0. Outline of the Paper

The traditional innovation diffusion literature (summarised by Rogers 1995) models the rate of adoption as a function of the number of agents who have already adopted. Two obvious refinements to this approach are to model the rate of adoption as a function of the number of a particular type of agents who have already adopted (Tapeiro 1983 is a typical example) or to use a multi-agent approach and model the adoption decision not as a function at all, but as a succession of actual interactions between agents which have the potential to change both their internal states and their outward behaviour. In the innovation diffusion literature, the type of an agent is almost invariably defined in terms of the adoption process, for example an agent is unaware of the innovation, or unconvinced about its benefits. (An exception is provided by the micromodelling approach of Chatterjee and Eliashberg 1990.) However, it is clear that at least three other definitions of type are also important for the diffusion of innovations among farmers. Firstly, the type of farm. This type will be identified by such factors as the crops and livestock farmed, the techniques used (mechanised, intensive, extensive, organic), the land area/quality (large farm, small farm, marginal land) and the economic state (profitable, part-time, indebted). Secondly, the type of farmer. This type will be identified by the decision process of the farmer as well as the extent to which they are forward looking, economically minded, successor orientated, cautious, innovative and so on (Gasson 1973, Jacobsen et al. 1994). Thirdly, the type of social network. This type will be identified by whether the farmer has many or few associates, whether they are central or peripheral to a network, whether the associates are close friends or merely acquaintances, whether they are emotional or professional associates and so on (Scott 1991). All these different kinds of types will be important but it is possible to make different assumptions about the extent to which each constitutes a formal type: in the sense of a set of well defined attributes which can be used to divide a group of farmers into exclusive or exhaustive categories. To the extent that such a division is not possible, a multi-agent approach is indicated.

This paper provides detailed descriptions of two simulations which use the same basic framework, based on the four types (farm state, farmer decision process, network position and adoption state) described above, but developing the parts of this framework in differing
degrees of detail. The first simulation is designed to be extremely simple and abstracts almost completely from the state of the farm and the farmer decision process. It concentrates entirely on the role of network position and adoption state in modifying the conclusions of traditional innovation diffusion models. In particular, it appears that diffusion is very sensitive to the number of associates (if that number is quite small), to the presence of a farm advisor and to the farmers tendency to “get bored” with passing on messages about their adoption state (Chattoe and Gilbert 1998a). The second simulation attempts to provide a general (but abstract and simplified) framework in which farm state, farmer decision process, network position and adoption state are all allowed to interact. This simulation can be seen as following a genuinely multi-agent approach.

1. The Basic Simulation

In this section, we describe the components of the basic simulation. Although there may be no point in implementing both simulations, partly because it may be possible to implement the second as a more general case of the first, describing the simpler simulation is a good introduction to the problem and some of the assumptions and terminology.

1.1 Introduction

The objects of the simulation are farms with attributes. For now, we assume that the decision making process of the farm has been agreed by all members of the farm decision making unit (typically farm family and employees, perhaps others) and that there is no difference in social networks between members of the farm decision making unit. In this way, each farm can be associated with a single decision making process, without the need to model individual members of the farm decision making unit and their interactions. Each farm consists of a number of different “modules” (one for each of the four kinds of “type” described in section 0 above), some of which are modelled in more detail than others. Figure 1 below shows the relationships between these modules in the simple simulation.
Farmers receive a succession of messages from their associates, which alter their readiness to adopt. If their readiness reaches a certain level, they will check if there are benefits to adoption and if so, they will become adopters, otherwise they will become non-adopters. Either of these decisions obviously affects the adoption state of the farm as does a change in readiness to adopt. For all farmers, the current adoption state determines the nature of the message that they transmit to their associates. (The transmission of a single message, purely dependent on adoption state, is obviously an extreme simplification that will be relaxed in the advanced simulation.) In the next subsection the structure of farms will be described in more detail.

1.2.1 Attributes of Farms

Each farm has the following attributes:

- A unique identity number.
• Unique x and y co-ordinates on a two dimensional grid with edges that “wrap around” to form a torus. We assume that each position in the grid is occupied by a farm.
• A binary variable, randomly distributed, indicating whether or not the farm will benefit from adoption.
• A current level of readiness to adopt which is a number.
• A target level of readiness to adopt which is also a number, randomly chosen for each farm between 1 and a maximum value inclusive, which is a global variable.
• An adoption state which is determined by a combination of the current level of readiness to adopt, the target level of readiness to adopt and the binary variable determining whether or not the farm will benefit from adoption. The current readiness to adopt begins at 0, when the farm is ignorant of the innovation, after that, the farm is in one of the various states of readiness to adopt, but it can never be ignorant again, even if readiness drops back to 0 or even becomes negative. Once the current readiness to adopt is greater than or equal to the target readiness to adopt, the farm becomes an adopter if its binary variable indicates that it will benefit from adoption, otherwise it becomes a non-adopter. (In the same way that one cannot return to ignorance, one cannot revert to readiness from either adoption or non adoption.)
• A message that the farmer transmits to associates, depending on the adoption state of the farm. This message is the (positive or negative) change to the current level of readiness to adopt which will result when an associate farmer receives the message. (For now we assume that there are no transmission errors or issues about credibility.) Ignorant farmers obviously cannot have any effect on the readiness of others and transmit no messages. Farmers who are ignorant have a relatively small positive effect on their associates readiness to adopt. Farmers who are adopters have a relatively large positive effect on their associates readiness to adopt. Farmers who are non-adopters have a relatively large negative effect on their associates readiness to adopt. The simulation should be implemented so it is easy to specify different relationships between adoption state and the message transmitted. For example, we might want to say that farmers in any state of readiness to adopt have no significant effect on their associates readiness to adopt, but can only remove ignorance of the innovation, changing current readiness to adopt to a very small positive value, but only if it is currently zero. (This assumption distinguishes information from persuasion.) Alternatively we might want to assume that the effect a farm has on an associates readiness to adopt is a function of its own readiness to adopt. (Keener farmers are more effective at persuading their associates.)
• A list of associates that a farmer is capable of transmitting messages to. How this list is generated is determined globally according to the social network structure specified.
• A “clock” variable that records the number of simulation periods for which a farmer has been transmitting messages about their current adoption state. After a certain number of periods (determined globally), farmers “get bored” and stop transmitting. (As soon as their adoption state changes however, the clock is reset, they will start transmitting again. The behavioural assumption is that farmers will talk about “news” with all their associates for only a finite time.)
• A binary variable that indicates whether or not the farmer is currently transmitting messages. (Recall that ignorant farmers never transmit messages but that other farmers always do so unless they get bored according to value of the clock variable above.)

