are dealing with a truly social-science theory. In reality the field is more fragmented than this with good links between, for example, the geographical and sociological contributions to the field, but poorer links between the work of social anthropologists and either geographers or economists. This is particularly true for studies based in the developed world: research in the Third World has succeeded in generating rather greater interaction between the social sciences.

(i) Defining the field

Convenience and practicality suggest that the scope of innovation diffusion studies be restricted by defining the terms 'innovation' and 'diffusion'. In many early studies the term 'innovation was confined to technological developments, particularly machinery. This had the merit of identifiability since the innovation was a physical object with clear boundaries, usually very similar to other objects with the same name which were produced in a factory to a restricted range of standard designs. Thus a tower silo, combine harvester or steam train present the researcher with relatively few problems of identification. More recently 'innovation' has been widened to include new methods of organisation (eg. a co-operative or flexi-time), or political developments (eg. a land reform movement or riots) which are less easy to define. At what point does a noisy meeting become a fracas, hooliganism, a fight or a riot? If the events were not personally witnessed by the researcher, the difficulty has to be faced of relying on descriptions given by a variety of, perhaps, partisan observers or even participants. Nonetheless, a wide definition of innovation will be used in this book and so our concern will be with 'change' broadly conceived (Rogers, 1962).

The diffusion of innovations means the way new ideas are accepted (or not) by those to whom they are relevant. Geographers have often concentrated on the spatial aspects of diffusion, illustrating their work with maps of successive distributions of the innovation; the contribution of HNgerstrand (1952 and 1953) has been influential in the use of such maps. Geographers have been concerned to model these distributions, to predict the spread of similar innovations in the future and to explain why adoption is faster in some areas than others. Other social scientists, particularly rural

sociologists, have investigated the characteristics of the early adopters of innovations in order to see if particular traits are correlated with personal innovativeness (Rogers, 1962). Again, a predictive or explanatory purpose is evident in this work. Diffusion can, of course, be speeded or hindered. It may be accelerated by salesmen of various kinds, and their influence on diffusion has been studied (L. Brown, 1981). Others have measured the barriers to diffusion which may exist in the form of mountains, patents, cultural norms or the lack of the complementary infrastructure needed for an innovation (Yuill, 1964). The eventual concomitant of adoption is abandoning the innovation in favour of something else - this 'diffusion in reverse is sometimes called the paracme of the innovation (Ilbery, 1982; Barker, 1977).

A general distinction needs to be made between diffusion and invention. Diffusion starts once the innovation has been invented and developed to a usable form. Technical modifications may occur during the period of the innovation's spread of course, but the initial invention or the first application of the innovation is usually taken as the datum for diffusion studies.

There is also a large volume of work on the diffusion of diseases. Although some geographers have played a part in the development of such epidemiological studies - the geographer's techniques of spatial analysis are invaluable (Gilg, 1973) - the underlying processes are quite distinct. Circumstances may raise or lower an individual's genetic susceptibility to a disease but no one consciously chooses to have measles; on the other hand, free will and decision making are often components in the study of socio-economic changes. Disease diffusion needs an altogether different theoretical explanation and consequently is outside the scope of this monograph.

(ii) Components of the field

The immense volume of work on innovation diffusion has inevitably produced a corpus of literature which is very diverse in its purpose, structure and scale of analysis. Consequently, it is helpful to have a model which classifies this literature. We may identify three types of study, with a creasing scale of generality, which may be called the structural, process, and cultural components of innovation diffusion (Figure 1).

The structural component is the most abstract and is at the highest level of generalisation. It describes the role of innovations in the evolution of the structure of societies and economies; the relationship is usually conceived as involving an interaction between innovations and socio-economic structure. Thus current society and economy mould innovations and their diffusion; innovations in their turn are part of the mechanism by which society and economy evolve and affect each other. The structural component of the literature explores these interrelationships. At this level, innovation diffusion theory is related to other theories, particularly those concerning the state and development.

The process component is perhaps the most varied of the three in the way it has developed, and certainly it has come to acquire the status of the orthodox geographical approach. The characteristic unifying this large volume of work is its concern to make general statements about aspects, or types, of innovation diffusion. There is more concern than in the structural component to place diffusion (or some case studies) at the centre of the study and much less emphasis on diffusion in its wider context. Attention

STRUCTURAL COMPONENT	PROCESS COMPONENT	CULTURAL COMPONENT
(Chapter III)	(Chapter II)	(Chapter IV)
a) Modelling how society and economy affect, and are affected by, innovation diffusion b) The role of innovations in the interactions between society and economy	Analysis of a) an aspect of innovation diffusion b) innovation diffusion under specific circumstances c) spatial patterns of diffusion	Case studies of one or a few specific innovations stressing their cultural context and their interrelationships with their own societies and economies
Links with other theories		
Theories of development, location and the (local) state	Decision-making theory Theory of the firm	Anthropological and cultural theories

Figure 1. Components of innovation diffusion

is focused on either a systematic aspect of the process - the role of communications, innovativeness or salesmen, for example - or on innovation under a tightly constrained set of circumstances - the work of Hägerstrand, for example - or on the spatial patterns of diffusion. The results of these process studies tend to be specific to particular circumstances; a period of history, a region or a type of socio-economic organisation. Links to other theories are sometimes made; decision-making theory and the theory of the firm, for example.

The cultural component also includes a large number of studies and is distinguished from structural and process studies by having the lowest level of interest in inductive generalisation from particular studies to whole societies and economies. The component includes case studies conducted either for their own sake or because of a practical interest in one specific innovation. The focus is on the detail of the innovation, on what it means to different people and on exactly how it affects, and is modified by, its particular cultural context. Many studies by cultural geographers, social anthropologists, local historians and agricultural development agencies fall into this category.

Like all classifications, this threefold grouping is only a guide; some studies transcend the categories. In addition it should not be interpreted as suggesting that the categories are mutually exclusive. Process and cultural studies must contain some framework of structural assumptions even if these are of secondary interest or, indeed, are left unacknowledged. Similarly, structural studies are illuminated by knowledge of how specific innovations have spread (the process component). The best cultural studies are concerned with how new ideas alter the workings of a specific culture; it is a difference of scale, therefore, which lets us distinguish the cultural component (a micro-scale) from the structural (a macro-scale) with process studies intermediate in their scope. All three are components needed for a full understanding of the field.

It is helpful at this point to distinguish between two aims for innovation diffusion studies which have affected the form it has taken. Agnew (1979) identified an instrumentalist view and a realist view. The former regards the function of theory as the reduction of what is complex and unfamiliar (reality) to something simpler and understandable (a model). This approach leads naturally to simulation models, often formulated mathematically, and the prediction of future diffusions on the basis of past ones. Thus a model showing general empirical regularities is conceived as a prediction before the event and, if model and outcome are similar, a successful explanation after the event. Explanation and prediction are, therefore, the two faces of the same coin of understanding. This instrumentalist view is very similar to the positivist conception of (social) science described by Keat and Urry (1975) and others. A realist approach, however, views explanation and prediction as separate processes either of which can be carried out successfully without the other. Good predictions need tell one nothing of the processes which affect diffusion, and an understanding of the processes need not help forecast future diffusions. A realist view sees the causal explanation of events as the central task; simulation and prediction are descriptive rather than theoretical statements. Researchers into innovation diffusion can be found in both the instrumentalist and realist traditions.

Innovation diffusion studies have evolved considerably during the last thirty years and this parallels to an extent the shifting focus of interest in geography as a discipline. M. Brown (1981) has interpreted recent work as a series of critiques of, and developments from, the writings of Hägerstrand and his work is described first in Chapter II.

II THE PROCESS COMPONENT OF INNOVATION DIFFUSION

How do innovations spread? Some people adopt them, others are unable to and a few may have a professional or personal interest in their diffusion. Process studies are concerned to make general statements about the mechanisms by which innovations are accepted and so spread over an area or through a society and economy. Consequently much, though not all, of the work in this tradition has been concerned with adoption by individuals or organisations at a micro-scale; case studies have played a prominent part and inductive generalisations based on these have often formed the results of this research.

The volume of process studies is immense and it is useful to distinguish two emphases which may be called the demand and supply approaches. The former (the more diverse and extensive) focuses on the adoption of innovations which are available to everyone: the critical question to be answered is why some people accept the innovation before others. The supply approach deals with cases where the innovation is not universally available since its supply is controlled. Many real-world innovations require both approaches to be successful, although most studies have used only one of them.

