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The influence of technology characteristics
on the rate and speed of adoption

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Abstract

This paper analyses the impact of technology characteristics on the rate and speed of adoption. In a case study of the Meru district in Kenya, 17 dairy technologies are analyzed with respect to the influence of relative complexity, relative risk and relative investment characteristics on adoption. Technology characteristics were measured by a scoring approach which involves assessments made by extension workers working in the study area. The study found that the past process of adoption and diffusion was significantly influenced by the characteristics mentioned above. Considering the speed to completed adoption, the influence of relative investment was smaller while relative complexity and relative risk showed significance. The strong influence of relative complexity and relative risk of the technologies on the adoption can be explained by the characteristics of farmers and the farming circumstances. Meru farmers are poorly educated and face shortage of labor making them hesitant to adopt complex technologies. Moreover, the risk of production is high leading farmers to adopt new technologies that reduce risk relative to the traditional technologies. Knowing this, planners in research and extension should advise the development of risk-reducing technologies with a low complexity as compared to the technologies that should be replaced. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

Adesina and Zinnah (1993) distinguish two types of paradigms of technology adoption and diffusion: The innovation–diffusion paradigm and the economic con-straint paradigm. Though both assume that the technologies' characteristics determine their adoption and diffusion, these are included only in few empirical models (Fliegel and Kivlin, 1966; Byerlee and de Polanco, 1982; Adesina and Zinnah, 1993; Adesina and Baidu-Forson, 1995). Most empirical studies concentrate on the effects of farmers' characteristics on adoption decisions. They compare farmers who have adopted or rejected a certain technology at a point in time, but say little about the influence of technology

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characteristics on adoption and diffusion of different technologies. However, this knowledge would improve planning for research and development considerably. Knowing the characteristics which have determined the adoption and diffusion in the past would indicate which characteristics new technologies should possess to become quickly and widely adopted in the future which is the information prior to be known for planning purposes (Anthony and Anderson, 1991; Alston et al., 1995).

This paper aims to explain the rate and speed of technology adoption by the impact of technology characteristics. The approach used specifies technology adoption and diffusion as a function of technology characteristics, farming circumstances as well as farm- and farmers' characteristics. Using a case study from the Kenyan dairy sector, adoption data of different technologies were collected from a relatively homogeneous sample of farmers and analyzed. This allows to explain adoption and diffusion of technologies by technology characteristics rather than by farmers' characteristics as it can be found in most adoption studies in the literature.

The paper is organized in seven sections. In Section 2, the case study is described. Section 3 presents the research approach, followed in Section 4 by a concept to measure technology characteristics and adoption parameters. A summary of adoption and diffusion figures of the case technologies and their characteristics is given in Section 5 and Section 6 presents the results of the statistical analysis. Finally, in Section 7, conclusion are drawn for the implications of the results for planning purposes.

2. The case study: the zero-grazing technologies of the National Dairy Development Program of Kenya

The National Dairy Development Project of Kenya (NDDP) has been promoting milk production since the early 80s by introducing a zero-grazing package to smallholder dairy farmers. Zero-grazing is an intensive milk production system which is attractive in areas where land is scarce and farms are small. The package consists of several technological components such as housing, feeding, animal health, and calf rearing, each consisting of a number of technologies. Table 1 presents the zero-grazing technologies that have been identified and their traditional alternatives. Most of the technologies were introduced in the zero-grazing package of NDDP while others such as spraying technologies and fencing stem from different sources.

Table 1
New and traditional dairy technologies

Components	New dairy technologies	Traditional dairy technologies
Housing	Cow-shed Fence/corral[a] Calf pen Manure pit Milking place	Free grazing/herding including combinations with Tethering of the calf Compost making Traditional milking
Feeding	Napier grass By-products Dairy meal Minerals	Grazing with use of farm residuals and by-products
Animal health	Dipping of the cows Spraying of the cows[a] Deworming of the cow Dipping of the calves Spraying of the calves[a] Deworming of the cows	Picking and burning the ticks Using herbs and roots Picking and burning the ticks Using herbs and roots
Calf rearing	Bucket feeding Concentrate feeding	Suckling

[a] Not promoted by NDDP.

For the purpose of this study, the Meru district was chosen for a case study. The Meru district in Kenya was among the first districts in which NDDP introduced the zero-grazing package. As in other districts, zero-grazing was not new to the Meru farmers when NDDP started its activities and many farmers had already modified or replaced traditional technologies (Metz et al., 1995). It was, therefore, assumed that the zero-grazing technologies are known by all the farmers in that area and that a considerable number of farmers adopted zero-grazing technologies without being clients of NDDP.