1.2.2 Parameters of the Simulation
In addition to the attributes for individual farmers, there is also a set of global parameter values for the simulation as a whole:

- The number of farms: 1000 is a typical value. (It may be easier to specify the dimensions of the grid and derive the number of farms from that.)
- The number of periods the simulation will run for.
- The maximum number of associates which any farmer can have. Each farmer has a list of other associates among farmers with a length between 1 and this maximum number inclusive.
- The probability of passing your message to each associate in each period. For simplicity, this probability is assumed to be the same for all agents and all associates.
- The number of initial (period 0) adopters located at random x-y co-ordinates on the grid.
- The probability that your associates will be chosen from within a certain x-y co-ordinate radius of your position on the grid. If they are not chosen from within this radius, they will be chosen randomly from the x-y co-ordinates of the grid as a whole.
- The radius from within which associates must be chosen if required.
- A binary variable indicating whether or not there will be a “farm advisor” or change agent operating in this run of the simulation. (Farm advisors are assumed to know all farmers, to have their own separate probability for passing messages in each period and to “convince” all farmers they talk to so that their current readiness to adopt becomes equal to their target readiness to adopt immediately.)
- The proportion of farms that will benefit from adoption. Farms that will benefit are randomly distributed on the grid.
- The maximum value which the target readiness to adopt can have.
- The number of periods for which farmers will transmit a message about their current adoption state before getting bored and ceasing transmission.
- The changes in readiness to adopt that will result from messages received from associates in different adoption states.

1.2.3 The Algorithm

Once the parameters of the simulation and the global variables are defined, the algorithm for the simulation is extremely simple.

- For each agent, if they are currently transmitting messages, go through their list of associates and check whether a message will be passed to each according to the probability. If so, increment those associates readiness to adopt according to the adoption state of the current agent, change their binary variables for message transmission and reset their “clock” values.
- If there is a farm advisor operating, go through the list of farmers and check whether a message will be passed to each according to the probability. If so, increment those farmers readiness to adopt so that it is equal to their target readiness to adopt.
- For each agent, if the current readiness to adopt is now greater than or equal to the target readiness, check whether the farm will benefit from adoption, change its adoption state to adopter or non-adopter as appropriate, change their binary variables for message transmission and reset their “clock” values.
• For each agent, check if they are bored with transmitting messages about their current state and if so, change the binary variable for message transmission so they will not transmit again until their adoption state changes.

A “period” is defined in the simulation as one pass through this process. Strictly speaking, a multi-agent approach would use message passing and random updating rather than defining arbitrary “periods” but for this simple simulation it probably makes little difference.

1.2.4 Output of the Simulation

There are three important visual outputs for the simulation, one dynamic and the other two static:

• A “map” of the farm grid which changes dynamically as the simulation runs. This shows non adopters in black, those ignorant of the agri-environmental measure in white, adopters in red and those in states of intermediate readiness to adopt in some sort of colour gradient. Those agents currently transmitting should have a border while those who are not transmitting should not.

• In addition to the dynamic maps, it should also be possible to display static maps of the farmers who will and will not benefit from adoption and the locations of associates for particular sets of farms. (These will be the maps that display social networks.)

• For each run, summary graphs showing the total numbers of ignorant, adopters, non adopters and possibly those in various readiness “intervals” (for example those with negative readiness, those with readiness less than 50% of target and those with readiness more than 50% of target) over time. A table should also indicate times to some specified percentages of total adoption (for example 10%, 30% and 50%) and also the percentage adoption at “infinite” time when the simulation finishes.

1.2.5 Extensions to the Simulation

With the exception of some of the graphical output details, the simulation described so far was that implemented and used to generate the results presented at the Saint-Sauves D’Auvergne meeting (Chattoe and Gilbert 1998a). If it is decided to implement the simple simulation separately, there are a number of extensions which would be useful for further experiments:

• Farms benefiting from adoption are not randomly distributed on the grid but clustered, reflecting geographical correlations with farm type, climate and so on.

• Instead of a static list of associates, farmers work from a copy of the list each time their adoption state changes and delete those associates they have already passed the message to. (In practice, being told the same piece of information by the same farmer would not increase readiness to adopt. If duplication of messages is perfectly monitored by transmitters, there is no need to duplicate monitoring by receivers.)

• In the same way, farm advisors are likely to have at least approximate knowledge of the current adoption states of their clients and would not waste time talking to those who were already adopters or non adopters. They might, as Weisbuch and Boudjema (1998) suggest, concentrate their efforts on those who were least ready to adopt but this depends on their level of knowledge about adoption states and particularly intermediate states of readiness.
• The simple simulation allows for some spatial clustering by assigning a probability that associates will be chosen from a certain radius. However, since these radii overlap substantially, there is little additional social network structure imposed by this assumption. Other research on social networks (Granovetter 1973, Friedkin 1982) and casual empiricism suggests that it might be useful to consider social networks which are exclusive or arbitrarily close to being so. For example, we can imagine a situation in which associates are all chosen from among those visiting the nearest market town and there are far fewer associates among those who visit different market towns.

• It would be useful if, as well as presentations for total numbers of farmers in different adoption states in each period, graphs could also be presented which showed the longitudinal “history” of adoption state for specified individual farms. This is because we can triangulate these “adoption histories” independently with the interview data.

1.2.6 Limitations of the Simple Simulation

In this subsection we describe four obvious limitations of the simple simulation and suggest ways in which these might be removed. The removal of these limitations using an integrated model representation is the most important way in which the advanced simulation differs from the simple one.

1.2.6.1 The “Flatness” of the Social Network

Although the randomly generated lists of associates for each farmer do capture certain aspects of social networks (such as the fact that farmers have different numbers of associates and may be well or badly connected to the bulk of the population), they also exclude many factors routinely considered in the standard literature (Scott 1991). In particular, the social network described in the simple simulation is completely “flat”, in the sense that friends are not distinguished from colleagues, neighbours, employees, family and members of the same trade union or sports club. All associates are assumed to be equally influential and credible, to be met equally often and to have the same spatial distribution and other attributes. What is needed is a small set of parameters that can be used to characterise and then generate multiple lists of associates of different kinds where the simple simulation uses only a single list. The basic algorithm for the simulation remains the same, but different lists can be expected to be more or less credible or persuasive and to be in the business of transmitting and receiving messages of different kinds. A simplified set of parameters for different kinds of networks would probably have to include the following:

• **Credibility:** The extent to which messages are taken at face value rather than being “discounted” in the learning process. Friends and family are much more credible than acquaintances.
• **Persuasiveness:** The extent to which an associate is socially “entitled” to transmit affective or persuasive messages rather than merely informative or technical ones. Weenig and Midden (1991) observe that it is socially acceptable for acquaintances to “warn” (provide negative word-of-mouth) but only for close friends to “persuade” (provide positive word-of-mouth). This may explain the negative tenor of much gossip.

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1 Work is ongoing to identify parameters that are especially relevant to farming communities but for some unknown reason there appears to be a shortage of social network analyses in rural areas not counting research in LDCs which is of uncertain transferability (Boahene 1985).
• **Frequency**: The probability that one will interact with each member of a particular kind of network in a single period. The probability would be much higher for friends and close family than for distant family. Independent probabilities allow for periodic “large gatherings”, though at a rate declining rapidly with size, which may have a dramatic effect.

• **Specificity**: The extent to which certain kinds of messages will be transmitted in a particular network. Colleagues might only transmit informative messages and not persuasive ones. All except the best of friends might avoid discussing financial matters.

