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An Approach to Predicting Demand for an Agricultural Innovation[1]

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Abstract

Historically research about diffusion has largely been focused on rates of adoption and explanations for them. This is a matter of secondary importance, arguably, to the question of the likely total level of adoption. In the case of agricultural innovations total adoption can be expected to be strongly correlated to the value attributed to the innovation by those producers for whom it is relevant.

In this paper a model is presented which frames the components of the farm management context that substantially determine the valuation of innovations. This model has been developed over two decades of research into potential adoption.

Introduction

To propose that human decision making is informed by the context within which decisions are made is unexceptional. Potentially, 'context' relates to all phases of decision making including recognition of the need for decision.

The challenge in analysing and forecasting decisions is in framing context efficiently. Identifying the specific salient components of the environment external to the decision maker, and salient characteristics of the decision maker, is an empirical task of considerable magnitude. While this task may be an efficient research undertaking when few decision makers are of interest, as the set of people of interest increases so does the incentive to employ increasingly summary, sometimes implicit, models of contexts and components of contexts.

Summary models are predominantly deductive and derive from academic disciplines rather than inductive and derived from grounded research. Implicit elements of models can spring from disciplinary bases. This deductive approach is doubtless efficient for the cumulative enhancement of the knowledge base, and analytical power, of disciplines. A tension can arise, however, when the detail of contextual differences subsumed in such a process includes determinants of differences in human behaviour of interest to a particular research question.

The need, in this circumstance, is to explore behavioural variation using models that can detect causal linkages between aspects of context and deviations in behaviour predicted by summary models. That is, back-checking of the validity of the model has to be explored still using summary models. An example of this is the analysis of farmer behaviour with respect to innovations. Expectations form about the positive value of an innovation to farmers. These expectations may be sourced in assumptions made by agricultural scientists, agricultural economists, extension workers, consultants, accountants and 'leading' farmers. Adoption is rarely instantaneous, leaving in abeyance, at any point in time, validation of the projected level of penetration by an innovation: excessively optimistic expectations of ultimate uptake cannot be distinguished from slow adoption.

Analysis of non-instantaneous adoption typically relies on models of diffusion of innovation, seeking explanatory idiosyncrasies of innovations or of farmers. Other contextual detail is out of view, in a sense already assumed away.

In this paper an alternative approach is proposed to research questions for which the context of farm management matters. It is an approach that coheres with Akerlof's (2007, p. 29) observation that '[t]he individual economic unit, be it a firm, a consumer, or an employee, behaves the way it does for a reason. And if these actors behave as they do for a reason, we can expect to find those reasons from the structures that we see in close observation; and because of those structures their behavior will also tend to be duplicated.' The approach outlined in this paper has been developed over two decades, involving some thirty projects, of research into farmer decision making with respect to innovating and other issues. It is relevant for the analysis of likely adoption and disadoption, where the latter might better describe the target of a government or industry policy.

Origins

The approach presented here arose from an interest in developing a closer and more detailed understanding of determinants of farmer decision making to inform analysis of policy designed to facilitate adjustment. Familiarity with farmers as targets of extension efforts evoked concern among the researchers that existing relevant aggregate models were too aggregate to enable contemplation in detail of likely responses to policies. An indicator of the problem was the absence of useful bases for the development of, and choice among, extension activities with plausible likelihood of success. Another indicator of the problem was a disconnect between extension theory and practise and extant theory and practise in business marketing. Particularly, the specific, unique management context into which adoptions would have to be inserted by each adopter appeared, generally, to be overlooked, ignored or undervalued.

Extension overlaps 'promotion' in marketing to a large degree. A substantial literature related to promotion has developed over the past half century, together with considerable research into consumer behaviour and buyer decision making. Yet there are few signs that either has informed

the analysis of farmers as ‘buyers’ of innovation or adjustment policies. The appropriate scales of aggregation in models, though, might reasonably be expected to be similar. Yet, adoption research seemed often to involve much higher levels of aggregation.