(i) The demand for innovations

The demand side of process studies, for a long time the only approach used, drew some initial inspiration from cartographic evidence of the spread of innovations. Work by Hägerstrand (1952) on the adoption of motor cars in

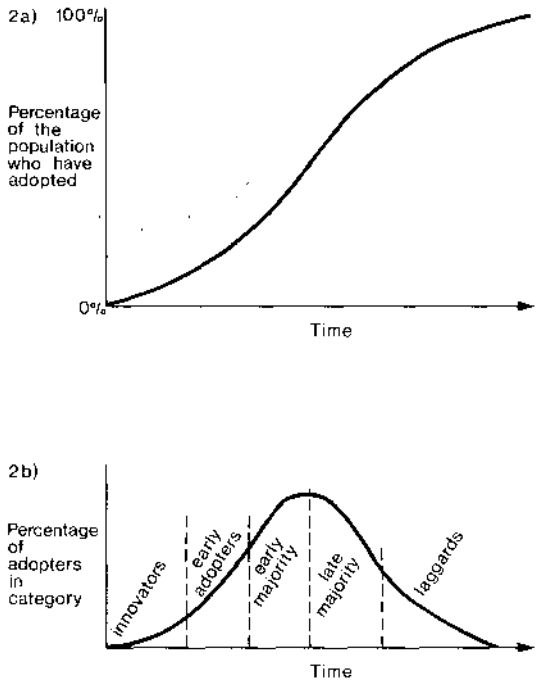


Figure 2. Cumulative adoption of an innovation:
a) the cumulative proportion of adopters
b) the early and late adopters

Sweden in the 1920s comprised a series of maps showing how car ownership spread geographically. There was a clear element of simple outward expansion from a small number of starting points and so this came to be called a contagious or neighbourhood pattern; Hagerstrand used the metaphor of a wave of adoption and others have extended it and elaborated it mathematically (Morrill, 1970; Hudson, 1972). Other studies showed that cities often acquired new ideas before the countryside and so hierarchical and neighbourhood patterns may co-exist: nationally diffusion may be hierarchical (from the largest cities to the smallest, for example) while locally it may follow a neighbourhood pattern. Furthermore, the cumulative proportion of the population who have taken up an innovation often follows a curve such as that shown in Figure 2a - a few early pioneers, a steep rise as the early and late majority take up the idea and then a tailing off as the laggards eventually complete the diffusion. This curve has often been called a logistic curve, this being the classic pattern for the diffusion of infectious diseases. However, this curve assumes that the innovation's attractiveness is constant over time and that the susceptibility of potential adopters to accept is both constant and equal for all adopters. The inherent

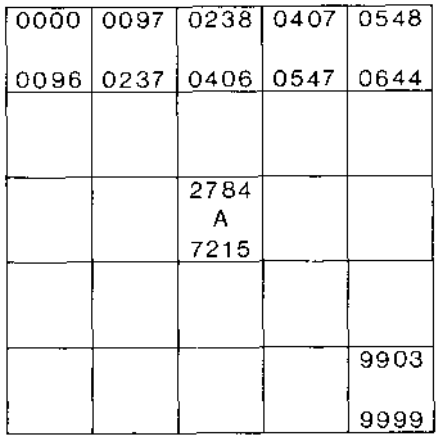
implausibility of these assumptions suggests that cumulative adoption does not follow a logistic curve (as has been widely claimed) but rather approximates to one of the other curves with an S-shape (eg. a cumulative log-normal curve) (Davies, 1979). Much early work took the neighbourhood and hierarchical patterns and the supposed logistic curve and based studies around their explanation and simulation.

a) Hagerstrand's contribution

In 1953 a Swedish geographer, Torsten Hagerstrand, published perhaps the best known study in geography of innovation diffusion. He was influenced by the cultural geography of Sauer (1952) on the spread of new crops and livestock. Hagerstrand's research concerned the acceptance by Swedish farmers of certain government subsidies and grants which were available to all farmers but which some claimed before others. Explaining why this should be so was his task.

He started from the observation that those who had accepted the subsidies most recently tended to be the neighbours of previous adopters. Hence there was a pattern of expanding clusters of adopters. From this he supposed that the critical factor promoting adoption was face-to-face communication; one farmer recommending the idea to another who was most likely to be a neighbour since personal mobility was limited and social interaction was localised. He attempted to measure by indirect means the rate at which person-to-person communication declined: he used surrogates such as the reduction in telephone calls and local migration with distance. Having in this way estimated the distance decay in the transmission of information, he then constructed a probabilistic model to simulate the wave-like diffusion of the acceptance of the subsidies. A series of random numbers was generated and used to locate new adopters within the 'mean information field around each existing adopter (Figure 3). This was constructed so as to ensure that there was a high probability of new adopters being near the existing ones. The mean information field was placed over each existing adopter who then generated one new adopter. When all the existing adopters had produced a new adopter, a new round in the simulation started. The existing adopters and the new ones from the previous round generated another new set of adopters. Soon the rapidly expanding number of adopters saturated the core area where the diffusion had started and the proportion of adopters also rose in the peripheral areas. Finally everyone had adopted the innovation and the simulation came to an end. This method of simulation is called a Monte Carlo technique and it can model quite closely an S-shaped curve of acceptance and a neighbourhood pattern of adoption. It is a flexible technique and many later diffusion studies have modified it (eg. Bowden, 1965; Johansen, 1971; Yuill, 1964). The probabilities in the mean information field can be modified to reduce diffusion in a particular direction in order to simulate a topographic or cultural barrier to communication. Some geographers have used different variables to estimate the decline in communication with distance. It is even possible to simulate having to tell a potential adopter two or three times before he 'gets the message'.

This method of analysing diffusion was itself innovative and was used by other researchers. While it might be a slight exaggeration to go as far as M. Brown (1971) and claim that all recent work has been a reaction to unsatisfactory aspects of Hagerstrand's model, it is nevertheless true that this model is best seen as applicable to diffusion only under a very specific



The mean information field is placed over each adopter in turn; here an adopter is at point A. What will be the location of the next person to adopt under the influence of A? To find out, generate randomly a four-digit number and locate this on the grid. If the number were 0007, the next adopter would be in the top left-hand square; if it were 9995, he would be in the bottom right-hand square. Since 44 per cent of the random numbers are in the central square, the next adopter is most likely to be very near A; he is unlikely to be a great distance from A although peripheral locations are still just possible.

Figure 3. Hagerstrand's mean information field

set of circumstances. His original data (the actual pattern of adoption) has been extensively re-analysed with statistical techniques not available in the early 1950s. Cliff (1968) has cast doubt on whether the original pattern of adopters was in fact clustered since he was unable to demonstrate that there was a significant neighbourhood effect. Cliff and Ord (1974) have also used Hagerstrand's data to assess the closeness of the evolving pattern generated by the model to the actual diffusion of the innovation. This work on spatial autocorrelation has questioned whether the exact form of the model used by Hagerstrand captures all the features of the actual dissemination of the innovations.

More fundamental than these questions about patterns is the criticism that even if the model were a perfect simulation of reality it would be of little explanatory or predictive value. It is difficult to argue that the model is of general predictive value unless the socio-economic circumstances found by Hagerstrand are replicated; that is, an innovation of low cost, available simultaneously to all', with few infrastructure requirements, introduced to a homogenous group of uniformly small-scale pastoral farmers for whom personal contact with neighbours is dominant. If any of these conditions is seriously violated, no amount of calibration will make the model useful.

The explanatory value of the model is also limited because Hägerstrand produced little evidence about the nature of actual communication in his area. The model was based on unproven assumptions about the primacy of conversation among neighbours in encouraging adoption. Therefore, it tells us nothing of the processes involved in adoption or diffusion although it may suggest hypotheses and directions for future research.

The diffusion of innovations was modelled by Hägerstrand and others within a framework of two dichotomies; whether the pattern of adoption is hierarchical or contagious and whether the spread of the innovation is controlled by (and hence can be predicted using) economic or social variables. Hägerstrand modelled it as a contagious and social process. Sheppard (1976) has used Pedersen's (1970) model to investigate these dichotomies. The model takes the form:

$$I_{ij} = k.P_i.P_j^{\alpha}/d_{ij}^{\beta}$$

where I_{ij} = the interpersonal interaction between zones i and j

P_i and P_j = the populations of zones i and j

d_{ij} = the distance between zones i and j

α and β = exponents

In this model, as α tends to zero, so interaction becomes increasingly a function of distance (ie. a contagious pattern). As β tends to zero, so interaction becomes a function of population size (ie. a hierarchical pattern). This gravity model formulation recognises explicitly that elements of both patterns may be present in the diffusion of any specific innovation. Sheppard's study of the spread of planned regional shopping centres in Canada used an extension of this model and regression analysis to measure whether social or economic factors were the better predictors of the timing of adoption. There were two main conclusions:

a) diffusion becomes more contagious lower down the urban hierarchy;

b) in all cases economic and social factors are both influential but the economic are usually the more important. (Webber and Joseph's parallel study in 1977 suggested that the economic factors are particularly important early in diffusion.)

The difficulty with this model, as with so many of a mathematical or statistical character, is that one is unclear how valid are the conclusions. Sheppard commented that the reliability of the exponents in his model depended on an evenly distributed population and he noted that variations in personal preferences for spatial interaction will affect the parameters. More generally the operational definition of concepts such as 'economic' and 'social' factors is treated as unproblematic which clearly is not so since these terms are susceptible to a wide variety of definitions which could affect the results. In this case, population size is a major variable used in the definition of both factors. Furthermore, Pedersen's (1970) comment on his own influential model is germane. "Consequently, although mathematical in formulation, the present model is qualitative in scope and simple in structure." He goes on to note how predictions using such models are not likely to be reliable since the model's calibration (the values of the constants and exponents) is purely a matter of trial and error. It is based

on inductive generalisation from case studies which are not necessarily valid in other contexts, unless we make the very ungeographical assumption that innovation diffusion is the same everywhere and under all circumstances. Indeed, Pedersen's long-term view of innovation over the centuries requires one to note how the parameters and exponents are likely to change over time as communications improve and, what is more, they will alter at different rates and perhaps in different ways for different places and different social groups. The value of mathematical modelling lies in formulating the model since this forces one to think clearly about the nature of the diffusion process and what meaning should be attached to important concepts like 'economic factors and 'communication'. Actually calibrating the model is of secondary importance, being of more descriptive value for the case study in hand than of theoretical or explanatory value.

Hudson (1972) noted rightly that stochastic rather than deterministic mathematical models were conceptually better particularly when dealing with small groups. However, non-linearities make the stochastic models complex to solve explicitly and so deterministic mathematical formulations have been favoured. It is also arguable that the nature of the pattern of diffusion and crude explanatory terms such as 'economic factors' or 'interaction' are of little use in explaining the processes at work. Several possible processes can be hypothesised from any given pattern. It is to the study of processes and particularly those involving communication and interaction that we now turn.

b) Communications

The original formulation of Hägerstrand's model and of several others which followed could be criticised for treating the flow of information as a simple and self-evident process. Much research has been conducted into the true effect and prediction of information despite obvious practical problems in defining and measuring so nebulous a concept.