• **Attributes**: Some networks may be defined in terms of commonality of attributes, for example sheep farmers, weekend hunters or farmers with children.

• **Size**: The typical number of people to be found in a particular network. A political party may be extremely large while a circle of close friends seldom exceeds ten and may be smaller.

• **Locality**: The probability that members of a certain network will be spatially close to each other. Neighbours (by definition) are always adjacent to each other while members of the same trade union may be all but randomly located spatially.

• **Exclusivity**: The probability that members of one network will also be members of another. Barring feuds, there will be little exclusivity between family networks and a farmers group, but the exclusivity of political parties is usually almost complete.

• **Logical Relations (Reciprocity, Transitivity)**: For both computational and empirical reasons, nothing more complicated than reciprocity will typically be assumed in a social network. If farmer A is in a friendship network with farmer B, then the converse is assumed to be true. However, even reciprocity may be too strong for some networks: farmer A may offer technical information to farmer B without this ever being reciprocated. [xx Is there a problem with defining group membership without even reciprocity?]

• ... [xx Help!]

Obviously, even with a relatively small set of parameters, there are an enormous number of possible social network structures, particularly if multiple networks with the same parameter values can still have a distinctive effect. (Is it the case, for example, that diffusion speeds up dramatically if people are members of two sports clubs rather than just one, even though sport club membership has standard properties?) For this reason, experiments will typically be done with a relatively small number of networks with “indicative” properties. As a further step in limiting complexity, parameters are still assumed to be constant at the level of the network type. (We are also assuming that social networks are fixed, although within the same framework, we can envisage “transition probabilities” between networks: colleagues may also become friends and friends may sometimes become enemies.)

From the point of view of simulation, it is necessary to be able to generate initial lists of associates with the “correct” properties for the network type. (Since this is only done once at the start of the simulation if fixed networks are assumed, computational efficiency may not be paramount.) The parameters above can be divided into two classes. The first four parameters do not restrict membership of associate lists and only affect what happens once the social networks have been defined. By contrast, the last five parameters actually affect the *construction* of associate lists. Implementing some parameters (like random spatial location) is trivial. Others, like exclusivity are more difficult, or at least more tedious. (Having picked associates for one network, when picking associates for the second, if an associate is indicated who is already part of the first network, they are only selected for the second if a
randomly generated number is less than the exclusivity probability.) Another efficiency issue needs consideration. For small networks, it may be more efficient to list all the associates as part of the description of each farmer in a particular network. By contrast, for networks formed by the catchment areas of market towns, it will almost certainly be more efficient to give each farm an attribute (parameter) which contains the identity number of the relevant market town. When the time comes for message passing in this network, resampling must take place from the population of farms rather than a list of associates within a single farm.

Finally, the existence of multiple social networks provides an additional sense in which farmers can be said to be “well connected”. As well as numbers of associates in a single network, farmers can differ in the number of different networks they belong to. Granovetter’s (1973) hypothesis about the importance of “weak ties” can be realised by comparing what happens when farmers are or are not allowed to belong to more than one highly exclusive friendship group.

1.2.6.2 The Absence of a Farmer Decision Process

In the simple simulation, all affective and motivational factors are compressed into the readiness to adopt and all economic and utilitarian factors into the binary variable that determines whether or not a particular farm will benefit from adoption. (In addition, the binary variable reflects an “objective” valuation of costs and benefits leaving no room for social interaction or information transmission.) Thus the decision process is fixed not only in terms of its parameter values, but also in terms of its time order. (All agents must be emotionally persuaded before even considering the utilitarian aspects of the decision.) Theoretical arguments about the relative importance of individualistic economic motivations and social affective motivations are seldom worthwhile. Instead, we need a framework which allows both kinds of motivations to be represented in a plausible and unified way rather than just subsuming one into the other. In addition, we need to represent the decision process in such a way that it can change over time.

In most approaches based on rational choice, new information can only alter the parameter values of a fixed agent model. Empirically, new information can also affect the way in which a decision is made and change the attributes of the decision process which are considered to be important. In subsection 2.2, we describe Decision Plan Nets as a framework suitable for modelling decision processes with these desirable properties.

1.2.6.3 The Absence of a Farm State

This is the aspect of the innovation diffusion process which is most highly abstracted in the simple simulation, being represented by a single binary variable! In fact, the absence of a dynamic model of the agent which decides whether or not to adopt the innovation is a major limitation of almost all innovation diffusion models. It is important because, even if we consider purely economic motivations, the absence of a dynamic model forces us to exclude important factors like learning-by-doing (the costs of adopting an innovation may fall over time), necessity led innovation (if agents are conservative, they may innovate only if their current behaviour is not sustainable rather than if there are additional benefits from doing so) and dynamic constraints (a farmer may want to adopt, but be too busy to do so over the harvest period or there may never be a time during the year when they have adequate resources to pay for a farm survey). In subsection 2.1, we describe a simplified dynamic
model of farm state, based on the notion of activity plans, which is able to take account of these factors.

1.2.6.4 The Triviality of Messages Passed

This is actually only a derived limitation of the model. There is nothing in the programming of the simulation that compels the messages passed to be trivial but the assumptions about the farm state and the farmer decision process mean that there is just nothing very interesting for farmers to say to each other! Once farm state and the farm decision process are modelled in more detail, farmers can pass on information about the innovation, their current thinking on the decision, the relation between the innovation and changes to the farm state and so on. How these messages can be fitted into the same framework as the farm state and the farm decision process will be discussed in subsection 2.3.

2. The Advanced Simulation

In this section, we use the basic framework of the four “modules” from the simple simulation (farm state, farmer decision process, adoption state and network position), describing each in turn and in detail to specify the structure of the advanced simulation. (This specification will not be as formal as the one for the simple simulation since it describes a simulation which has not been programmed yet and new details are certain to arise during implementation.) As will be seen from Figure 2 below, the basic structure of the modules remains the same, but the flow of information between the modules has changed and become somewhat more complex. The dashed arrows show additional message flows beyond those described in the basic simulation and the flow between farm state and adoption state has now been removed. This is because any changes in the farm state have their effect on the farm decision process and impact on the adoption state through that. Before, only the adoption state determined the messages transmitted by farmers. Now, in addition, they can transmit messages about their decision process (as when they persuade another farmer that they should make the decision in a certain way) or about the farm state (as when they indicate that changing to satisfy the conditions of an agri-environmental innovation is expensive). The farmer decision process impacts on the adoption state (as before), but it also impacts on the farm state (when the farmer introduces a new crop or changes farming practice for example). Finally, these changes in farm state will obviously have a converse effect on the decision process. (If a new crop proves to be highly unprofitable, the farmer will probably reverse the decision to plant it during the next season.)
2.1 The Model of Farm State: Activity Plans and Agri-Environmental Measures

The purpose of this module is to provide an explanation and underlying “structure” to the costs and benefits of a decision to adopt a particular agri-environmental measure in terms of current farm practice. As has already been remarked, the absence of such a dynamic model in many innovation diffusion models is a serious drawback as it removes any possibility of modelling or explaining essential factors like learning-by-doing. The problem is even more severe for the IMAGES research project because the excluded factors are precisely the kinds of policy control variables that it is important to study. (For example, does the cost of a farm survey reduce adoption? Can the application procedure or conditions for acceptance be designed so that farmers are not paid to do what they are doing already? What effect does moving from a yearly application cycle to continuous application have? Will a measure have undesirable effects in shifting farmers to a completely different crop rather than complying with measures on the current crop?)