Marketers are active in the search for relevant differences amongst consumers of a given type of product so that optimal tailoring of promotion (and products) can be defined. A central question is whether or not sub-groups (‘market segments’) exist that have sufficient similarity in characteristics relevant to products and promotion, and are of sufficient size to warrant targeting them with tailored output. The disciplinary interest is thus quite ‘disaggregated’. Indeed, notwithstanding the language (‘segments’ and ‘segmentation’), the interest is in identifying criteria for aggregation into groups.

The exploration of segments of the population has refined the precision which marketing researchers bring to the notion of product as potential acquisition. This, and promotion, are intrinsically linked since criteria applied to product choice logically guide the content and emphasis of promotion.

The need for closer understanding of decision making contexts requires marketers to capture data directly from subjects. A census (of consumers) is inefficient and models inevitably guide data collection. Broadly, these models relate to the engagement of the consumer with the decision problem of interest, net positive outcomes (ie benefits) sought from choice and psychographic and demographic correlates. Jointly, these determine the relevance of a product to a consumer, their openness to relevant information about it and the capacity of the seller to reach them with tailored output, including promotion.

Adoption and diffusion theory

Diffusion theory is the only extant model of market segmentation through time (Bagozzi 1986). It is contemplated by marketers[2] as well as in disciplines in which there is more immediate interest in agricultural adoption, specifically. It embodies a model of stages between ignorance and use (awareness, interest, evaluation, trial and adoption) through which different adopters move at different speeds to acquire an innovation (Rogers 1995). The central driver of the process is argued to be personal and social-situational differences in individual adopters (see Rogers 1995).

Differences in speed of adoption among consumers are commonly specific to product categories, are in part related to personal adopter characteristics, such as age and innovativeness, and are influenced by marketing effort (see Steenkamp and Gielens 2003). In marketing the judgement is widespread (McColl-Kennedy and Kiel 2000, p. 371-3) that characteristics of individual consumers, in terms of category traits of adopters, are of secondary importance to product characteristics and other situation-specific factors such as intensity of competitive marketing effort.

‘Product characteristics’ include relative advantage (cf existing substitutes), compatibility (with needs, attitudes and experience), observability, simplicity and trialability (McColl-Kennedy and Kiel 2000, p. 373). These are, originally, Roger’s (1995) ‘characteristics of innovations’ (with ‘simplicity’ expressed as ‘complexity’) and are commonly reviewed as sources of barriers to adoption/diffusion of a specific innovation.

This characterisation, of product characteristics as factors moderating adoption, marks the point of departure of our approach from more conventional analysis of adoption. It is an unhelpful perspective to adopt. There are various problems with it. The most fundamental is the implicit notion that the innovation is intrinsically meritorious. The starting point for analysis is that the innovation has value for somebody. Marketers refer to such an approach as a 'product orientation' or 'sales orientation' (McColl-Kennedy and Kiel 2000); in either case a poor response by buyers to the product is viewed as a challenge for selling and advertising rather than cause for evaluation of the basic appeal of the product.

A related problem is that these 'barriers' include some that can slow adoption (complexity, trialability) and some that can deny adoption altogether (relative advantage and compatibility).

These features of the 'adoption perspective' arguably encourage a tendency for those promoting or projecting adoption to make unfounded assumptions about likely total adoption. They are linked to an observation of Rogers (1995): he described as 'strange' the rarity of research designed to identify why a product is adopted. In the absence of this knowledge it is not possible to project final uptake reliably. Nor is it possible to contemplate efficient ways to promote adoption to potential adopters facing diverse different costs and benefits associated with adoption.

Also, the approach can make it difficult to disentangle stable features of adopter categories from other causal influences and lead to confusion:

> Overall, despite numerous studies, the results of research in this field have been disappointing. Most of the statistical models developed have low levels of explanatory power despite long lists of explanatory variables…. Furthermore, the results of different studies are often contradictory regarding the importance and influence of any given variable.
>
> (Abadi Ghadim and Pannell 1999).

For reasons advanced below, there may be good reasons to expect that the personal/social situational factors that cause buyers to lodge in one or other adopter category may be even weaker in explaining adoption paths in the case of innovations directed at farmers than seems true of final consumers. One indicator of this being the case is marked differences in rates of adoption within an industry, such as the rapid adoption of elite-sheep breeding principles in contrast to the slow adoption of quantitative genetics in sheep breeding (Kaine and Niall 2001a).