Meru farmers are small-scale farmers with an average farm size of about 4 acres. The main cash crops are tea and coffee, while the main food crops are maize, yams and potatoes. Land-use is dominated by mixed farm systems in which every farm-household keeps at least one cow. The main animal feed is Napier grass which is grown at an average of 0.4 acre per farm (Batz, 1998).

3. Approach to explain technology adoption as a function of technology characteristics

For the purpose of this study it is assumed that farmers make adoption decisions based upon utility considerations. Comparing the new technology with the traditional technology they will adopt a new technology if its utility exceeds the utility of the traditional technology. (1) The probability that a farmer adopts a new technology is a function of its relative utility. (2) The expected utility of a technology is determined by its characteristics as attributed by the farmers, the characteristics of the farmers, the farming system and the farming environment (3).

$$Y_N = 1 \quad if \quad EU_N > EU_T \qquad (1)$$

$$P(Y_N = 1) = f\left(\frac{EU_N}{EU_T}\right) \qquad (2)$$

$$EU = f(T_C, Fa_{Ch}, FS_{Ch}, FC) \qquad (3)$$

where: $Y_N = 1$ is the adoption of new technology, EU_N the utility of new technology, EU_T the utility of traditional technology, P the probability of adoption; T_c the technology characteristics; Fa_{Ch}, is the farmers' characteristics, FS_{Ch}, the farming systems characteristics and FC is the farming circumstances

Consequently, the probability that a farmer adopts a new technology is a function of the technology characteristics, farmers' characteristics, farming systems characteristics, and farming circumstances (4). Under the assumptions that the term $f(T_{CN})/f(T_{CT})$ in formula (4) equals $f(T_{CN}/T_{CT})$ and that the effects of the different variables are additive, the probability of adoption is now a function of relative technology characteristics, farmers' characteristics, farming systems characteristics, and farming circumstances.

$$P(Y_N = 1) = f[(f(T_{cN})/f(T_{cT})), Fa_{Ch}, FS_{Ch}, FC] \qquad (4)$$

$$P(Y_N = 1) = f[(T_{cN}/T_{cT}), Fa_{Ch}, FS_{Ch}, FC)] \qquad (5)$$

where T_{CN} is the characteristics of new technology, and T_{CT} the characteristics of traditional technology.

This specification of the adoption model has two implications for the empirical analysis of adoption and diffusion. First, if one considers a given, single technology with given characteristics, the decision of a farmer to adopt a technology depends on the farmer's characteristics, the farm characteristics and the farming environment (6).

$$P_f(Y_N = 1) = f(Fa_{Ch}, FS_{Ch}, FC) \qquad (6)$$

$$P_t(Y_N = 1) = f\left(\frac{T_{CN}}{T_{CT}}\right) \qquad (7)$$

where P_f is the probability that farmer adopts a new technology.

Most of the empirical studies in the literature follow the model-specification in formula (6) and analyze the impact of farming circumstances, farm and farmers' characteristics on individual adoption decisions. Using logit, probit and tobit models such studies provide information on the conditions that led to adoption of a given technology in the past. However, they do not allow to compare different technologies with respect to their characteristics that led to a fast adoption and to a high rate of adoption in the future.

These comparisons can be made by applying the model as specified in formula (7). If the farmers-sample is relatively homogenous with respect to farm- and farmers' characteristics and if farmers are working under comparable farming circumstances, the adoption of a technology (P_t) depends on their characteristics. A farmer will adopt a new technology if its

characteristics promise a higher utility than the characteristics of the traditional technology. The probability is the higher, the higher the relative utility derived from the new technology.

This lays the basis for investigating the impact of technology characteristics on adoption and diffusion: Since in a homogenous group of farmers utility is a function of technology characteristics, speed of adoption is a function of the relation between the characteristics of the new and traditional technology (8). The rate of adoption at time t depends principally on the same variables but is additionally determined by the time that passed by from the introduction of the new technology until the year of observation (9).

$$Speed(Ceiling) = f\left(\frac{T_{CN}}{T_{CT}}\right) \qquad (8)$$

$$AR_t = f\left(time, \frac{T_{CN}}{T_{CT}}\right) \qquad (9)$$

where Speed is the speed to completed adoption, Ceiling the maximum rate of adoption, AR_t is the rate of adoption at time t and time is the number of years passed by from the introduction of the technology until the year of observation.