Three important aspects of farm decision are the relatively long time scales over which plans are realised (typically a year for a crop, but sometimes thirty years or more for reforestation or
building up a line of good breeding stock), the habitual or conservative nature of much farm activity and the complexity of the task of changing (let alone improving) farm practice (which must take into account scheduling, soil, climate, technology, biology and labour relations along with constraints on time, money and lifestyle). Such circumstances are a paradigm case for models based on bounded rationality (Simon 1981). Such models cannot involve any optimisation of utility due both to the profound uncertainty and computational difficulty of the choice problem. Instead, change is incremental and proceeds by such mechanisms as trial-and-error, imitation or communication. Although some farmers may try to increase income incrementally, others may only try to maintain it at a stable level.

To represent these processes, we use the concept of an activity plan (Chattoe and Gilbert 1997). This is simply a fixed length list which describes (in an abstract manner) a particular period of time during which the farmer carries out a set of activities. (The farming year is an obvious example of such a period.) The simulated farmer simply moves through the list, a position at a time and carries out the activity indicated. Once the end of the list is reached, that year is over and the farmer starts again at the beginning. Each position in the list either consists of a positive integer or 0 (the symbol for “do nothing” or “don’t care”). Positive integers are the identity numbers corresponding to a set of farm practices like ploughing, burning, harvesting, applying fertiliser and so on. Most of these processes only incur costs, but some, like harvesting, also produce benefits from the sale of the resulting crop. (In fact, we only need to consider net costs and benefits for each process.) For this reason, the other component of the farm state is the current account, the amount of money the farmer has at any point in the activity plan. The current account is incremented by income from crop sales and decremented by the costs of carrying out various farm management activities. The farmer also has a non negotiable per person subtraction in each period to maintain his family at a subsistence level. Any surplus beyond that can be devoted to the farm or to “luxury” spending, with different consequences for the well-being of the farm family.

The proportion of “do nothing” symbols indicates the amount of “slack” that farmers have in their lifestyle, something which may well also be part of their well-being function. If there is too little slack, the farmer can only take up a new activity (form filling for example) if another is discarded.

If each position in the activity plan was independent, farmers would, at least in principle, be able to calculate the optimal activity plan to maximise income although (even in this simple case) the problem would be combinatorially explosive. In practice, positions are plainly not independent. To harvest potatoes in November, you must plough in April, plant in May and apply fertiliser in August. (For now we will abstract from all issues of “degree” in the activity plan. In practice, applying fertiliser might still be possible in July or September with a corresponding reduction in yield.) We assume that farmers know, at least for the crops they grow and possibly for some others, the precise pattern of activities required to achieve a harvest. (There is an important role here for the public knowledge provided in “farm handbooks” which seem to exist in many countries.) A “crop” can thus be seen as consisting of a list like the overall activity plan, but with a much larger number of “don’t care” symbols, reflecting the fact that most crops don’t require continuous attention. Crops are compatible if their have “don’t care” symbols at complementary positions. (Obviously it is possible to do

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2 This approach may sound trivially deterministic, but now the decision process for farmers involves changing activity plans as they see fit. In fact, habit is extremely important in providing a stable background against which the effectiveness of change can actually be measured.
more than one thing at once, particularly by hiring additional labour, but we are abstracting. In fact, there is little structural difference between a “swop”, described shortly, and paying for extra labour to do two things at once.) In Figure 4 below, crops 1 and 2 are compatible, but crops 3 and 4 are not, since each requires an activity to be carried out at positions 3 and 4. Obviously farmers will be interested in compatible crops which also serve to diversify and smooth their income. However, their choice problem is more difficult than this. Firstly, changes to the activity plan incur costs above and beyond the costs of the activities themselves, reflecting purchase of additional machinery and so on. (These costs are a function of the number of changed positions.) Secondly, the number of compatible crops is typically rather small and for this reason, in order to make an adequate living, farmers must not only know about crops but also about “swops”. These are permitted changes to the activity plan for a particular crop. For example, you may water twice in April and August rather than once in July without any negative effect on yield. Such a swop may make the activity plan compatible with an additional crop and some swops are very cheap or almost free. The catch is that knowledge of feasible swops is rather scarce and hard won by individual farmers. The reason for this is that inept trial-and-error learning about swops can cost you a whole crop! (In fact, we model learning by generating the set of all legal swops and their costs randomly at the beginning of each simulation run. Only a subset of these swops are randomly allocated to the farmers in the population, but every now and again a “new” swop is given to someone in the population as a result of some learning or reasoning they have done.)

Thus each farmer has a small “knowledge base” of activity plans for crops and swops that they know about. In keeping with the assumptions of bounded rationality, we may assert that they have, say, no more than ten such pieces of knowledge at any one time. [Might it be better to have finite but separate knowledge bases for crops, swops and AEMs?] These pieces of knowledge may also be transmitted between farmers, at least if they are on good terms. Crops and swops are associated with costs and these may be transmitted as part of the definitions or separately. (For example, a farmer may know that a particular swop exists but not how much it costs.)

Using this framework, it is clear that an agri-environmental measure is simply another list, isomorphic with the activity plan, but with more “don’t care” positions. (It will also have a flow of payments associated with it.) The fewer “don’t care” positions a measure has, the more “restrictive” it can be said to be and the less likely farmers are to be in a position to adopt it. Just like a crop, a measure can be compatible or incompatible with the current set of crops. (In fact, a measure can be a crop, but with a different set of activities attached, leaving full grown grass longer before harvesting for example. Alternatively, it can consist of a completely different set of activities like fence building, barn repair and reforestation. One advantage of activities like this for farmers is that it matters less when in the year they are done, although there may also be others kinds of constraints, like the weather, which limit the set of possible swops.)
Depending on the requirements of the legislation, there may also be permissible “swops” for the measure but these are likely to be approved at the negotiation stage and farmers might be penalised for making their own swops without approval. This is one of the sources of uncertainty about new measures. Apart from needing to know the official requirements of the measure, it will also be necessary to find out about relevant swops, since relatively few farmers will be in a position to adopt immediately. (In fact, those that are may be precisely those who “shouldn’t” be paid for doing what they are already doing.)

This framework allows us to represent the initial uncertainty about the “real” costs of a measure and the effects of learning-by-doing in a way that is plausible and intrinsic to the model. Given only the official definition of the measure and their current knowledge of swops and crops, some farmers will simply not see a way to make themselves eligible, while others will see possible swops but the costs will be prohibitive given what they know. However, message transmission following the announcement of the measure will include reports of “relevant” possible swops and swops actually agreed during negotiations for people who did adopt. (The latter will presumably set a precedent for later negotiations.) In consequence, farmers may see ways of accommodating the measure or change their perception of its costs to them. (It may also be possible for them to alter their activity plans gradually, through a sequence of cheap swops, in order to achieve eligibility at some point in the future.)