The importance of determining what proportion of potential users would wish to adopt, prior to analysis of adopter characteristics, is methodologically obvious. To do this it is necessary to conceptualise the contexts within which the potential adopters act.

Contextual framework

The framework for considering adoption detailed below has been developed through a string of projects focused, variously, on farm management, farm performance and adoption. It is comprehensive of context and provides a guide for farm-level enquiry into likely evaluation of innovations. 'Context' refers to the current farm operations and associated endogenous factors;

those aspects of the farming system that influence the benefits to be had from adopting an innovation.

The framework, called the Kaine-Lees-Wright (KLW) Frame©, spans biophysical endowments, technology and practice mix, labour and lifestyle constraints and strategic perceptions. The rationale for the inclusion of each follows. It is pertinent to note that the interest here is not, essentially, with adoption paths through the population of adopters; it is with the identification of that population and substantive groups within it. This interest is not with dynamics. Indeed, the prospect that different groups may value innovations differently casts doubt on notions of continuity in diffusion processes.

At its broadest the objective is to segment the group of economic agents who might plausibly adopt into adopters and non-adopters. In that process the analysis enables further segmentation into groups that, as groups, value innovations differently due to differences in context.

'Context' is a broad church. To estimate segment populations it is necessary to identify relevant contextual differences. The accuracy of estimates then relies on the information available, or which can be established, as to the distribution of these characteristics amongst potential adopters.

When final consumers comprise the actors of interest the functional appeal of an innovation to needs and wants has to register with adopters via the informational pathways that link them to the world of available products. These are usually attenuated. This is reflected in notions, such as opinion leadership and product mavenism, that one encounters in the adoption literature. Most consumers have a weak, or no, incentive to scan the environment for innovations. Innovators, as an adopter category, are different in this regard (Rogers 1995). We know, as noted above, that consumers fall into adopter categories differently according to product category and that Innovators are a small proportion of all adopters.

Attention to market information about a product category is a defining feature of adopter categories. While this is probably valid in the case of consumers, it may be only marginally relevant in situations, such as farms, where innovations face derived demand. It is assumed in marketing that 'organisational buyers', acquiring inputs, are a very different animal to final consumers: they reflect on their needs; they have quite clear, and focused, objectives; they often use explicit, structured decision making processes (which, in the case of innovations especially, may involve a set of decision makers); they are few and often in direct communication with input producers. In short, they are 'professional' buyers, where consumers are amateurs, with clear incentives to avoid purchase error.

Characterising engagement with decisions

In marketing theory the extent of engagement of a decision maker with a decision is modelled as a variable that impacts upon cognitive effort devoted to the decision making process. The lower the cognitive effort, the more decision-makers will rely on psychological and behavioural shortcuts. This, inevitably, increases the risk of decision error. The entertainment of that possibility, by the use of shortcuts, indicates that engagement with a decision is likely to be related to perceptions of the prospect and materiality of the risks involved. That is, the expected impact of error influences the degree and manner in which the decision-maker engages with a decision. Impacts may arise in

a variety of domains. A decision may cause a person to acquire an unsuitable product, pay too much for it, think themselves a fool or believe that relevant other people will think them a fool.

The term most commonly used in marketing for decision engagement is 'product involvement' (McColl-Kennedy and Kiel 2000), reflecting the seller-oriented perspective of marketing.

High involvement implies the most extensive operation of decision making processes, including contemplation of relevant needs and alternative solutions. As noted above, in the context of producing organisations, it is assumed in marketing that, in contrast to purchase decision-making by consumers, high involvement is pervasive. That is, choice criteria are derived from desired output characteristics and production processes and are clearly defined, and attention to relevant innovation is routinely high. Moreover, alertness to innovation, and preparedness to adopt, will tend not to be product-category-specific for reasons other than organisational relevance. That is, consumers may be highly involved with regard to mobile phones but not clothing; buyers for organisations are expected to be highly involved with all input decisions.

Whether such an assumption is valid with respect to farmers is a key issue. If it is, analysing adoption through the lens of adoption models is problematic: the assumed pathways of information and influence for decisions (Rogers 1995) may well be wrong, or less important than assumed, causing conflation of causes of adoption over time.