One approach has been to treat communication or interaction as though it were a physical force similar to magnetism or gravity whose strength could be estimated by reference to surrogates such as the size of the interacting places and their distance from each other. This gravity model formulation was developed by Webber and Joseph (1978; 1979) to predict when information about an innovation would reach a given city. To make this prediction for a specific innovation and city, it was necessary to know only five things: the settlement pattern, the size of the largest city, the diffusion rate of the innovation, the extent to which there was a distance decay in information flows, and the nature of the rank-size distribution of settlements. This instrumentalist model gives priority to simplification of the process rather than understanding its components in the real world. The model also has other limitations as a genuinely predictive tool rather than as a useful *aide-memoire* of important factors in the rate of diffusion. Some of the factors are not independent but interact with each other (eg. the settlement pattern and the rank-size distribution of settlements) and some are difficult to estimate in practice (eg. distance decay in information flows). It is not clear how to incorporate into the model the country's level of economic development and the nature of the media, telecommunications, the education system and the system of government.

An alternative approach has been to disaggregate 'information and 'interaction' into the specific types of communication which comprise these terms. There is person-to-person information, the mass media, sales literature, specialist advisers and the specialist press; together these form the 'information' a person receives. Some sources are more important in the early stages of adoption (the mass media often first alert potential adopters and are now an urban-dominated source of information) whereas specialist advice is more important in the run-up to a final evaluation and decision. Some sources are more influential at particular stages of economic development, and so are important in different countries and periods of history. It has also been suggested that early adopters are more willing to act on specialist advice whereas later adopters rely more on personal recommendations from family and friends.

Attempts to measure information flows have been rather limited, doubtless due to the practical problems entailed. Adams, however, has established the network of correspondence between leading Scottish landowners in the late eighteenth and early nineteenth centuries (Adams, 1980). This group, sometimes also related to each other by blood or marriage, instituted many of the changes in farming which in a few decades transformed the Scottish countryside. Adams has traced letters favourable to the enclosure of farms, new forms of lease and planned villages. This provides us with some tangible, and all too rare, evidence of the efficacy of information flows for innovation diffusion (Figure 4).

Other researchers have questioned whether neighbours still have the most influence. When all farmers produce the same crops and animals on roughly the same scale, then neighbours' opinions may well be relevant. However, if a farmer is one of three who grow between them 95 per cent of British cucumbers, then there are only two other farmers whose views are important, and this is true irrespective of where these three farmers are situated relative to each other. Peer-group communication may have superceded family and neighbours as the most influential for would-be adopters of innovations now that social fragmentation, economic specialisation, personal mobility and migration have proceeded so far (Maclennan, 1973).

Studies of information have often been rather simplistic tending to separate information from behaviour, and to minimise the extent to which individuals operate under constraints and are able to seek out their own information from a wide variety of sources. Hudson (1972) has tried to build a model of communications which allows for both mass media and interpersonal interaction within and between 'mutually influencing groups' of varying cohesiveness (eg. socio-economic groups). In this model it is possible to simulate several features of communication such as people changing their opinions and a variable or constant rate of diffusion. Yet even this model cannot cope with a non-random mixing of population, nor with variations in the number of contacts and in the time lag as diffusion progresses. The mathematical models of diffusion are still too simple to be realistic and yet too complex to be usable in practice.

c) Innovativeness

Running parallel to the work of geographers on the spatial patterns of diffusion were studies of the socio-economic character of adopters, these being held to help explain differences in the timing of adoption. This work

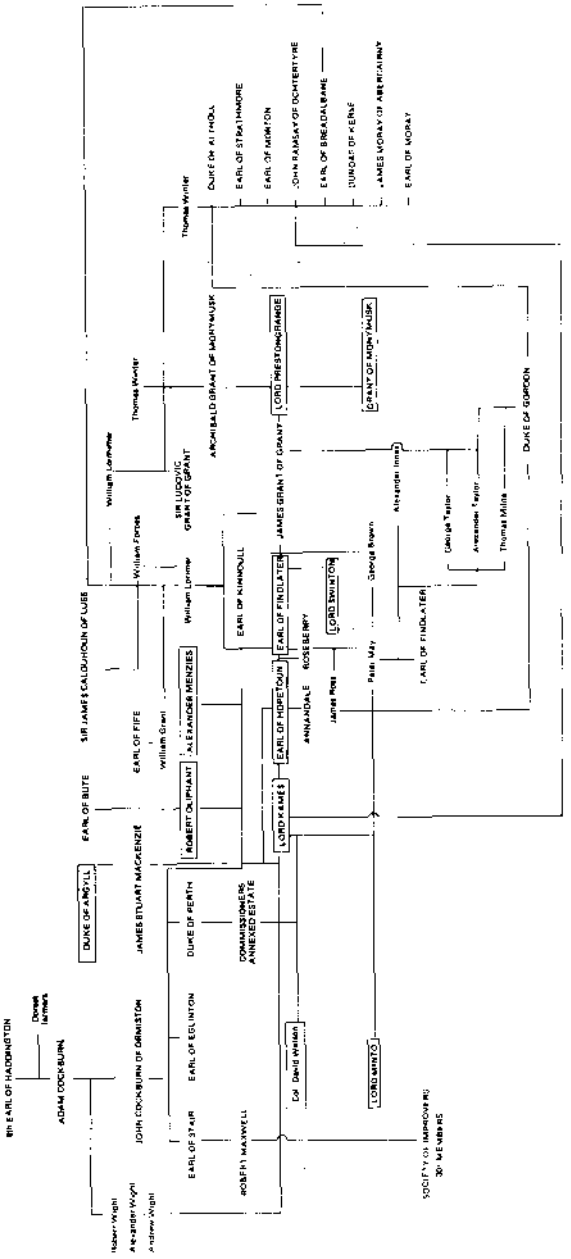


Figure 4. Communications about agricultural innovations between major Scottish landowners in the mid-eighteenth century (From Adams, 1980, p. 158)

Each line represents documented flows of information. Every Scottish county is represented in the diagram.

was particularly relevant to development agencies and salesmen who wanted to know who was most likely to adopt first and so set an example to others. The essential concept here proved to be 'innovativeness - the propensity to be among the earliest adopters of innovations - the people at the left-hand end of Figure 2b. This has proved to be nearly as elusive a concept as 'information', although early work was quite dogmatic in its conclusions. Rogers (1962) identified a series of dimensions with early and later adopters as complete opposites. Early innovators had the following characteristics: a modern orientation, use of more impersonal and technical sources of information, younger, higher social status, wealthier (often indicated by a surrogate such as farm size; Bowler, 1976), more specialised businesses, a more cosmopolitan outlook, and they acted as opinion leaders.

This sort of typology has been criticised and questioned recently on two grounds. First, its characterisation of late adopters has been seen as too harsh and too ready to 'blame the victim'; the pejorative term 'laggard' is used as frequently as 'late adopter' in the literature. Late adopters include those almost too poor to afford the innovation and those for whom it is only marginally suited on technical grounds. Others may not adopt because they are not in the business (farming, for example) in order to maximise production or profits; a pleasant life, low work-load and scenically attractive farmland may be more important for them. The typology has also been criticised because some studies have produced contradictory results. Youthfulness, for example, and wealth tend to be positively correlated with innovativeness yet the young tend not to be wealthy and the wealthy not to be young. Literacy is another problem variable - in developed countries it may well be associated with innovativeness whereas in less developed ones this need not be so. Status also presents difficulties when associated with innovativeness. Status may be a historic relic of deference (the British aristocracy, for example); it may not be related to present-day power or trend-setting. Indeed, the diffusion of some innovations is negatively correlated with status as conventionally measured - television and package holidays in Spain, for example, were less rapidly accepted by high-status British people. Finally, as an antidote to the tendency in the literature to hero-worship innovators and castigate laggards, it is worth noting the findings of Linton and Barnett on early adopters: "very frequently misfits in their societies, handicapped by atypical personalities", "truly marginal individuals", and "the disgruntled, the maladjusted, the frustrated or the incompetent are pre-eminently the acceptors of culture innovations and change" (quoted in Rogers, 1962).

d) Properties of the innovation

The rate at which an innovation is accepted is also likely to be affected by the innovation itself. This is an under-researched area but Rogers (1962) has identified five aspects of an innovation which will affect its attractiveness to those for whom it is relevant. He argued that speedy diffusion would be a feature of innovations which have a high relative advantage over current practices, are compatible with other aspects of the culture, easy to understand, divisible and have advantages which are easy to describe.

Relative advantage is the most difficult concept to define, since it may refer to advantage over periods of time of various lengths; short-term and long-term advantage may not be the same. The concept may also be used with respect to the innovation's capital cost (relative to other investments) or

its effects on the running costs of the system (relative to current running costs). Very few measurements of the relative advantage of innovations have been taken. The attractiveness of innovations which are compatible with existing practices is obvious; for example, the incompatibility of a co-operative movement with a basically individualistic society will handicap its diffusion. The hindrance faced by complex innovations, such as computers, is considerable even when they bring major benefits. Divisibility is a useful trait for rapid adoption since it means that small-scale trials can be conducted before a major financial or organisational commitment is undertaken. A new crop can be tested first in a small plot, whereas even a prototype nuclear power station represents a major indivisible investment. Divisibility helps useful innovations and expensive ones to spread rapidly. The analysis of the diffusion of any innovation needs to use these five criteria to help explain its progress.