It is also clear that transmission errors can have a profound effect on perceptions of the measure and, once identified, may require targeted publicity to dispose of. Each time a message is transmitted, there is a chance that it will be distorted slightly and in this way erroneous beliefs can become widespread. (For example, if someone is upset to discover that they are required to leave land fallow at a certain very inconvenient time, they may go round reporting this as generally the case, when in fact it only applied to the situation on their farm. There may be alternative sets of acceptable measures from which farmers are allowed to choose only one while the disgruntled farmer reports that the restriction applies in all measures.) A related point is that farmers may have “arbitrary” attitudes to the values of particular positions, for example they may reject any measure that forces them to work at Easter or hold that reforestation is simply “wrong”. Such views constitute moral beliefs or cultural norms. They may not be falsifiable or susceptible to cash compensation so acceptance of measures violating these views may have to proceed by negotiation or the diffusion of acceptable swops rather than through setting higher payment levels.
The only important thing that the activity plan approach does not define clearly is the allocation of land to different crops. In fact, neither of these simulations address the issue of farm size at all. Empirically, many farms have a major crop with one or more additional crops. For simplicity, we assume that cultivating a particular crop simply implies a fixed allocation of land which is part of the specification for that crop. This also takes account of the fact that, strictly speaking, a farmer with a big wheat crop might have to use more periods ploughing. Against this can be set the argument that a big wheat farmer would have more machinery, more labour and so on. In fact, this assumption will probably have to be relaxed and the role of farm size and crop allocation developed further because important issues connected with the adoption of measures hinge on these issues. For example, large farms may not adopt because the payments have a fixed ceiling rather than being per hectare, while if the converse is true, small farms may not adopt. [xx This is awkward. Any better ideas?]

The final piece in the farm plan jigsaw is the impact of economic mechanisms. For now we can assume that all farm practices and crops have fixed costs and prices. In this framework, it is still possible to vary support subsidies to explain how measure adoption might increase when farmers lose income from other sources. Alternatively, prices can be modelled as bounded random walks or time series tracking real data.

2.2 The Model of the Farmer Decision Process: Decision Plan Nets

This subsection describes the role of Decision Plan Nets in modelling the farmer decision process. The first part describes DPNs in general terms and the second part applies them to this particular problem.

2.2.1 The Basic DPN Approach [xx This subsection verbatim from Clermont paper!]

In economics, it is typical to assume that all the important dimensions of a decision (moral, social and financial) are commensurable and can be compressed into a single utility function which will nevertheless be well behaved from an analytical point of view. Another way of putting this is to say that there is always a trade off between dimensions. By contrast, Tversky (1972) proposed a radically different theory of decision based on the process of “elimination by aspects”. He argues that for many choices, agents treat attributes as totally incommensurable. Instead of trading off, the agent decides on a “target value” for each attribute and accepts or rejects a choice depending on whether all these target values are met. Figure 3 shows a possible decision process for apartment choice using the process of elimination by aspects. A DPN is simply a graphical representation of a decision process of this kind (Oskamp 1992). The decision maker first determines the cost of the apartment and rejects it if it is more than $125,000. Only then do they inquire about the number of bedrooms it has, rejecting it if has less than three. Finally, they find out whether or not it has a garden and if it has then they accept it. Attributes that are higher up the tree obviously lead to more rapid rejection if the target value is not reached. However, this should not necessarily be equated with “importance” in other respects, since the ordering of attributes may indicate other factors like a desire to narrow the search space rapidly.

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3 There is a more general issue here. The intention is to produce a simulation in which the decision process for adoption of the measure takes “centre stage”. Representing other aspects of the farm decision process, like land allocation will increase the complexity of the model considerably.
Several things can be said about this approach. Firstly, it is obviously an empirical matter whether the attributes of choice are typically commensurable or incommensurable. DPNs are perhaps more plausible for sequential rather than simultaneous choice and for complicated choices rather than simple ones. (In both these respects, they are appropriate to adoption decisions for agri-environmental measures.) However, the DPN approach does not deal only with strictly incommensurable attributes. For example, a flat without a garden might still be accepted if it was also less than $80,000. However, the DPN is still a far more economical way of representing that kind of decision than postulating a very “sparse” utility function. Secondly, it is much easier to collect data for DPNs in real situations (Gladwin 1989). In particular, decision makers do seem to report their targets in terms of individual attributes even if they are later capable of making an “all things considered” decision. Thirdly, as suggested earlier, this decision process is embedded in time, the decision-maker does not start asking about the number of bedrooms until they have found out the cost of the flat. This may make little difference if all the information is coming from the same source, or is visible at a glance as it may be with tins on a shelf, but it is much more important when data is coming from different sources and takes time to collect.

![Decision Plan Net](image)

**Figure 3. A Decision Plan Net for Apartment Choice** (based on Oskamp 1992).

There are also several obvious ways in which the DPN approach can be extended without compromising the original insight. Firstly, like most economic decision making models, it is

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4 Although in principle each choice point can represent a calculation of arbitrary complexity, this will rapidly defeat the representational advantages of the DPN, particularly if calculations at different nodes interact. However, empirically, agents do seem to break their decisions up into relatively separable stages in this way.

5 Note that the existence of an “all things considered” decision does not support the claim that attributes are commensurable. We need to know about the decision process before we can say that.
typically assumed that the whole DPN is “visible” to the decision maker from the outset. Although one can say that data will not be gathered until it is needed, strictly speaking an agent with the full DPN available would be foolish to turn away data about a choice point they had not already reached. On the other hand, if we suppose that agents do not have their whole decision process in view, it may very well be that they will not seek data about the next stage of the process until they have completed the last. This will also be true if they are unable to proceed for other reasons like institutional constraints. Secondly, it is clear that we need not regard a DPN as a static structure. Agents may modify their own target values over time as a result of learning or changes in circumstances. (For example, if a decision maker spent long enough rejecting apartments costing more than $125,000 they might have time to save more money or they might have to resign themselves to taking out a larger mortgage.) Furthermore, the very attributes of a decision may also change over time. A garden may cease to be an essential criterion if the decision maker manages to secure an allotment or they may simply be persuaded through conversation that a guest bedroom is less valuable to their well-being than they previously suspected. (This brings in social considerations in an important sense. With an experience good, there may be no “facts of the matter” a priori about which attributes conduce to well-being.) Another possibility for dynamic DPNs is that a negative outcome may lead not to outright rejection and termination of the decision process, rather a transition to some earlier choice point. Agents may also “pace themselves” using the target values of a decision attribute. Rather than modifying the maximum value they are prepared to pay, they may simply postpone the decision until they are in a position to pay that amount. (This sort of approach is probably more plausible with non financial attributes. For example, a farm household may “decide” that they will only investigate an agri-environmental measure when they have heard about it from more than three people.) Finally, the DPN approach typically focuses only on the attributes of the object of choice. However, it is also reasonable that an agent might first check the size of the mortgage they were likely to get and then look for a flat that cost up to 90% of that. This draws attention to two factors. Firstly that an adoption decision involves information about both the agri-environmental measure and the farm household. Although it is possible to argue that collecting information about the state of the farm household is an individualistic process, the same is not true of information about the agri-environmental measure, particularly if it is information about how the agri-environmental measure works in practice rather than how it is officially defined. Secondly, information necessary to the decision may come from a variety of sources and in a variety of forms. Some may be directly available to the farm household such as its own accounts. Other information will come from official sources. Households may be interested in “what everybody is saying” about the new agri-environmental measure. In this sense, the social network itself may come to be regarded as a separate medium with properties of its own.