For the purpose of this study it is assumed that farmers' adoption decisions are determined by four major types of technology characteristics which are summarized in Table 2. The relative profitability of technologies is expected to be an overriding factor in farmers' decision making (Byerlee and de Polanco, 1982). Farmers will adopt technologies that give high returns to investment relative to the traditional alternatives. High relative profitability accelerates the speed of adoption and also leads to a high ceiling of adoption. The relative profitability of the technologies concerned was defined by taking into account, that the technologies may not only affect the dairy

enterprise but also other farm enterprises such as the tea and coffee production.

Risk characteristics of technologies were considered to determine farmers decision making, since grade cows, as kept in the Meru district, face a high risk of infection by tick born diseases such as Anaplasmosis and East Coast Fever (Batz, 1998). Some technologies can be assumed to have a risk-reducing effect in a high-risk environment, whereas other technologies may either have no effect on risk or even increase it. It was hypothesized that technologies with a high risk-reducing effect compared to their traditional alternatives will be adopted faster and to a higher ceiling than technologies with a low relative risk reduction.

Initial costs determine adoption decisions especially in the case of the resource-poor smallholders. They can become a limiting factor for adoption since farmers cannot adopt a profitable technology if capital is scarce. This means if farmers are resource poor and access to capital is limited, profitable technologies might not be adopted if they require a high capital outlay. In order to consider this relation, an index called relative investment was developed which expresses the relationship between initial costs and relative profitability. A high relative investment index means that initial costs are high compared to the additional profit that can be obtained and vice versa. It is hypothesized that technologies with high relative investment index will be adopted more slowly than technologies with a low relative investment index.

Finally, it was assumed that technologies differ in their relative management complexity. Leaning against systems theory, complexity was defined as a function of the number of activities that have to be performed to adopt and to use a technology weighted with the difficulty of these activities (Willke, 1991).

Table 2
Definition of technology characteristics

Type of characteristic	Definition of characteristics
Relative profitability	Partial effect of the technology on the farm profitability
Relative risk	Partial effect of the technology on the risk to lose a cow
Initial costs	Costs to purchase the smallest unit of a technology
Relative investment	Costs to purchase the smallest unit of a technology divided by its partial effect on the farm profitability
Relative complexity	Number of activities to adopt and use a new technology, weighted with the difficulty of activity and decision making, relative to complexity of the traditional technology

Complexity is high when a farmer has to carry out many activities to establish and to run a technology. The higher the scores, the more difficult those activities are and the more difficult it is to make the decision that lead to the activity. Relative complexity of an innovation is then the higher the more complex the new technology is in relation to the traditional technology. Technologies with high relative complexity diffuse more slowly than others and will finally reach a lower ceiling of adoption.

4. Measuring technology characteristics and adoption parameters

Technology characteristics were measured by applying a scoring approach which involves assessments made by extension workers working in the study area. The use of a scoring approach became necessary because quantitative assessment of the profitability and risk characteristics for each technology would have involved considerable costs for data collection and farm-modelling. However, though scoring approaches are less costly they have some limitations. One limitation is the loss of information due to the use of scores instead of a continuos measure. This may result in a lower explanatory power of the models estimated. The loss of information depends to a large extent on the range of the scale that is used for scoring. Moreover, the usefulness of such an approach depends to a large extend on the quality of information given by the experts. Since reference data on the characteristics of the technologies are not available, the results of the assessment cannot be verified. For the purpose of this study it was assumed that extension workers can provide a good assessment of the technology characteristics since they are familiar with the new and with the traditional technologies. As they are farmers themselves they are able to assess the advantages and disadvantages of the technologies from a farmer's point of view.

Extension workers were asked to assess new and traditional technologies with respect to their characteristics taking into account local conditions in which the farmers operate. With respect to profitability and initial cost assessment, the extension workers were asked to give scores from 1 to 9 for each technology concerned. The extension workers assigned low scores to technologies with low profitability or costs and high scores to very high profitability or costs. The risk associated with the use of a technology was assessed by using 'plus' and 'minus' scores. Extension workers assigned a minus (−) if a technology reduced the risk of losing a cow and a plus (+) if it increased the risk. If an effect was expected to increase or decrease this risk strongly, the extension workers could assign one additional minus or plus, respectively. These scores were translated into numbers in such a way that low numbers indicate a high risk-reducing effect. Finally, complexity was measured by counting the activities that a farmer had to undertake to acquire and to use the technologies. These activities were listed and a score between one and three was assigned, respectively, for the difficulty of the activity and for the difficulty of the decision making leading to these activities. Since all these assessments were performed in individual interviews, differences in the assessments were discussed in a plenary session with all the extension workers. If it was agreed that an assessment deviated too much from the average, it was adjusted accordingly.