Such an analysis would also have to bear in mind that the innovation itself may change as it spreads. Hybrid maize, for example, was not one innovation but several, different varieties of maize each developed at a different time for distinct environmental conditions (Griliches, 1957). Industrial products are frequently modified to suit different conditions after their launch through improvements in design, robustness, capabilities or cost. Therefore we may argue that the simple curve in Figure 2a is inaccurate for many physical products since it fails to show that the innovation is often a family of products each designed for a separate market. The cumulative adoption of an innovation may, therefore, be illustrated better by Figure 5. The upper curve corresponds to the simple S-shaped curve as traditionally measured. The lower curves represent the separate diffusions of three variants of the product which in total form the upper curve. Each variant meets the needs of sub-markets of different sizes. Later variants

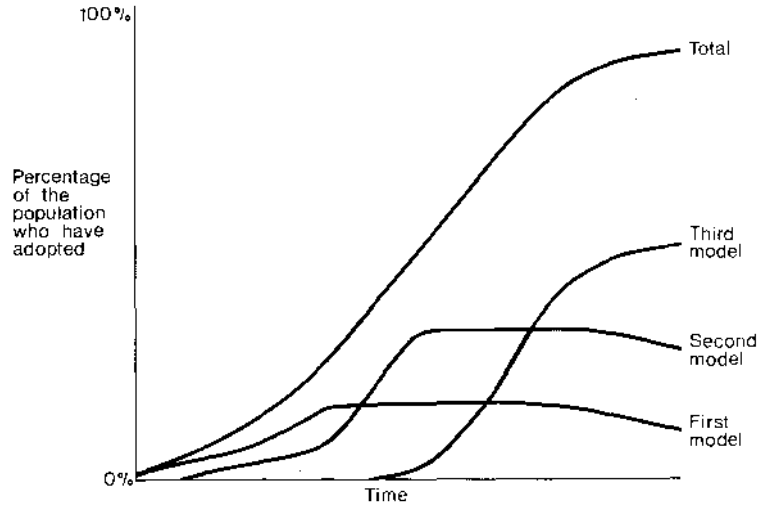


Figure 5. Simple and compound logistic curves

diffuse faster than the earlier ones and, towards the end, the early markets switch from the first models to the later, improved versions. Clearly, therefore, the slow take-up of a product in its early days (the left-hand end of the upper curve) can partly be explained by adopters waiting for anticipated improvements to be made and fearful of the cost and unreliability of adopting an incompletely developed product.

e) Decision making and demand

Studies of the demand for innovations have also made use of work on decision making and the behavioural approach adopted elsewhere in geography. An early attempt was to model adoption as a progression through a series of stages - awareness of a problem - awareness of the innovation as a possible solution - gathering information about the innovation - trial - evaluation - adoption. At any point in this progression the innovation might fail to meet requirements and be rejected; only if it passes all these tests is it accepted. This model was a fruitful one since it was possible to attach to it several of the ideas already discussed in this chapter. Different sorts of information (personal or impersonal, from friends or specialists) played their part at different stages in the model. The divisibility of the innovation was important in determining how easy a trial would be, while its complexity and compatibility would be critical at the evaluation stage.

There have been few case studies of the exact stages followed by those evaluating an innovation but work on a related problem (industrial location) suggests that a stage-by-stage model of decision-making is more a normative statement (how it would be done in a rational world) than a description of the much more incoherent way real decisions are made. The question of whether information, for example, is assessed properly in the evaluation of innovations is particularly relevant here. Audley commented that "what makes up a mind is its history, and evidence too - but only if that is in the right direction. Or to put it another way, minds quite often come already made up" (Castles *et al.*, 1971). Personal history may not, of course, be relevant to the evaluation of the innovation, while evidence not in the right direction may be vital. A lack of time or resources may also curtail evaluation of the choice and lead to hasty and perhaps sub-optimal decisions about adoption (Flowerdew, 1976).

If pre-existing attitudes are at least as effective as fresh evidence, the origin of attitudes and preferences becomes important in the study of innovation diffusion. The danger lies in seeing attitudes as an independent and external influence on decisions. Attitudes have a reflexive relationship with behaviour and what is possible, while behaviour and decisions may reflect neither real nor professed preferences. Preferences are tempered by what is legally, administratively and financially possible and then actions can alter attitudes and preferences (what is called *post hoc* rationalisation). One might prefer a Rolls Royce but, if it is too expensive, one may buy a smaller car and take the view that one "never really wanted to buy a Rolls Royce, anyway".

The influence of the possible on attitudes is also important when considering the role of attitude to risk. A willingness to take risks has traditionally been seen as one of the hallmarks of early innovators whereas laggards were thought to be averse to risk taking (Jones, 1967; Gasson, 1973). Risk taking, with its connotations of pioneering and entrepreneurship,

was part of the reason for the laudatory way in which early innovators were treated. This must be questioned. In a study of farm amalgamations in Scotland, Clark (1977) found that although expanding farmers shared most of the socio-economic characteristics of early adopters, their principal, indeed only, reason for expanding their farms by amalgamation rather than by intensification of their existing land was that this was the less risky method of expansion. This was in spite of their view that amalgamation was more expensive and had smaller and slower financial returns. Jones (1962) has reported a similar finding to explain the adoption of refrigerated bulk milk tanks in Lincolnshire. Capital investment in this new way of storing milk on the farm neither reduced production costs nor raised output, but it did reduce the risk of financial loss inherent in the use of milk churns. Early adoption may involve buying something which will be improved later, the bugs in the system may cost money to correct, and the product may come down in price later due to competing models, a drive to mass production or the paying off by the manufacturer of tooling-up costs. Yet early adopters more than outweigh this technical uncertainty with their greater financial resources and so innovation does not necessarily appear risky to them.

(ii) The supply of innovations

There are some kinds of innovation, such as a government subsidy, which are available simultaneously to all potential adopters. If they do not all accept it at the same time, it is reasonable to explain the timing of their demand by reference to the adopters themselves - their distance from other innovators, their sources of information, their innovativeness, the local culture or their economic situation. However, this demand approach can only be a partial explanation if the supply of the innovation is not universal. In such cases it is essential to discover and explain the rationale behind the strategy for making the innovation available. This may be a purely academic exercise or it may be designed to improve future marketing strategies. This interest in the supply side as a set of constraints on individual behaviour parallels other managerialist studies in geography which seek to explore how a few key individuals control the allocation of resources (Bassett and Short, 1980).

The most extensive analysis of diffusion using a supply approach has been provided by L. Brown (1981). He considered the marketing strategies pursued by firms or agencies ('propagators') which supply innovations. He proposed a framework for the separate analysis of diffusion by propagators with different forms of organisation. An organisation with centralised decision-making, he argued, would adopt different marketing strategies to those employed in a situation of decentralised decision-making.

A centralised system of marketing would be much concerned with the order of entry into the various market areas (Hodgart, 1978). Different strategies may be used depending on, first, the financial resources available to the propagator and, second, his objectives. A lack of capital may force a propagator to give prominence, over all other objectives, to minimising the cost of marketing (eg. using an existing sales force or marketing in the home area). Alternatively the propagator might be in a position to attempt to maximise sales or profits. Therefore the dominant objective will affect the order and speed of entry into market areas. The sales and profits goals generally imply a ranking of areas with the best (ie. the most profitable or the largest volume of sales) being entered first. Sales maximisation implies

a more widespread marketing strategy, a faster build-up of sales and a faster diffusion. This will give the fastest return on the capital needed to develop the product, tool-up for its manufacture and acquire stocks of raw materials. Speed of return on capital and cash flow advantages may be decisive. On the other hand, profit maximising is more likely to be strongly hierarchical, especially for higher-order goods. Thus, the fastest, most modern trains operate on the busiest or most prestigious routes or those between the largest cities. A new variety of wheat is sold first in the main wheat-growing areas and only later in marginal regions. There is some scope, however, for alternative spatial strategies for achieving profitability. The product might be sold in the home area if transport costs are high and demand is price elastic. Alternatively, sales in major conurbations may yield greater revenues particularly for higher-order goods. Finally, propagators with an inferior product may seek out areas with less competition in order to maximise their profits through higher margins.

A decentralised system of decision-making, for example, a franchise system of marketing, will produce a rather different diffusion pattern. If the independent entrepreneurs are subject to weak or no co-ordination by a central agency, then the macro-scale diffusion will be more random. It will be a function of the distribution of entrepreneurs with sufficient capital and of the flows of information to such people. Profitability and the costs of logistics and transport will be less important. Brown suggests that this will lead to a stronger neighbourhood effect if diffusion is controlled by information flows. The important decision will be about the opportunity costs of using the entrepreneur's capital for this innovation rather than in some other way. The decision-making will be more restricted in terms of spatial choices than in a centralised system but more open in terms of the field of investment. Of course, the greater the degree of co-ordination within a decentralised system, the more likely it is that the marketing strategy will resemble that within a centralised system.

Finally, Brown considers briefly the much under-researched topic of diffusion where profitability is not the principal motivation for the propagators (eg. farm advisory services or family planning clinics). He concludes that there is usually a concern to maximise the service provided within the constraints imposed by the propagator's (usually restricted) financial resources. This leads to locating offices in the areas of greatest 'sales potential', that is, the districts with the highest demand or the greatest need for the advice or service. Consequently, the absence of the profit motive will lead to a diffusion pattern not too dissimilar to some of those used by commercial organisations.

So far, the supply of an innovation has been examined with respect to the physical availability of the product directly or through salesmen. However, the sales strategy may also be spatially influenced by the price charged; the higher the price, the more the potential availability of the product will be a reflection of the distribution of net disposable income in the target population. Charging the full cost of transport will reduce availability in areas distant from the warehouse - the extent of this will depend on the price elasticity of demand for the product. The channels for, and style of, advertising may reinforce the marketing strategy by stressing certain qualities of the product (eg. value for money, prestige) or linking the product with particular groups (eg. housewives, teenagers).