The research on which this paper is based has enabled analysis of this question.

The KLW Frame©

The frame lists the characteristics of a farmer and farm that may need to be specified to identify the attractiveness of an innovation. It also indicates the temporal context in which each is considered, adapted and reviewed. The objective in developing the frame has been to define a window on the context within which a farmer operates which, while being comprehensive, is as concise as possible. Its purpose is as a guide for field research which enables reliable projections of total adoption. In some projects (eg, Kaine and Bewsell 2005, Bewsell and Kaine 2006, both of which report on adoption by apple growers) this has been via a census; in others (Reeve et al. 2000, Kaine and Niall 2001, Kaine, Court and Niall 2002, Kaine, Sandall and Bewsell 2003, Bewsell and Kaine 2005, Boland, Bewsell and Kaine 2005) it has been by extrapolation of segment membership from sample data.

Promotional effort (extension programs) and/or research has, in some projects (Kaine and Niall 2001, Bewsell and Kaine 2002, Kaine, Court and Niall 2002, Boland, Bewsell and Kaine 2005), subsequently been designed on the basis of information about segment characteristics.

Context is specified as being composed of existing operational components and various constraints. The interest is in the 'fit' of an innovation with existing production processes and constraints: the frame of reference the farmer brings to contemplation of an innovation.

At the same time, it is necessary to allow for the range of disruptiveness across innovations: some innovations imply significant modification to existing practices but may, nonetheless, appeal. That

is, fit with existing production processes should not be assumed to be of defining importance. Any contextual frame must be capable of guiding enquiry about criteria that will be applied to highly disruptive innovations. (Even identifying the extent of disruption that adoption would entail requires close analysis of the context, of course.)

The key challenge for any frame is the identification of a conceptual model that defines the farm system as the farmer views it. This is the device required to reduce the variety of detailed farm and farmer characteristics to manageable proportions. Conventional management analysis begins such a quest at the most fundamental level: strategy. That is, how does the farmer view both the nature of the game they are playing with the environment external to the farm and the production capabilities of the farm?

Strategy in most farming contexts cannot meaningfully be described in terms developed in the realm of corporate or competitive strategy. Rivalry with competing suppliers is an empty notion in near perfectly-competitive situations. Rather, farm strategy is closer to the decision theory construct of 'games against nature'. In this domain perceptions of control over dimensions of inputs, outputs and goal achievement (including profitability) comprise the perceived character of key linkages with the external environment.

These perceptions are in part determined by the production capabilities perceived for the farm; particularly, the enterprises thought to be feasible. Farmers pursue strategies, composed of enterprise choice (including degrees of diversification), reliance on debt, and sensitivity to change in salient data (such as price), according to their perceptions of control (Kaine, Lees and Sandall 1994). This can be expressed another way: they strategise against nature according to the ambiguity they perceive in data about their environment and their psychological response to it.

The strategies, as they are translated into operating plans, can embody responses to perceived risk in many aspects of farm practices, proposed changes to which may attract 'strategic' concern (Murray-Prior 1994). The strategies they choose fundamentally constrain their flexibility to adjust production behaviour in response to relevant environmental change (see Murray-Prior 1994 and Murray-Prior and Wright 2004). The same constraints are active over the evaluation of innovations. The way strategy affects context seems best to be captured by identifying its specific adjustment constraints within the practices employed on the farm (see below and Murray-Prior 1994) and by identifying a summary driver of response to perceived, real risk: perceived control.

At any point in time the perceptions of control can be captured, as appropriate, by application of psychological tests (eg, self-efficacy, locus of control) (Kaine, Sandall and Bewsell 2003, 2004). These condition the felt riskiness of behaviour and can be expected to play a significant role the greater the change in farm practices implied by adoption of an innovation (Kaine and Niall 2001, Kaine, Court and Niall 2002). For many innovations the strategic context, as measured here, may not be relevant; it will depend on the disruptiveness and the changes that adoption of a specific innovation is perceived to imply for control and risk. 'Lower level' strategic constraints are captured in farm practices.