2.2.2 Implementing the Farmer Decision Process as a Decision Plan Net

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6 It is also possible to test other hypotheses, for example that agents will only remember the last piece of information about a particular attribute. In the absence of an attribute, they may not bother to “process” successive pieces of information into a composite value.

7 There are two ways of representing this process which are not equivalent. Either the same choice point may occur later in the decision tree, or else an agent can be assumed to literally return to an earlier choice point. In the latter case, they will not have to go through all the choice points again to return to the previous state. Note that movements within the decision tree and repeated choice points cease to be trivial only if the attributes of choice or state of the decision maker change over time. For example, there is no point in having two choice points about the cost of an apartment unless the dynamics of the decision makers finances are also being modelled.
Each branch point (dimension) of a Decision Plan Net, like the readiness to adopt described in the simple simulation, consists of a current value and a target value in specified units. There are thus two main differences between the decision process in the simple and advanced simulations. Firstly, the increased variety of messages passed between farmers and the increased sophistication of the farm state model mean that there is more than a single dimension of decision. Farmer decisions can take account of financial calculations, the adoption states of associates, the impact of the measure on the activity plan and so on. The possible dimensions of decision will be dealt with in this subsection. Secondly, there are more transitions between distinct adoption states, defined explicitly with reference to both the application process for the agri-environmental measure and the farmers position in the Decision Plan Net. These factors will be dealt with in subsection 2.3. The following is an incomplete list of possible dimensions of decision:

- **Compatibility (Complexity):** These dimensions are treated separately in Rogers (1995, pp. 224-234 and pp. 242-243) but here it is argued that they are aspects of the same thing. (Complexity, which Rogers describes as an ability to comprehend the measure, is asserted simply to be a function of the “distance” between the specification of the measure and the current practice. If the distance is too great, the farmer simply cannot “deal with” the measure.) Farmers may reject measures because of simple incompatibility with the current activity plan using a comparison of “don’t care” positions. However, there are also more sophisticated criteria. For example, a farmer may check whether compatibility with the specification is “reachable” given the current swops and crops they know. To do this, they might just try a finite number of swops at random or use a deliberate planning algorithm. (It seems unlikely that a farmer would give up a crop to ensure compatibility but they might.) [xx It might be possible to realise rejection owing to complexity in a simple manner using the Hamming Distance between the measure and the activity plan, but there is a problem because the numbers at positions represent arbitrary practices and not scale variables. However, practices might be ordered by cost or the activity plan transformed in some other way. Any ideas?] The reason why this is dimension of decision, as described in the previous subsection, is that if a farmer makes the transition from awareness of the measure to actually getting a farm survey done on the basis of, say, simple compatibility, then they will “stick” at this point in the decision process if the measure is incompatible with what they currently know. However, they will come to know new things over time and on the strength of these, they may make the transition at a later date. (For simplicity we assume that people continue to move forward through the DPN or else become definite non adopters. We could also assume that they lose interest after a certain period of time spent at a particular choice point and though this would be straightforward to implement, the possibility will be ignored for now.)

- **Cultural Values:** Measures may be rejected if they are incompatible with various forms of cultural values, also expressed as sets of activity plans. Such sets of cultural values will tend to be shared by social networks and transmitted between members of those networks. The absence of cultural values implies a strictly “pragmatic” attitude to the measures. We will ignore the possibility that farmers can “falsify” cultural values by violating them. [xx Perhaps this aspect should be left out of the simulation for now?]

- **Financial Considerations:** Farmers are very likely to reject a measure if it entails a loss and are more likely to accept it the greater the net benefit it produces. However, they may operate on the basis of a target level, perhaps anchored by farm turnover, above which additional payments will have no additional incentive effect. This is the relative
An advantage criterion described by Rogers (1995, pp. 212-223). As before, farmers may reject on financial grounds exclusive or inclusive of swap costs.

- **Effort Considerations**: A measure may be rejected if it reduces the number of “don’t care” positions by more than a certain number.

- **Time Considerations**: A farmer may elect simply to wait for a certain period of time before taking any further action. This waiting period may represent information gathering, time for reflection, a particularly busy period on the farm or external circumstances (sick relatives, waiting for the children to leave home).

- **Social Considerations**: Farmers may use the behaviour of associates as a proxy for explicit financial considerations. Possible examples are “I’ll get a farm survey done if three of my friends adopt” or “I’ll get the details once half my neighbours have adopted”. Farmers may only count associates from a particular set of networks, weight associates from different networks or just count heads. (As an aside, it appears that social considerations cannot drive early adopters, while individualistic considerations like financial reward will have to do so. This may be an interesting general result. However, it does not imply that social considerations are marginal or secondary.)

- **Attitudes**: In addition to providing information about the measure, associates also have an overall “attitude” to it which reflects their own perceptions of the measure. This will be some function of financial considerations, time considerations and compatibility with current practice and cultural values. For simplicity we will assume that farmers take their associates attitudes at face value, but they could also be qualified by similarity measures between the activity plans, knowledge bases and cultural values of farmers. This dimension corresponds to the readiness to adopt in the simple simulation and involves arbitrary units. When a farmer has received a certain amount of “good attitude” or motivation, they may move on in the adoption process. If they receive more than a certain amount of “bad attitude” or demotivation, they may lose interest and reject the measure. [Strictly speaking, it is not clear whether this is a DPN dimension or just a state variable. Thoughts?] It is also possible that this dimension should be disaggregated so that attitudes describe the measures as “not very profitable” or “too bureaucratic”.

- ... [xx Help!]

A final determinant of adoption described by Rogers (1995, pp. 243-244) which is obviously relevant to agri-environmental measures is trialability. This is the extent to which the measure can be “piloted”, tested for a limited period or applied to a limited part of the farm operation without penalty. Obviously, the decision not to model farm size and the allocation of land to crops excludes the last interpretation at least for now. However, trialability and the related concept of autonomy (the extent to which the farmer is committed to leaving certain aspects of the activity plan fixed in the future, regardless of such things as changes in relative prices) are obviously dimensions of decision. Unfortunately, introducing autonomy considerations also requires farmers to model future prices and this seems like an excessive complication at this stage.