The adoption pattern of the case technologies considered were measured by interviewing a total of 112 randomly sampled farmers that had not participated in the NDDP. Farmers were asked about the technologies currently in use, and the year when they adopted them. Based on this information, a number of different adoption parameters were calculated. The rate of adoption (AR_{94}) and speed of adoption up to the year when the survey was carried out (Speed$_{94}$) were calculated to describe the history of adoption. AR_{94} indicates the percentage of farmers that had adopted the technology by 1994 (10). Speed$_{94}$ was measured by dividing AR_{94} by the number of years between the year of first adoption and 1994 (11).

$$AR_{94} = \frac{N_{CA}}{N_{PA}} \qquad (10)$$

$$\text{Speed}_{94} = \frac{AR_{94}}{t_{(t1...94)}} \qquad (11)$$

where AR_{94} is the rate of adoption in 1994, N_{CA} the number of current adopters, N_{PA} the number of potential adopters, $t_{(t1...94)}$ the time from the start of adoption up to 1994.

In order to describe the whole process of adoption, the expected speed to completed adoption (Speed), and the expected maximum adoption (K) were estimated, using a logistic growth function (12) which is normally used to describe adoption profiles of technologies (CIMMYT, 1993).

$$Y_t = \frac{K}{1 + e^{-a-bt}} \qquad (12)$$

where Y_t is the cumulative percentage of adopters in year t, K is the ceiling of adoption, a is the constant term, b is the rate at which adoption occurs an e is the basis of the natural logarithm

In order to generate starting values to run the Non-Linear Regression procedure the logistic function in formula (12) was transformed to formula (13), following the method proposed by Griliches (1957) and CIMMYT (1993).

$$\ln\left(\frac{Y_t}{(K-Y_t)}\right) = a + bt \qquad (13)$$

Running the non-linear regression procedure of SAS-software package, values for (a), (b) and (K) were estimated and used to calculate the speed of adoption.

There are different ways to calculate the speed of the adoption process. One way is to use the rate at which adoption occurs (b). The limitation of this parameter is that it depends on the ceiling of adoption. Since one can assume that not all technologies will reach the same ceiling level this parameter is not well suited as dependent variable. Another way to calculate a figure for speed of adoption is to adjust the rate of acceptance for the ceiling following Griliches (1957) by transforming (b) to $b' = bk$. The limitation of both approaches is that the figures obtained are not illustrative and difficult to use for descriptive explanation of the adoption process. We therefore decided to use the linear slope of the diffusion curve as an indicator for the speed of adoption.

For this purpose, the ceiling of adoption (K) was divided by the number of years passing by until K is reached. Theoretically, it is not possible to calculate the years to maximum adoption since the logistic function only approaches K. Instead, the time was calculated when K minus 10% of K ($t_{K-10\%}$) will have adopted the technologies by using the formula below (14). The speed to complete adoption (Speed) was now measured by the ratio of $K-10\%$ over $t_{K-10\%}$

which is the slope of the linearized adoption curve and represents the linear speed of adoption (15).

$$t_{(K-10\%)} = -\ln\frac{[(D/(K-10\%)) + a]}{b} \qquad (14)$$

$$\text{Speed} = \frac{K}{t_{(K-10\%)}} \qquad (15)$$

where $K-10\%$ is the ceiling of adoption minus 10%, $t(K-10\%)$ is the number of years to $K-10\%$.

This approach yields a figure which indicates the percentage of farmers that adopt the respective technology per year. This figure should be highly correlated to b', is easy to understand and illustrates the speed of the process in a more comprehensive way.