This discussion of the marketing strategy of firms should stress that propagators are not free agents able to control the availability of the product to their best advantage. Just as potential customers are subject to constraints of knowledge, conservatism or poverty, so organisations too are limited in what they can do. The product may require some pre-existing infrastructure over whose provision they have little control - electricity, literacy or a road network, for example. The diffusion of tube wells to supply irrigation water in Pakistan was accelerated by the advance of rural electrification since this improved their economics over diesel-powered tube wells (Mohammed, 1970). The supply of innovations dependent on infrastructure will of necessity be controlled by the distribution of the latter whatever strategy the company might wish to follow in an ideal world.

(iii) Industrial innovation diffusion

There is no good academic reason why the diffusion of industrial innovations should be considered separately, apart from the change of scale to diffusion among organisations (firms) rather than individual decision-makers. Yet the topic has been studied in partial isolation; many of the researchers have been economists rather than geographers or sociologists, and there is a lack of intellectual and methodological integration into the mainstream of diffusion studies. This isolation may be held to be sufficient to merit the field's separate treatment, although it is to be hoped that it will not prolong it.

Much of the research has reflected the fascination of economists with regression analysis as a technique and has attempted to use this to explain the timing of a firm's adoption of innovations by reference to characteristics of the firm and its industrial sector (Mansfield, 1961). It has attempted to define and predict the innovativeness of firms in the same manner as personal innovativeness has been studied. Several aspects of an industry are held to be diagnostic of early adoption; the aggressiveness of the managers (difficult to measure without a circular argument), weak trades unions, managers of wide experience of other firms or sectors, the size of the firm (increasing size is usually equated with faster adoption), the firm's labour intensity, the competitiveness and rate of growth of the industrial sector, and the size structure of the sector (the existence of a few firms of equal size is associated with the most rapid adoption) (Carter and Williams, 1971). The innovation itself also plays a part in the rate of adoption. A rapid spread is related to products with a high rate of profit, those which are not too complex or radical in their consequences for production or administration, and innovations which are additions to existing equipment rather than replacements.

Economists have also pursued in detail the relationship between innovation and the state of the economy, particularly interest rates, investment cycles and the volume of risk capital available. The importance of real interest rates rather than nominal ones has been emphasised recently by inflation; the real rate of interest is the nominal rate minus the rate of inflation. More important, however, have been the increasingly complex efforts to introduce even greater realism into the modelling of investment decisions by comparing the benefits of investments in innovations with other investments. This has involved including a time-preference (ie. a discount rate) in the innovator's summation of the relative costs and benefits of the innovation over a number of years. Subjective expectations of costs and

benefits have also been included, these varying greatly between investors depending on their access to information and different tolerances of uncertainty and risk. Carter and Williams (1971) suggest that the timing of investment in innovations is also affected by technical pride, copying competitors, the level of orders, expectations of future demand and accountancy conventions for paying off past investments.

The importance of a firm's organisational structure has also been stressed as a factor in innovation. This point has been made particularly clearly in the regional policy literature where regional variations in managers' innovativeness have been examined (Thwaites, 1982; Oakey, 1979). There is an emerging model of regional industrial geography which links the location of innovations with the organisational structure of multinational companies and Vernon's theory of the life-cycle of products (Vernon, 1971). According to this model, new products and the advanced technology needed to make them are developed first near the core of the multinational company - its headquarters and research centre. The manufacture of mature, well-developed products is then transferred to branch plants on the periphery of the company, perhaps in a foreign country where production costs are low. So the adoption of industrial innovations is modelled as paralleling the locational decisions made by multinational companies on where to manufacture their newer and older products (Alderman *et al.*, n.d.).

There is also a danger of circularity in our explanations of industrial decision-making. The education of industrial managers has been developed much further than that of farmers, and investment appraisal is always taught. The textbook method of making investment decisions tends to be based in part on mimicking the best practice in companies. Future studies of managers will have to remember that their actual behaviour is a mixture of 'natural' decision-making and how they have been taught to act on the basis of previous research studies. It would not be surprising, therefore, if behaviour similar to normative models of rational decision-making were found; businessmen are being taught to behave like this or, at least, to claim that this is how they act.

The use of the logistic, or any other S-shaped, curve as a summary of adoption over time by industrial firms poses considerable problems. Apart from the fact that the specific assumptions behind the logistic curve are not applicable to firms (see pp 7-8), any general historical model of this type implies that there is only one path for a firm to take, though some firms set out earlier along that path. This assumption of linearity (the lead-firm hypothesis) is also found in many models of spatial development, as well as in Rostow's model of economic development and in the idea of a demographic transition. It is necessary to be very wary of such an assumption when analysing industrial innovation diffusion. Firms can pursue economic and entrepreneurial goals in many ways: innovation is only one way. Others include changes in organisation, location or product. It is now widely recognised that industrial firms have many goals; they also have many more ways of reaching them than just through innovation.

There is also evidence (Malecki, 1977; L. Brown, 1971) that on some occasions the earliest industrial adopters are medium-sized firms in medium-sized cities as opposed to the traditional primacy given to large firms in large cities (the classic hierarchical pattern). The latter was well-suited to statistical modelling using a gravity, rank-size or central place

formulation (Berry, 1972; Hudson, 1972; Hanham and Brown, 1972). Against this, it is argued that the largest firms are slow to make decisions and are basically conservative; hence their risk-minimising preference for large-city locations. Medium-sized firms, which often are found outside the larger cities, have some of the capital resources of the large firm and a greater desire for growth and market share. This, allied to faster decision-making, leads Malecki to suggest that they are the real industrial innovators and his work on the banking industry in Ohio provides some support for this view.

(iv) Conclusion

The volume of research on the processes by which innovations spread is immense and a much fuller understanding of the complexity of the processes at work has become available. It is clear that the strands within this research need to be better integrated: the separation of industrial and agricultural studies is unhelpful, and the contribution from other social sciences needs to be more fully appreciated in geography. Partial studies of diffusion must be avoided - neither a demand nor a supply approach is satisfactory by itself in most cases. The trend in geography has been to move away from predictive and simulation models towards explanatory studies. This may lead to the danger of forgetting how useful robust predictive models would be both for commerce and public agencies seeking to improve welfare. Their advantages would tend to be functional rather than theoretical, however.

It is also important to remember that studies of patterns of diffusion cannot tell us how the diffusion took place. The slow and clustered early adoption of an innovation may be the result of one or more of the following processes: a poor communications system, a complex innovation of low relative advantage, too high a price, expectations of imminent improvement to the product, word-of-mouth communication between adopters, a lack of infrastructure or a small localised sales team. Each process could produce a similar spatial pattern - this is known as the principle of equifinality. The value of studying patterns is to suggest a small number of explanations and hypotheses worth testing so as to arrive at a better understanding of the processes of diffusion.

III THE STRUCTURAL COMPONENT OF INNOVATION DIFFUSION

One criticism of the process studies described in the previous chapter is that they leave out of their account two important aspects. First, they limit their scope to events closely related to the diffusion and are silent on how the nature of the economy and society affect the diffusion. Second, process studies do not show how innovations alter the socio-economic systems in which they occur. The structural approach eschews the fine detail of adoption for a broader canvas and a different set of questions. This approach considers the way innovations are linked to major socio-economic changes such as the Industrial Revolution or the transition from feudalism to capitalism. The structural approach studies innovation in its broadest context as both a product of, and an influence on, a given society and economy.

(i) A reflexive relationship

One of the principal findings of structural studies of innovation is that there is a reflexive relationship between innovations and their society and economy; they influence each other. Innovations are the mechanism by which societies and economies 'modernise' or are restructured. Equally, societies and economies influence which innovations are produced and their rate and incidence of adoption. The example of the mechanisation of agriculture will illustrate this point.

Machinery can be seen as not only a technical change in how a farm produces food, but as a catalyst for many other changes in agrarian society. One possibility is that it will promote farm expansion so that each farm becomes big enough to use the machinery to its fullest extent and hence at its most profitable scale. This in its turn may displace small-scale farmers whose land is absorbed into the mechanised farms. Mechanisation may also encourage specialisation in a few products by each farmer and hence the trading of surplus products. This requires not only a cash economy but also substantial investment in transport systems. Specialisation through expensive equipment also makes farmers more vulnerable since they are less flexible in what they can produce; they cannot change enterprise until the equipment has been fully paid off. This in turn creates greater pressure on governments to stabilise the prices farmers receive for their food. Finally, machinery and larger farms may require workers to be employed. The social structure of a society of small-scale farmers may evolve from one of equality between farmers to one with a polarisation between marginal, non-mechanised family farmers stigmatised as 'traditionalists or 'laggards' and expanding, larger-scale, mechanised farms employing wage labour. The latter group can be equated with a capitalist section of agriculture, and the former with a pre-capitalist section. It would be wrong to suggest that mechanisation alone is responsible for all these changes, but it has certainly promoted them given the kind of machinery that has been introduced over the last one hundred years. It is possible to envisage types of machinery that are suitable for small-scale farming with a mix of crops, a high degree of self-sufficiency and no wage labour employed. However, most mechanisation has generally not been of this kind. The exact effects of mechanisation will vary between particular societies, but any innovation such as mechanisation will always have some structural consequences.

The corollary is that society and economy in their turn affect innovation, which should not be thought of as a random, external process. Innovations and their dissemination are closely affected in many ways by the existing culture - indeed, the propensity of societies to innovate is part of a people's culture. The example of mechanisation again illustrates this well. General economic policy and investment cycles affect the rate at which farmers invest in machinery; a fuel subsidy (as in the United Kingdom) may speed adoption of powered vehicles whereas legislation for patents may hinder it; the scale of subsidies for farm products will affect farmers' incomes, their weaTth and ability to withstand the risks inherent in specialisation associated with mechanisation. In conclusion, groups and individuals bring forward innovations and create conditions for them to spread; innovations in their turn alter socio-economic conditions. The latter may inspire further innovations as other groups seek to adapt to these new circumstances or turn them to their own benefit.