From the point of view of implementation, the best choice of representation for DPNs is not completely clear. A list of lists is an obvious possibility with the main list representing the whole DPN and sublists representing each individual dimension in time order. However, in addition, there must be some way of indicating changes in adoption state corresponding to particular positions reached in the DPN. (For example, a farmer may go from being aware of the measure to having a survey done on the strength of financial calculations but then move on from that to signing the contract on the basis of the attitudes of current adopters who are
also friends.) Dimensions will consist of three arguments, a target value, a generating function or procedure which returns the current value and a binary variable which indicates the farmers advance awareness of the dimension. For some dimensions, like attitude, the generating function will just be a running total. For others, the generating function may be a relatively complicated calculation, taking into account farm state, knowledge base and so on. (This functional approach is important as it allows new dimensions to be added incrementally merely by writing new functions or procedures based on the prevailing specification of agents and the environment.)

The final argument for each dimension requires some discussion. Although, from the perspective of the simulation, “complete” DPNs will be generated or specified for each farmer at the outset, there is no presumption that the farmer is self-aware enough to map out the whole decision process in advance. The binary variable thus shows whether or not the farmer is currently aware of particular dimensions, although they are obviously aware of the dimension they are currently at and, almost certainly, of the dimensions they have already passed through. Awareness of dimensions has an impact on both messages transmitted and received about the decision process. Farmers cannot pass on messages about dimensions they are unaware of and may not “register” messages that deal with those dimensions, thus rejecting potentially useful information. On the other hand, farmers may be influenced to replace “unknown” dimensions with dimensions suggested by other farmers. The same logic applies to the social construction of “target values”. (These points and mechanisms of decision process change are discussed further in subsection 2.4.)

2.3 The Structure of the Adoption Process

Now that the adoption decision process is specified in much greater detail, there is a sense in which the adoption state is merely a derived value of the Decision Plan Net. At any time, the adoption state can just be said to be where the farmer “is” in the DPN. However, this is not quite true for two reasons. Firstly, there are three adoption states (ignorance, adoption and non adoption) where the farmer can be said either not yet to have started on the DPN or to have completed or perhaps left it. (In fact, this is not quite true either, since the DPN may also include a dimension for the renewal or reconsideration of the contract.) Secondly, there are stages which are imposed by the institutional arrangements of the application process. (For example, if a farm survey is required, farms can be divided into those who have the survey done and those who have not. This is also important because if every farm has its own idiosyncratic DPN, it will be quite hard to compare the progress of different farms in an empirically meaningful way. You can’t just say that two farms have both “gone three dimensions”.)

Rogers (1995, pp. 161-203) divides the adoption process into five stages. The first is knowledge, which in our framework is simply that the farmer has the formal specification for the AEM in their knowledge base. (Though nothing is presumed about knowledge of relevant swops, costs or payments.) Rogers then lists persuasion and decision as separate stages. From our perspective, however, persuasion can be seen as just one dimension of decision. [xx Though perhaps not? See previous comment about the attitude dimension.] The next stage is implementation which involves actual changes to the activity plan. Finally, there is confirmation, when the actual outcome of adoption is compared with the anticipated outcome. The confirmation stage will affect subsequent adherence to the contract and subsequent
renewal. A serious discrepancy may lead to continuing negative word-of-mouth which will have a demotivating effect on many potential adopters.

It is encouraging that the simulation framework is broadly compatible with the Rogers discussion, which is a synthesis of extensive empirical work in a number of fields. In addition, the framework is also compatible, in a somewhat abstract way, with important aspects of the application process for various different measures, as described by the farm experts:

- **Application**: This involves the farmer providing a description of the farm, which we will equate with the current activity plan, though it may also include details of other farm attributes. It is at this stage that the administrators of the measure can reject certain kinds of farms if they have any discretion to do so. (This approach allows the simulation to be extended so that the administrators have to learn adaptively about the effect of the measure from the kinds of application that are received.)

- **Farm Survey**: This is the stage at which the reported activity plan is compared with the “actual” plan. (It is also possible to view the application as an “incomplete” summary of the activity plan which may need to be supplemented with on-site inspection and more detailed questioning in particular instances.)

- **Negotiation**: This is the stage at which it may be possible to agree swops or perhaps “trade offs” in the design of a contract for a particular farmer under the measure. It is probably not necessary to model the negotiator from the administration explicitly. Instead, the negotiation process can be represented as a set of alternative measures from which the farmer can chose.

- **Contract**: This is a statement of the actual activity plan which is to be carried out and the time period over which it will remain in force in return for payments under the measure. It will also specify when payments are to be received.

- **Renewal and Renegotiation**: There may be an option for the contract to be renegotiated at various stages. This may reflect changes in external circumstances (prices, removal of traditional subsidies, the existence of new measures, redesignation of the land under various categories) or the farmers more accurate perceptions of the costs and benefits of the measure once it is in place.

- **Monitoring**: This involves the administrators checking that the activity plan specified in the contract matches the actual activity plan being carried out.

Finally, it should be remarked that there is a potential contradiction in modelling the adoption of measures in terms of an activity plan since the time costs of application are obviously not habitual and it may be these costs (rather than those of adopting the measure) which affect the decision process in the early stages. This factor, while not definitely significant, can be taken into account if required by specifying that changes in adoption state can only take place at the next “don’t care” position in the activity plan reflecting the need to spend time filling forms, meeting advisors and so on.

2.4 Specifying Social Networks: The Transmission and Reception of Messages

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8 Application procedures differ considerably. Not all these stages apply to all measures and the list is probably incomplete. For an extremely detailed list of agri-environmental measures see Deblitz and Plankl (1998). Certain stages like contract and monitoring will not be modelled because they require too many additional assumptions about farmer decision making regarding compliance. (Rumour transmission about monitoring and farmers getting caught for non compliance ought to fit into the framework though.)
We have already discussed the generation of overlapping social networks of friends, associates and those in other categories. In this subsection, we consider the various different mechanisms which influence the transmission and reception of messages.

2.4.1 The Nature of Messages

The following kinds of messages can be passed on within the current framework:

- **Crops**: Descriptions of the practices which must be carried out in order to produce a particular crop. We assume that the practices are transmitted accurately but that the costs of practices may be transmitted inaccurately or not at all.

- **Swops**: A pair of activity lists for a particular crop which allow one set of activities to be replaced by another at a certain cost but without any loss of yield. Again we assume that the technical aspects of swops are transmitted accurately while costs can be transmitted inaccurately or not at all. One interesting side effect of this representation is that swops can become “submerged” in an activity plan allowing co-evolution of a set of farming practices to maximise compatibility between crops. Swops for standard farming practices are different from negotiated swops during the adoption process and are stored in a separate knowledge base.

- **Measures**: A formal description of an agri-environmental measure. We assume that there can be errors in the transmission in these descriptions as well as in the specifications of payments.

- **Costs**: These are not really a separate category, but messages about swops, crops and measures can be transmitted with incomplete or inaccurate cost information so the effective content of some messages is just about costs. For simplicity, we assume that conflicting cost information is averaged and missing cost information is simply copied in from the new message. (We can allow averaging and overwriting because costs and benefits are not “all or nothing”. Averaging would not be possible for activity plans and Beliefs about measures, crops and swops can be aggregated or used as replacements. However, either mechanism can be a source of error.