The operational core of the farm context is the set of technologies and practices employed in production. Specifying these in a meaningful way involves mapping the physical process of production. While notionally this could be a major undertaking, in reality the task is limited by two

factors. One is the commonly limited array of feasible production processes. The other is the framing role of the nature of the innovation itself with its specific requirements for practice change.

Innovations can fit more or less well with existing production processes. Consequently, when mapping processes the aspects of interest are those which are key in determining the ease, costs and benefits of the fit of the innovation. These are those that determine compatibility and those that the innovation displaces which construct the existing levels of system performance. The technology in use and the skills available may be among these aspects.

Biophysical resources and constraints come into analysis, likewise, to the extent that they intersect differently with the innovation than does existing practice and/or that they moderate the fit of the innovation.

Reviewing labour availability and lifestyle preferences is similar. The relevance of this source of constraints depends on existing labour usage and the changes, in level or timing, of labour usage implied by the specific innovation.

Jointly, these components of the frame comprise the qualitative physical, practice and strategic dimensions pertinent to farmer evaluation of a specific innovation. They determine the opportunity costs, profitability and perceived riskiness an innovation implies for a farmer.

Financial constraints are not regarded as part of the context. While they may obviously play a role in speed of adoption, they relate to capacity to invest in an innovation, independent of its attractiveness to a farmer. Impacts of financing requirements on the evaluation of innovations will surface in considerations of risks to goal achievement. That is, the value of an innovation will be influenced by costs and risks that financing options may add to it, but finance is not a constraint that operates in the way a consumer's budget might. Other input constraints, such as labour and land, would be treated similarly if they were equally continuous (i.e. less lumpy).

While our interest is in identifying distinct segments within potential adopter populations rather than diffusion dynamics, a part of context is temporal. This is the persistence of attention to, frequency of adaptation to, and frequency of review of the dimensions of context.

Managerial attention is a limited resource. Allocation of attention can be described as being either to ongoing operations or to innovation. An endogenous opportunity cost of attention thus exists (see Gifford 2005). Attention will be allocated according to perceptions of relative benefits to be derived from attending to alternative targets. For information related to innovation in farm operations, whether strategic or technological, this is likely to be conditioned by lead times in production processes and other constraints associated with modifying farm practices, perceived rates of change in relevant environmental characteristics (such as price variability, local land sales, family circumstances, flow of innovations, and so on), the perceived cost of delay in innovating and the history of farm performance. As well, perceptions of control will condition the perceived salience of information.

Each farm has an idiosyncratic dynamic, spawned by its context, to which the allocation of attention is linked. The allocation of attention coheres with context.

By identifying the frequency of review of context, which is the 'baseline' attention to context influencers, frequency of adaptation (of operations or strategy) and persistence of attention, the intelligence system of a farm can be described. This is suggestive of the openness of a farm to external information and the degree to which high perceived value is required to attract attention.

These 'attentional' manifestations of the farm dynamic lead to patterns of monitoring of the operating environment of the farm and farm practice, and adjustment, that is 'practically sensible' for a farm manager.

Their effect, in the context of adoption, will be to influence speed to adopt. This suggests that adoption may be distributed through time for completely context-specific reasons and that a single farm could vary considerably in this from innovation to innovation (as was clearly evident in, for example, Kaine and Bewsell 2005). (This intersects with the information-based component of the model of adoption that Lindner (1987) proposes.)

As well, they have implications for the promotional (extension) strategies that may be required to attract farmer attention to innovations focused on state variables which are less frequently attended or reviewed. While this may seem to contradict the argument that farmers are pervasively highly involved in decisions affecting the farm, the matter is more to do with the durability of such state variables. The infrequency of attention and review reflects farmer perceptions that rational, or forced, change will be infrequent. Such variables are foundational for more ephemeral variables.

The implications of innovations in less-frequently attended variables reach more deeply into the operation of the farm. Such innovations, and innovations targeted at practice and which imply adaptation of more durable state variables, can only be promoted successfully if the magnitude of the consequences of adoption are understood. Government policy seeking to modify farmer behaviour possibly lodges here more often than does the output of agricultural research.