(ii) Innovations and development

The thesis that culture and innovations have a reflexive relationship has been elaborated in detail with respect to the Green Revolution. This was initially conceived, and described, purely in terms of technical innovations and increasing the output of food.

The starting point was new varieties of cereals, notably rice and wheat, which had the potential for much higher yields than the varieties traditionally used. High-yielding varieties of cereals seemed to offer the prospect of raising food production in the Third World at least as rapidly as the growth in population. Early studies of the Green Revolution concentrated on the adoption of innovations at the level of the individual farmer. Adoption was assumed to be self-evidently beneficial and non-adoption was a waste of productive potential. Some farmers adopted before others, some regions were more 'progressive' than others and these observations needed to be explained, if only to help speed adoption in the future. In time, however, the behaviour of individual farmers came to seem less relevant than the broader changes in rural areas which occurred after the widespread adoption of these new methods. Traditional societies were undergoing rapid and radical changes in their economies and such changes have recently received much more attention in the diffusion literature.

Extra production from the new seed varieties required a capital-intensive infrastructure of roads, chemicals, water supply and defence against pests if the potential was to be harvested. Such infrastructure was available already in some parts of the Third World, areas near cities for example, but not in others. Also, the capital necessary for chemicals, irrigation and seed was available more easily, or at a lower rate of interest, to larger-scale farmers and those with a reputation for progressiveness who would be judged better risks by commercial sources of capital, government agencies or money lenders. Such people would also be sought out by development agencies and commercial salesmen as the ones most likely to adopt new methods first and so set an example for their neighbours to follow. Just as the best jockeys have the pick of the horses, so a reputation for progressiveness will be systematically advanced by easier access to capital and by such farmers being targeted by salesmen. Consequently, progressiveness is not only a personal trait but a self-fulfilling prophesy.

After the innovation early adopters would benefit from windfall profits - L. Brown (1981) calls this 'adoption rent'. The innovative farmers would raise their individual output, but would have a proportionately small effect on total supply and the market price. Hence, they would reap a double benefit of more output and higher profits per unit produced. These windfall gains can be characterised as either the fair reward for inherently risky investments or as the exploitation of a technical and intellectual monopoly. As the innovation spreads and total production rises, the price will tend to adjust downwards and so the windfall profits will disappear for the later adopters. However, the gain for the early adopters will allow them to build up capital for further expansion of their farms and another round of innovations. Their wealth will make them stand out from their neighbours, and as they expand they will need to employ workers so becoming the early capitalist farmers whereas the others will remain in a feudal or pre-capitalist economy. Studies of the Green Revolution have, therefore, come to focus on how innovations have affected the social structure of the countryside (usually

seen in terms of polarisation) and the nature of the economy (the advance of capitalist agriculture) (Frankel, 1971). The geography of the Third World is also changed since the differential access to infrastructure is seen as having a polarising effect accentuating differences between the level of development of 'advanced and 'backward' regions.

The publications of L. Brown (1981) and particularly those of Yapa (1977; Yapa and Mayfield, 1978) have taken the argument further by using the concepts of factor bias and social bias introduced into the literature by Griffin (1974). Factor bias refers to the tendency of some innovations to raise the marginal physical productivity of one factor relative to others. Yapa notes the tendency for many innovations to lower production costs by augmenting the capital input rather than by benefiting labour. This can lead to the windfall profits noted by others, but Yapa extends the analysis by noting how access to those materials increasingly essential for the Green Revolution is socially biased. Certain small groups in Third World societies have control over most of the land needed for farming and are able to obtain other factors such as capital, fertiliser, pesticides and water more easily and cheaply than the mass of Third World farmers. The problem for the rural poor is that they have ready access to the only factor, their own labour, which is not favoured by most innovations. Furthermore, farmers will tend to minimise those inputs which are the most expensive for them and so small-scale farmers will have a clear incentive to under-invest in the sort of expensive materials-dependent innovations which are so common and to over-invest in their own labour. The structure of society, it is argued, forces the non-adoption of innovations by the poor and contrives to make such a lack of innovation seem an economically rational course of action. The result is a tendency for 'class rent' to accrue to those who already control the factors of production and thereby enrich them further; the distribution of income becomes even more unequal. Innovation acts to enhance a capital-rich class by its inevitably uneven adoption and the entire culture of the area is altered. Yapa opposed this trend and advocated policies to help poor farmers - innovations which favour labour, and more equal access by poor farmers to all the factors of production, credit and transport.

There are, however, some dissenting voices in the literature arguing against this model of the structural role of innovations. Goss (1979) reinforces the earlier work of Gotsch (1972) by placing less stress on the role of the innovation itself in social change and more on the spatially variable character of society before the innovation. The effect of an innovation, they argue, depends less on the nature of the innovation than on the type of society into which it is introduced. Gotsch cites the example of tube wells; these are a means of obtaining irrigation water by sinking a tube into the ground and attaching a pump to bring water to the surface. This capital-intensive innovation has been introduced into both Pakistan and Bangladesh. In part of Pakistan where there was a wide range of farm sizes, over 70 per cent of the wells were operated by the larger farmers with over 10 hectares (25 acres) of land, while only 4 per cent of the farmers with under 5i hectares (13 acres) had one. Farms with tube wells were roughly twice as large as those without them (Mohammed, 1970). The wells provided water which was essential to obtain the benefits of the higher-yielding cereals of the Green Revolution and their capital cost could be repaid in one to three years. In Pakistan the innovation had the polarising effect of accentuating pre-existing differences between farmers. In Bangladesh, however, there was a more even distribution of farm sizes, most of the farms

were small and tube wells were installed on a co-operative basis. Here the Green Revolution helped all farmers to roughly the same extent; it cemented the co-operative nature of village life which contrasted with the individualistic system in Pakistan. The same innovation had different effects in the two countries because their cultural starting points were different. Pre-existing social traits were reinforced in each case. Research in Kenya (Röling et a/., 1976) has also suggested that it is possible to devise ways of promoting a high rate of uptake of quite costly innovations among those normally labelled as less progressive farmers, even in an area where the symptoms of inequity enhanced by innovations have been observed previously.

An interesting perspective on the long-term relationship between innovations and (particularly urban) development is provided by Pedersen (1970) in his statistical model of innovations over four hundred years in Chile and other Latin American countries. He shows that innovations are diffusing increasingly rapidly as communications have improved and as some innovations become more specialised, and so are restricted to fewer cities. Indeed, he makes the useful point that innovations travel both ways through the urban hierarchy; spreading down the hierarchy first and then, as thresholds rise, retreating back up the hierarchy as services are withdrawn from smaller centres. Innovations are part of the development process and the latter in its turn affects diffusion which becomes increasingly hierarchical as development proceeds. Neighbourhood information flows are much more important for diffusion in less developed countries. Diffusion is also shown to be faster where the towns are growing in population, although, he argues, the effect of urban growth is greater in under-developed countries where information flows are restricted.

The conclusions to be drawn from the literature on the relationship between innovations and development in the Third World must be tentative, but the consensus would seem to be that most innovations are income-generating for the areas as a whole and for some individuals and companies within it. The majority of innovations, however, are not equally available to all because of their cost, their (indivisible) scale of operation, their need for a complementary infrastructure or the way they are marketed. Hence they tend to favour the larger-scale operator and those entrepreneurs on whom there are fewer constraints. They are one of the harbingers of a western style of capitalist agriculture in the Third World. There is no necessary reason why this should be so but, in fact, many innovations have conformed to this type unless specific measures have been taken to counteract these trends. The paradox is clear. Innovation is a part of what is ordinarily meant by 'development'; yet the commonly observed effect of innovations, entrepreneurship and competition is to augment those regional and inter-personal inequalities which comprise one definition and symptom of 'under-development'. Development also changes the context within which innovations spread. The higher the level of development in a country, the faster the diffusion, the more hierarchical it becomes and the less important are conditions of urban growth for speeding adoption (Pedersen, 1970).

(iii) Influencing new innovations

If it is the case that many innovations have this polarising effect because they require capital, reduce costs of production and generally favour the capital input rather than labour, why should this be so? What is it that influences the nature of new innovations? The key here is development rather

than invention. Of all the inventions which are devised and all the prototypes which are tested, only a few will get the public or private funding needed to convert the idea into a marketable, mass-produced product. Private funding will tend to go to projects which will yield a profit when sold (eg. a tractor rather than the idea of ploughing across slopes instead of down them). It will go to those projects which will give a higher return on the company's capital than competing investments.

Public funding could go to either this type of profitable product or to those which will be cheap and will help any farmer; studies of the strategies of public bodies from this point of view are fairly scarce. The case of public funds for the development of solar-powered electricity generation in the USA would suggest a preference for a tried system familiar to engineers, administrators and power companies; namely, the large, central generating-station at the heart of an extensive distribution system. Solar power, however, does not have to follow the pattern of nuclear or conventionally fuelled electricity generation. Small installations could be used to power a street or even a single house. Technically this is perhaps an easier task than a large station, but it is so different in terms of administration and the balance of power (both political and electrical) that it is perhaps understandable that public funding for such a system has been much more limited than for large power stations. Some studies of the distribution of funds for agricultural research suggest that a political dimension applies not only to solar research but also to the US agricultural research effort (McCalla, 1978; Paarlberg, 1978; Youngberg, 1978). The issue here is the prospects for public funding of research on alternative agriculture (ie. ecologically aware and organic farming). Analysis of the control of the distribution of public research funds shows that such topics will only be supported if they have a coherent lobby, favourable public opinion and backing from politicians, commercial interests and administrators. Although there is widespread concern about the general direction of modern farming in the USA, there is no coherent lobby for the sort of research the supporters of alternative agriculture want. Public opinion is not strident in its favour and many established sources of power in the bureaucracy, legislature and commerce are opposed to it. Hence its funding is meagre and there is a limited range of alternative-agriculture innovations in comparison with the continuing stream of 'orthodox' innovations in machinery, fertilizers, plant breeding and agro-chemicals. From these examples we may conclude that the innovations which are developed to a marketable form are those which are consistent with the aims of the people who control the disbursement of public and private funds. Hence we end with a rather elitist and managerialist model of the influence over the flow of new innovations.