- **Attitudes**: At any time, a farmer can signal an attitude to the measure based on their current beliefs about such factors as costs and benefits, restrictiveness, compatibility and so on. For now, we assume both that attitudes are taken at face value (rather than being adjusted by “relevance” or the similarity between the two farmers) and that attitudes are “hardwired” in the sense that the attitude generating function is the same for all farmers.

- **Cultural Values**: This is the level at which social construction (Scott 1996) and mutual social influence (Latané and Nowak 1997) operate in networks. Farmers are more likely to share the cultural values of their group (network) by a repeated sequential averaging process with mutation. (This may give farmers at central locations in the network greater influence on the resulting values.) Since we are modelling static social networks, the other normal response to cognitive dissonance - finding another group - is not currently available.

- **Target Values for Dimensions of Decision**: It is possible for a farmer to believe that a dimension should be important in the decision process, but not to know what a realistic target value would be. Such target values can thus be inherited from associates. This kind of inheritance applies both to dimensions that the farmer is aware and unaware of. As before, averaging takes place between discrepant values and missing values are inherited unchanged.
• **Generating Functions for Dimensions of Decision:** It is also possible for associates to transmit messages about what dimensions they believe to be important in the adoption process. This is another way in which responses to a measure can be socially constructed in a dynamic manner. We assume that this process only occurs with dimensions of which the farmer is currently unaware and the generating function from the associate (and the target value too if there is one) are inherited. After this process, the farmer is assumed to become aware of that dimension. (The idea is that some sort of discussion has taken between the associates on the subject of the measure which has clarified the farmers thinking on that aspect of the decision process.) We might also be effective to leave some spaces in the list for “null” dimensions and say that new dimensions can only be placed in these spaces. Farmers are always unaware of null dimensions. This also allows for the possibility than an associate will persuade you that one of your dimensions of decision is not important and should be replaced with a null dimension.

A final point about this framework is that the increased sophistication in modelling message passing also allows us to incorporate different kinds of publicity which have so far been left out of the basic simulation. Certain kinds of messages (on measures and their costs, crops and possibly swaps) can be transmitted “officially” by mailshots, posters and farming magazines. Farm advisors can also transmit this information, but in addition are likely to build up a large expertise (knowledge base of swaps) through repeated interaction with farmers. (Expert advice may involve suggesting the cheapest or smallest set of swaps needed for eligibility.) Finally, we can also envisage opinion leaders (including local dignitaries, trusted farm advisors and newspapers) having a longer term effect on cultural values. Implementing these differing sources of information in terms of the credibility parameter (discussed in subsection 1.2.6.1) can be realised simply by attaching a weighting factor to differing classes of network that determines the averaging process. (A weighting of 1 means that the new value will overwrite the existing one, a weighting of 0.5 indicates averaging while a weighting of 0 suggests that the new value will be completely disregarded. An official mailshot will be given a weighting of 1, at least as regards the formal description of the measure.)

### 2.4.2 Message Transmission

There are three different sources for messages and the message to be delivered can be chosen at random from these sources for simplicity:

- **Knowledge Bases:** Messages about crops, swaps, costs and measures originate from the farmers knowledge bases and each value has a small probability of being distorted in transmission or left out altogether.
- **Farmer Decision Process:** Messages about target values and generating functions originate here. Farmers can only transmit messages about dimensions they are aware of. Actual target values and generating values (ones the farmer is currently putting into effect or has already used) should be more credible than those still in the future.
- **Attitude Generating Function:** This is like other generating functions in that it takes in the states of farmers, their current knowledge about the measure and other inputs, returning a positive (or negative) attitude to the measure based on the associates current

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9 Because target values don’t have units, “inheritance” can also take place when the generating function changes but the target value doesn’t. We shall ignore this possibility for now.
knowledge. (Plainly this allows farmers to change their attitudes as more information becomes available.)

- **Cultural Values**: An averaging process takes place between the two sets of values concerned with a small possibility of mutation at each site. (For each pair of sites, there is a 5% chance that farmer A will change their value to that of farmer B and 5% chance that the converse will happen, 5% chance that farmer A will mutate, 5% chance that farmer B will mutate, otherwise nothing will happen.

To conclude this subsection it should be pointed out that we have now described three different mechanisms by which one farmer can alter the decision process of another (Chattoe and Gilbert 1998b, p. 13). The first is purely informational, as when the positive attitude of one farmer changes the attitude of an associate or a generating function takes account of the fact that another friend has become an adopter in returning a current value. The second can be seen as somewhere between information and persuasion, when a farmer takes account of the target value of another in some dimension of decision. Finally, modification can take place by pure persuasion when a dimension of decision is added, replaced or removed.

### 2.4.3 Message Reception

In this subsection we consider what happens to messages of different kinds when they are received:

- **Knowledge Bases**: Messages about crops, swops, costs and measures are distributed to the appropriate knowledge bases. Discrepant values are averaged according to the network type weights and blank values are replaced wherever possible. Totally “new” knowledge may require the removal of some piece of current knowledge since the knowledge bases are of finite size, perhaps on a FIFO basis.

- **Farmer Decision Process**: Messages about target values and generating functions are directed here. (Updates to the current values of dimensions resulting from calls to the generating function can also be seen as messages.) Restrictions on the modification of dimensions have already been discussed but another obvious restriction is that dimensions which have already been carried out cannot be modified.

- **Cultural Values**: The averaging process used in the transmission cultural values has already been discussed.

### Conclusions

Since the purpose of this paper is a technical one (to specify a simulation), there is little point in a formal conclusion. However, it might be worth reiterating the intention of the simulation in a few sentences. The object is to design a model which combines three elements: boundedly rational and time embedded decision making about the adoption of agri-environmental measures, the transmission of meaningful messages that are context dependent for both sender and receiver and a simple but plausible representation of overlapping social network structures. In the process of designing this model, it has been necessary to add other features like the farm state in order to “complete” the model and make it coherent. In a previous paper (Chattoe 1996) there is a methodological discussion of two sorts of abstraction: simplification of causal connections and simplification of process. It is argued that simplification of causal connection is not actually a valid form of abstraction at all, but changes the whole nature of the model and often makes it incoherent. (If these models are not
incoherent, the simplifications often simply “write out” certain processes complementary to the causal connections removed. For example, in order to give meaning to genuine “needs” for economic agents, you have to model bodily process at least to some extent.) This paper follows the other approach, retaining all the possible causal connections between agents and the environment, but simplifying and abstracting from the processes involved in these causal connections as far as possible. The acid test of this approach is that a large number of disparate facts and processes can be arranged (reasonably sensibly) around the activity plan representation. Furthermore, although there is a relatively large number of different mechanisms at work in the simulation, the implementation of each is neither unreasonably fiddly nor excessively contrived. The number of arbitrary (theory based) parameters has also been kept to a minimum. Instead, these have been replaced with “empirical” parameters like the number of farms and the amount of money they have.

References


**Other**

Need to look at questionnaire responses to ensure a relatively representative coverage of reasons actually given farmers. (Bear in mind Sarah’s point that some of the reasons given are rather general and should therefore be seen more as orientations or organising principles than dimensions of decision.)