The frame is summarised in Figure 1. Examples of state variables, the dimensions of context, are shown in italics. Under the 'temporal' headings are shown example, possibly quite typical, frequencies applying to each state variable category. 'Constant' indicates continuous attention, 'fitful' indicates that attention is attracted by a perceived, significant change in a state variable and 'episodic' review is provoked by the periodic appearance of opportunities for change.

Figure 1: Kaine-Lees-Wright Frame

STATE VARIABLES	ATTENTION	ADAPTATION	REVIEW
Biophysical resources and constraints: • *Climate* • *Topography* • *Soil type*	fitful	rare	rare
Strategic perception: • *Control over goal achievement* • *Control over output* • *Control over inputs*	fitful	rare	infrequent
Technology and practice mix: • *Irrigation delivery system* • *Planting density* • *Ram selection method* • *Farm layout*	constant	occasional	episodic
Labour and lifestyle constraints: • *Amount and timing of labour available* • *Lifestyle preferences*	constant	occasional	episodic

Application

Detailed coverage of the processes of data collection and analysis is beyond the scope of this paper. The nature of them is captured in the following.

The main technique employed is convergent interviewing (Dick 1998).

> Convergent interviewing is unstructured in terms the content of the interview. The interviewer employs standard laddering techniques (Grunert and Grunert 1995) to systematically explore the reasoning underlying the decisions and actions of the interviewee.
>
> Given a limited set of different farm contexts for an innovation then, in principle, that set can be identified by interviewing producers from each context. That the set has been identified can be known by the fact that the same patterns of reasoning keep

> recurring in interviews. All that is required is undertaking enough interviews to span the set of contexts. As the set of relevant contexts cannot be known in advance 'snowballing' sampling techniques (Cooper and Emory 1995) must be employed. As interviews progress the various characteristics that define different farm contexts for an innovation will emerge. Confirmation of the relevance of those characteristics, and the manner in which they influence the adoption of the innovation, is obtained by identifying and interviewing producers that differ on those characteristics as they are isolated.
>
> (Kaine 2004, p. 10)

Subsequent statistical analysis of the data commonly involves cluster analysis, a technique 'often used in segmentation studies' in marketing (Malhotra et al. 2002, p. 638).

Summary

The frame for analysis of farm context reported here has evolved over a long series of studies of farm management most commonly with a focus on farm innovation. The work has its theoretical roots in marketing theory and proceeds on the assumption that a close understanding of the determinants of the attractiveness of an innovation to farmers is essential for projections of the level of its market penetration (ultimate adoption/full diffusion). A variety of factors canvassed in the frame, including relative advantage (in effect), may play a role in determining the speed of adoption of a specific by different market segments as defined through application of the frame.

The assumption that farmers treat farm management decisions as high involvement decisions contradicts the notion that adopter category characteristics will play a strong role in determining the speed of the diffusion process. Specifically, relative advantage can trump innovativeness as a farmer characteristic, causing farmers to switch adopter categories. Across the studies in which the frame has been employed we have yet to encounter disconfirmation of the high involvement assumption.

Marketing theory has yielded an approach which can address the 'why adopt' question. The unique features of farming require accommodation in the approach. Particularly, high levels of relevant uncertainty and long lead times in production, compared to other industries, require attention to farmers' strategic responses as elements of context. Likewise, the often low control over output quantity and quality and the small business character of most farms require considerable understanding of farmers and farm management to effectively apply the frame.

> The process has been used to identify segments for innovations such as irrigation systems in the horticultural, viticultural, vegetable and dairy industries in Australia, breeding practices and animal health practices in sheep and cattle in Australia and New Zealand, and pest and disease management practices in horticulture and viticulture in Australia and New Zealand among others...
>
> (Kaine 2004, p. 11).

For the original concern, to enhance farm adaptation, application of the frame has enabled identification of groups of farmers who value innovations differently and why they do. This has allowed reliable projections of market penetration by innovations to be made, and the formulation of relevant promotion/extension, and innovation modifications, to suit segments thereby accelerating adoption.

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[2] The theory of the diffusion of innovations is the core conceptual foundation for the product life cycle, a model of life stages of products which can indicate appropriate shifts in output characteristics over time. Neither is now regarded as a reliable basis for the management of a specific product through time (see McColl-Kennedy and Kiel 2000).