(iv) Links with other theories

The structural component of the literature on innovation diffusion is also useful because it invites us to make links with other theories. Among the best examples are from the theories of development in economics. The dual-economy model of Third World countries proposes that their economies comprise two components; one is a modern, western, fully commercial sector and the other a backward, traditional, pre-commercial one. The two-sector economy may find spatial expression in the plantation and the 'bush', the capital city and 'up country', or progressive and less developed regions. One of the reasons usually advanced for this economic and geographical polarisation is the greater willingness of the modern sector to innovate.

If we remember the windfall profits some commentators associate with early adoption, then we have a mechanism for generating capital which can fuel further investments in the modern sector. Thus innovation diffusion theory provides one mechanism for powering the family of models of circular and cumulative causation associated with Myrdal and Hirschman (Keeble, 1967).

Innovations can also have an indirect structural effect. There are several theories which are not specifically concerned with diffusion but which accord innovations or innovators a key role in the processes of socio-economic change. It is beyond the scope of this monograph to examine these theories in detail, but it is worth recording some of them here to emphasise how often innovation diffusion is used as an agent of major structural developments. Boserup's theory (1965) of pre-commercial agricultural change viewed innovations in husbandry as the critical response by farmers to population pressure on food supplies. New methods of farming gave the lie to the Malthusian model of population growth outstripping agricultural production (Grigg, 1982). In another model of economic development, Schumpeter (1976) argued in 1942 that in the early growth of capitalism monopolies played a central role which was maintained by their control of technical innovations. However, after they had harnessed the faster growth created by innovations, monopolies would consolidate their position of dominance by stifling change. This, he argued, would lead to their downfall and the replacement of monopoly capitalism by a distinctive form of socialism. These two theories, chosen from many, illustrate how influential innovations are thought to be in structural change by theorists of varying philosophical and political stances.

The structural component of innovation diffusion theory has integrated the field into the mainstream of social science thought. The future lies in investigating further the relationships between spatial structure on the one hand and economic and social structures on the other, and clarifying the role of innovation diffusion in these relationships.

IV THE CULTURAL COMPONENT OF INNOVATION DIFFUSION

The cultural component of innovation diffusion requires us to change the scale of our inquiry and, in consequence, our concerns and methods. After studying major issues like the role of innovation in development (Chapter III) and the effect of propagators on diffusion (Chapter II), one is still left with a large gap in one's understanding of innovation; how does it affect communities, families and individuals? This is the central concern of the cultural approach. How are innovations perceived at the micro-scale of individual people and their daily lives? What do they mean to them? To answer this, one must probe their hopes and fears, their power, personality and relationships with family and neighbours. We can view this as the humanist component to diffusion studies.

These are not easy topics to study in the field. They defy simple measurement, the very language used does not mean the same to the researcher and the subject of the study, and the concepts have a life of their own, constantly shifting and changing. How, then, can we understand the effects of innovations on people? The methods most likely to succeed are those of the anthropologist - long and careful immersion of the researcher in the culture and life-style of the people studied so that the division between

researcher and researched is dissolved. Trust is built up, the innovation is experienced by the researcher as though he too is a member of the community. The questionnaire is replaced by conversation, while diaries and autobiographies become possible sources of information. There are dangers in this approach as in all others. The researcher might 'go native', uncritically accepting all he is told and failing to interpret his experiences by external standards. There are clear philosophical difficulties in simultaneously eliminating the gap between the researcher and the subject of the study so that they become as one, and yet still maintaining the ability to consider events by standards which are not those of the people observed. The researcher might think that he fully understands people when that is never possible. Nevertheless, when the technique is used well and appropriately, it can yield new perspectives on innovation diffusion.

It is tempting to try and summarise the cultural approach but this would do an injustice to a style of research which eschews generalisation and which places immense store on the inter-connectedness of what one might wrongly dismiss as mere details since these form the web of meaning and experience enjoyed by a specific group of people. Therefore, a series of extracts will be presented from the work within this cultural tradition. Each records some of the effects of specific innovations on small groups or individuals sometimes in their own words; a short commentary is given about each piece to place it in context. Limitation of space restricts these extracts to brief examples - longer works naturally yield much more of value. The symbol (...) indicates that a section of the quoted text has been omitted; the spelling is unaltered from the original. Together these fragments give an insight into the richness and potential of the cultural approach.

Example 1

Robbins and Kilbride (1972) examined the effects of small innovations on village life in the south-west of Buganda in southern Uganda. The research was conducted in 1967 and 1969 before civil war ravaged the country. In this extract the authors are concerned with the effects of bicycles which in recent years had come to be owned by 38 per cent of a sample of villagers.

> The bicycle is an extremely important item in Lusozi. (...) One informant (...) said, The bicycle comes first. It is used for transport to and from work and for making money by trade ... coffee, fish, bread and milk traders all use bicycles." He also noted that few women today ride bicycles, although girls will occasionally use them for pleasure. Part of the resistance to the use of the bicycle by women is undoubtedly due to the nature of women's clothing and to the fact that only "men bikes" (with a bar between the seat and steering post) are currently available. (...) Moreover, men would probably rather have their women without the mobility a bicycle affords (...) The essence of these remarks is that the bicycle is mainly of instrumental value to males and predominantly a masculine technological item.
>
> In Lusozi 38 per cent of the individuals surveyed in 1969 had bicycles and considered them their most important item. The most frequently mentioned uses of the bicycles are personal transportation and the movement of goods in distributive economic activities (...).
>
> In addition to enhancing the efficiency of these economic activities, people in Lusozi have also recognized several less obvious consequences

> of bicycle ownership and use. (...) Friends, and particularly relatives, who often live at a considerable distance from one another, can now be contacted and visited more frequently. People on personal visits usually return with information and gifts (often food) for their friends and neighbours. (...)
>
> For another thing, bicycles have promoted and solidified other social relationships. For example, the bicycle can be used to transport neighbours, friends and/or their goods as favors. Several informants stated that they felt more socially desirable because they possessed a scarce commodity. The temporary loaning of bicycles is also a sign of warm friendship and considerable trust (...).
>
> Conversely (...) bicycles are easily and frequently stolen. (...) Some people in the village also mentioned that robbery and burglary have increased since micro-technological items have become more commonly available.
>
> Auxiliary equipment (eg. locks) and continuing maintenance costs (eg. tires) often require the individual to increase his economic endeavors. One individual whom we know quite well told us he was going to have to manufacture *waragi* (local "illegally" distilled gin) the next day in order to acquire 24 shillings needed to purchase a used tire for his bicycle so that he could transport his and his neighbour's coffee to the processing plant. Bicycles and several of the other technological items we have mentioned have provided additional economic activities for mechanical experts, and many persons are now becoming part-time specialists in bicycle repair.

This extract stresses the social effects of bicycles (increased interaction) and it hints at greater changes to come in the role of women as they too become more mobile. The economic effects are less marked but increased trading with a cash economy and some occupational diversification should not be overlooked. The demand for bicycles is clearly more than a simple economic transaction; it includes aspects of social pressure, class and gender differences and a range of non-economic motives for expenditure. The demand-side approach, the authors argue, is more complex than Chapters II and III might lead one to believe and the effects of adoption are infinitely subtle and wide-ranging.

Example 2

Khan (1976) has studied and participated in rural development in Pakistan and this extract is taken from an address he gave to a conference. He is concerned with an innovation (a co-operative) which failed - the other side of the coin of diffusion and just as important to understand.

> What is much more important is the lack of human skills among the small farmers. To illustrate this we went to a village where a co-operative had been formed ten years ago. Of course it had collapsed within three months of its formation. We just wanted to find out what went wrong with the co-operative. The villagers were still in the process of repaying the loan which had been given (...). We were told that the co-operative inspector had come and said: "You can get money if you form yourself into a co-operative, and whatever you need you will be able to get with that money". Since they needed bullocks they formed a co-operative. Then they said: "You give us more money, then we will repay

you; but we shall need more bullocks after ten years". When they were asked why, they said: "Well, the trouble is that our bullocks die". (...) The bullocks died because there was a shortage of fodder. There was a shortage of fodder because there was a shortage of water. So in fact what the credit was needed for was not the bullocks; it was needed for providing them with an adequate water supply. (...) Now here comes the lack of skills. They could have borrowed for irrigation pumps, but they said that they could not arrange that, and that some government functionary must be sent to do it for them.

Here was a situation, where money was available and water was also there. (...) What is more, once the government functionary goes there, there will be complaints that he is corrupt because he is giving more water to somebody and less to somebody else. So unless the villagers manage the water distribution themselves with the technical assistance we were prepared to provide, it was just not possible to solve the problem. We came away, but I must say that after a year we had been able to convince them to undertake things which they could do themselves. This is where the human skills come in.