5. Empirical results of the study

Table 3 shows the results of the assessment of the new technologies' characteristics. The first column shows the values for relative investment. Technologies with a comparatively high relative investment include housing technologies and feeding of Napier grass in conjunction with by-products, minerals and concentrates. The relative investment was lowest for animal

Table 3
Results of extension workers' estimates for technology characteristics

Technologies analyzed	Relative investment	Relative risk	Relative complexity
Fence/corral	3.06	0.50	3.46
Cow shed	4.21	0.56	3.69
Calf pen	3.92	0.79	3.37
Manure pit	2.74	1.00	4.83
Milking place	3.55	0.60	5.00
Dipping of the cows	1.67	0.33	0.53
Spraying of the cows	3.74	0.50	1.37
Deworming of the cows	2.25	0.50	2.50
Dipping of the calves	1.02	0.85	0.79
Spraying of the calves	1.76	0.85	1.17
Deworming of the calves	1.04	0.92	2.50
Napier and by-products	2.56	0.47	1.44
Napier, by-products and concentrates	3.44	0.47	2.11
Napier, by-products, concentrates, and Minerals	3.33	0.40	2.75
Bucket feeding	2.60	0.92	4.67
Bucket feeding and concentrates	2.40	0.92	8.67

Table 4
Adoption parameters for case technologies

Zero grazing technologies	Start of diffusion	AR_{94}	$Speed_{94}$	K	Speed[a]
Fence/corral	1965	53.6	1.8	100.0	2.1
Cow-shed	1973	31.3	1.5	100.0	2.5
Calf pen	1973	22.3	1.1	100.0	1.8
Manure pit	1985	6.3	0.7	11.0	0.6
Milking place	1962	68.8	2.2	100.0	2.2
Dipping of the cows	1959	77.7	2.2	91.1	2.2
Spraying of the cows	1954	61.6	1.5	100.0	1.9
Deworming of the cows	1954	87.5	2.2	100.0	2.3
Dipping of the calves	1959	65.2	1.8	73.5	1.8
Spraying of the calves	1954	69.6	1.7	100.0	2.0
Deworming of the calves	1954	87.5	2.2	100.0	2.2
Napier and by-products	1954	93.8	2.4	100.0	2.5
Napier, by-products and concentrates	1960	49.1	1.4	100.0	1.6
Napier, by-products, concentrates and minerals	1960	49.1	1.4	100.0	1.6
Bucket feeding of the calf	1958	23.2	0.6	100.0	1.1
Bucket feeding and concentrates	1970	6.3	0.3	21.8	0.5

[a] The coefficients of correlation between speed and b (for technologies which are estimated to reach a ceiling of 100%) and b' were 0.85 and 0.93, respectively. Consequently, one can assume that the linearisation of the speed is a suitable simplification.

health technologies such as spraying, dipping and deworming.

The second column shows the values for the relative risk effect of the new technologies. The risk-reducing effect was greatest for dipping of the cows and the three feeding regimes on the basis of Napier grass. Deworming and spraying of the cows was still assumed to have a high impact followed by housing technologies such as fencing, cow-shed and milking place. Manure pit was estimated to have a neutral effect on the risk to lose a cow and thus had the lowest impact on risk. The last column gives the figures for the complexity assessment. Most of the technologies increase the complexity of farm management. Only the dipping technologies were assumed to be less complex than their traditional alternatives. However, very high increases in complexity relative to the traditional alternatives are caused by the use of bucket feeding, concentrates, milking place, and manure pit.

The results of the adoption calculations are presented in Table 4. The different technologies show highly different histories of adoption. Some technologies such as Napier grass, deworming, and spraying technologies had already been adopted by some farmers in 1954, whereas calf pens and manure pits started to be adopted in 1973 and 1985, respectively. Also the current AR_{94} was highly variable. Napier grass and

deworming technologies were widely adopted while housing technologies such as cow-sheds, calf pens, manure pits were poorly adopted.

Looking at the speed of adoption up to 1994 ($Speed_{94}$) the figures reveal that the technologies disseminated very slowly. All the rates of diffusions were below 3% per year. However, there were considerable differences between the technologies. Whereas Napier grass and by-products, dipping of cows and deworming technologies showed a relatively high speed of diffusion, manure pit, and all the calf rearing technologies have diffused extremely slow.

Estimates of K show that most of the technologies will reach a maximum level of adoption of 100%. According to the estimated logistic curves only manure pit and bucket feeding including concentrates of calves can be expected to remain very poorly adopted. Dipping of calves and cows may stagnate at a high level at around 73 and 91%, respectively.

Estimates on the expected speed to completed adoption (Speed) range from 2.5% per year for cow-shed to 0.5% for concentrate feeding of calves. Technologies with the highest speed to completed adoption were cow-shed, Napier grass and by-products, and the deworming technologies. Manure pit and bucket feeding including concentrates showed the lowest speed to completed adoption.