To understand diffusion we need to explain its failures. Here the difficulties lie very deep indeed. Can the villagers and the development agency define the primary 'problems to which some innovation is a possible solution? In this village, Khan argues, the problem was water, not bullocks, and the solution was a tube well rather than a livestock co-operative. The stumbling blocks which any propagator of tube wells had to overcome were a lack of confidence and skills on the part of the local people and their view that some jobs (installing wells and allocating water) could not be done by themselves. There is no simple marketing strategy or investment programme to overcome these barriers to diffusion but, with tact, patience and a sensitive appreciation of the villagers, they are not insurmountable. The author goes on to stress the importance of confidence building and education in its broadest sense in diffusion, although the literature reviewed in Chapters II and III hardly touches on these aspects of adoption.

Example 3

The two previous examples have been drawn from the very extensive literature on rural development in the Third World. The approach also has value in an urban-industrial context and this case study deals with Glasgow in the mid-nineteenth century (Kellett, 1979). The innovation in this case is the railway, and its history raises some major questions about the generalised supply-side approach described in Chapter II (ii).

During the early stages of railway building, in the 1830s and 1840s, until others took up the railway interest, industrialists of this type lent their capital and assistance even more wholeheartedly than their fellow landowners - the speculative builders, solicitors and *rentiers.* (...) William Dixon (contributed) to the projected Glasgow, Airdrie and Monklands Junction railway, was the sole proprietor of the small Pollok and Govan line, and was the originator and the largest shareholder in the Clydesdale Junction railway. Possibly Dixon's view of a railway's function might be criticised as rather narrow in conception. Like most industrialists he thought of the railways in terms of minerals, raw materials, heavy manufactured goods - indeed, virtually as an extension of his colliery and ironworks. (...)

Glasgow was the theatre for a bitter conflict between three rival railway groups which lasted from the mid-1840s until the end of the century, and was protracted by the even balance between the companies engaged, which at times produced a perfect deadlock, at other times long and obstinate arguments. (...)

The extensive facilities which it had purchased, however, and its large traffic and capital, placed the Caledonian railway company in a position of unchallengeable influence in the Glasgow area; and from the time of its formation, in 1845, the G. & S.W. and the Edinburgh and Glasgow, or later the G. & S.W. and the North British, formed what counsel for the Caledonian sarcastically described as 'a happy family'. It was not a formal alliance, and did not preclude arguments between the G. & S.W. and the N.B.:(...) but in Glasgow, at any rate, there was a tacit understanding that the two companies would both throw their weight in the balance against the Caledonian. (...) The result of this even balance between the Caledonian company and its opponents was a competitive struggle for traffic, for urban space, and for local influence which lasted for sixty years. (...) It was also reflected in urban affairs; and in Glasgow the siting of termini, the number provided, and the timing of their construction, can be shown to depend in large measure upon the precise relations existing between the three companies, and their relative success in canvassing their schemes.

(The St. Enoch station) became a further pawn in the competition between the three companies. Left to themselves to finance the project, the G. & S.W. and the North British proceeded very slowly, dragging out the construction of the St. Enoch station over twelve years (1864-76). The difficulties encountered in clearing away a vast tract of slum housing - the so-called 'Wynds' - and the strain placed upon the contractors who had offered to stand behind the scheme suggest further reasons for the delay in building and opening the new station. Throughout this period the Caledonian kept up the acid correspondence already referred to, and harassed the G. & S.W. and the North British by opposing all their supplementary Bills to re-route their southern approaches, and by putting forward awkward and obstructive link lines of their own.

The railway is a classic example of a propagator-supported innovation; it is the way the supply side was controlled that is crucial in explaining its diffusion. Yet here we see three disturbing complications for the simple supply-side approach presented in the literature so far (Chapter II (ii)). First, the propagator was not a neatly defined entity but a shifting coalition of commercial interests which at various times included one or more of the following groups - railway companies, the local authority, industrialists, landowners and financial institutions. When not in the coalition, some of these groups might be cheerfully plotting to prevent the diffusion of railways. Second, the most obvious propagator, the railway company, is actually several companies whose extreme mutual antipathy and rivalry is a major influence on the development of stations and railway lines. There is a rationale behind the supply of railways but it is several orders of magnitude more complex than the simple motives of, for example, maximising sales which the literature puts forward. Third, it is not at all clear what the innovation is. Superficially, the innovation to be diffused is a railway line but it might really be new housing, a building contract or a coal mine - the railway was sometimes a means to a variety of other ends and not necessarily the end in itself for the developers.

Example 4

This final example stands in sharp contrast to the previous one. The theme is the role of migration in the diffusion of innovation as exemplified by an interview in the mid-1960s with a farmer who had moved from Lanarkshire in central Scotland to 'Akenfield', a village in East Anglia, thirty years before (Blythe, 1969). The depression, particularly in cereal prices, had reduced living standards for traditional cereal farmers and farm tenancies were going begging in eastern England. Newcomers, especially the Scots, are traditionally credited with introducing many new methods into East Anglian farming between the 1870s and 1930s. This extract can be seen as belonging to a tradition of diffusion research in prehistoric archaeology and (particularly American) cultural geography which studies the contribution of population migration to changing the material culture of areas (Childe, 1937; Sauer, 1952; Kniffen 1965; Winberry, 1974).

> I came here in 1932. Most of us who came here after the First World War came from Lanarkshire and Stirlingshire. We came because we were land-starved back home and needed - what did the Germans used to call it? *- Lebensraum.* We were all young men in our early twenties, strong and adaptable, and mostly farmers sons. There was no official scheme. One came down and then another (...).
>
> There were all these fine farms standing idle and no great rush by anybody to work them. We got our jackets off and got stuck into it. A neighbour came south first and did so well that his Suffolk landlord wrote back to the Scotch landlord who had previously employed him, did he know of another Lanark man who would come down and take a farm? That is how I came. We were always tenant farmers. It is our tradition.(...)
>
> What a scene we found when we arrived! I don't know how to begin to describe it. Dereliction. The fields were wet, the hedges like forests. The East Anglian farmer had lived with his decline so long that he couldn't move, he couldn't think.(...)
>
> There was something else about the Suffolk farmers we Scots couldn't understand - their snobbery. In Scotland there is no distinction between a farmer's son and a farm-worker's son, for instance, but it was quite another tale in Suffolk.(...)
>
> The village men came to work for us and we saw how different they were. They were slow, their horses were slow. A Suffolk man would plough to the end of the field, stop there, then gradually turn his horses round and plough back again. Whereas a Scotch ploughboy would thrust up the field, kick his horses round and be back in no time.(...)
>
> We found the Suffolk men much more tolerant than ourselves. (...) The men lacked aggression.(...) We were generally speaking, more able, more industrious, more enterprising, less fearful. When a new machine was introduced, it was always a Scot who had brought it in. A Suffolk farmer would wait ten years to see whether a new method was foolproof - and then he would adopt it(...).
>
> This was what Suffolk was like when I, a young man from Lanark owning nothing more than a plough, came here a little more than thirty years ago.

This extract may be seen as a cautionary tale - the cultural record needs careful interpretation and nothing should be taken at its face value.

The farmer's account contains elements of national pride, of self-justification (not uncommon in diaries and autobiographies), of praising his new ways and criticising the old methods used by others and of perpetuating uncritically orthodoxies about Scottish society (its supposed classlessness, for example). This is a revealing interview but it needs some perceptiveness and background knowledge to fully appreciate the contribution and effects of this one farmer, let alone Scottish migrants in general, to the diffusion of new farming practices in East Anglia.

Conclusion

These case studies are useful in showing how much is lost when generalisations are made about diffusion - it is a much more human process than abstractions like supply, demand and information would suggest. The complexity it highlights can be argued to be more than just details of local interest; the complexity is so great that it transforms the situation - the complexity is the situation. Remove that, and simplification leads to simplistic judgments. The record, however, is not an easy one to interpret; it needs the same care and clear thinking as one would use in the structural and process approaches.

V CONCLUSION

A general theory of innovation diffusion has not yet been formulated; it is unlikely any one concise statement could cover diffusion at the structural, process and cultural scales of analysis. Because these three components differ in scale, they also vary in what is to be explained or simulated, the methods deemed suitable and the sort of evidence which is acceptable. One scale may be more appropriate than others for a particular purpose, yet all three are needed to give a full appreciation of diffusion.

In recent years geographers have tended to seek to explain rather than model diffusion - the trend to realism described in Chapter I. Simulation and predictive models have worked well for diffusion under highly specific sets of circumstances: general models have proved more difficult to formulate though their practical value would be considerable. The trend to studying the processes of diffusion has altered the role of the purely spatial aspect of diffusion. In one way it has been weakened because pattern alone cannot show how diffusion occurred, different processes having the same spatial outcome. In another way, however, the role of spatial structure has been enhanced since it is increasingly realised by economists and sociologists that a geographical perspective is of value in two ways. First, socio-economic structure affects, and is affected by, spatial structure. The former can only be fully explained by accepting that people and resources do not all exist at one point on the earth's surface and their distributions influence diffusion (the structural approach in Chapter III). Second, there is increasing interest in local studies which seek to show how general socio-economic processes have developed in the specific circumstances of a particular locality. This is roughly the equivalent of the cultural approach in Chapter IV although it also includes the work, mostly by sociologists, on the 'local state' (Urry, 1981).

If the most interesting current work is in the structural and cultural schools, the greatest volume of research is still within the process component described in Chapter II. This may be in part because it lends itself most easily to field work and a positivist and empirical approach well known in geography. The whole field has also been moving closer to the mainstream of social science theory with tentative links now to theories of development, location and the firm. The relationship with social theory is less clear-cut but the parallels are strong enough now for there to be a reasonable expectation of developments in this area. The evolution of innovation diffusion is a reflection of wider developments in human geography as a whole; a greater awareness of the work of other disciplines, a willingness to explore the potential of different philosophical positions, and a renewed appreciation of the central role of the many-sided concepts of scale and space in our understanding of human development. The volume of work in the field suggests that innovation diffusion is likely to continue to be a major centre of activity in human geography.

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