6. The influence of technology characteristics on technology adoption

The influence of technology characteristics on the adoption parameters was analyzed by using linear regression analysis. Ceiling was not analyzed since its values did not show a significant variance. The regression models were specified using combinations of relative complexity, relative risk and relative investment as explanatory variables for the adoption parameters. The basic models are presented below (16, 17)

$$AR_{(94)} = \beta_0 + \beta_1 time + \beta_2 Rel.complexity$$
$$+ \beta_3 Rel.risk + \beta_3 Rel.investment + e \tag{16}$$

$$\frac{Speed}{Speed_{(94)}} = \beta_0 + \beta_1 Rel.complexity + \beta_2 Rel.risk$$
$$+ \beta_3 Rel.investment + e \tag{17}$$

where time is the number of years passed by form start of diffusion until 1994 and e the random disturbance term.

The results of the best models for the current rate of adoption (AR_{94}) are presented in Table 5. The best model with one explanatory technology characteristic used the relative complexity as independent variable. The adjusted R^2 was significant and showed that the model explains more than 70% of the variance. The relative complexity was significantly related to the rate of adoption as hypothesized. The models using two and three technology characteristics are also significant. Using relative risk and relative investment together with time, their coefficients show the expected signs and are significant at the 0.5 and 0.10 levels, respectively. The model that includes all three technology characteristics yields a significant adjusted R^2 of 0.7267. Though only the coefficient for

time was statistically significant, all the technology characteristics show the expected signs.

The results of the best models for speed of adoption are presented in Table 6. All the models for speed up to current adoption ($Speed_{94}$) yield significant results. Considering relative complexity as the sole explanatory variable, the model explains about 45% of the variance. Consideration of relative risk and relative investment yields significant coefficients with an adjusted R^2 of 0.4983. The model which includes all three technology characteristics yields a significant coefficient for relative risk. Relative complexity and relative investment are not significant but the coefficients show the expected signs.

Finally, the results of the models analyzing the speed to completed adoption (Speed) show that the relative complexity of the technologies was the only significant variables in all these models. In the model which uses relative complexity as sole explanatory variable the model yields an adjusted R^2 of 0.4033. The model that includes relative complexity and relative risk leads to a R^2 value of 0.4730 which is highly significant. However, although both coefficients show the expected signs, only relative complexity is significant at the 0.5 level. The final model which considers the three variables is also significant, tough only the coefficient for relative complexity is significant.

7. Conclusions

The results of this study indicate that technology characteristics influenced the rate and speed of adoption. Farmers evaluated the new technologies available and compared them with their traditional alternatives. They adopted the new technology if its characteristics promised a higher utility than the traditional technology. The tendency to adopt a new technology was the

Table 5
Influence of technology characteristics on current rate of adoption (AR_{94})

	Constant	Time	Relative complexity	Relative risk	Relative investment	R^2
AR_{94}						
	8.32 (0.36)	1.89*** (3.47)	−5.03* (−2.12)			0.7002***
	67.50 (1.65)	1.60** (2.77)		−54.68** (−2.39)	−10.79* (−2.04)	0.7151***
	68.64 (1.72)	1.40** (2.38)	−3.09 (−1.22)	−41.29 (−1.66)	−8.67 (−1.59)	0.7267***

* Significant at 10%, **significant at 5%, ***significant at 1%. ( ) = t-values.

Table 6
Influence of technology characteristics on speed to adoption

	Constant	Relative complexity	Relative risk	Relative investment	R^2
$Speed_{94}$					
	2.22*** (10.51)	−0.21*** (−3.70)			0.4592***
	3.90*** (6.62)		−2.09*** (−3.80)	−0.35** (−2.79)	0.4983**
	3.49*** (5.80)	−0.11 (−1.68)	−1.44** (−2.21)	−0.23 (−1.69)	0.5606***
Speed					
	2.41*** (11.18)	−0.19*** (−3.33)			0.4033***
	2.90*** (8.13)	−0.15** (−2.41)	−0.97 (−1.68)		0.4730***
	2.83 (4.26)	−0.154* (−2.05)	−0.92 (−1.28)	0.02 (0.12)	0.4299**

* Significant at 10%, **significant at 5%, ***significant at 1%. ( ) = *t*-values.

higher the greater its relative utility which in turn led to a higher rate and speed of adoption. In this study the past process of adoption could be explained by the effects of the new technologies on management-complexity, risk reduction, and their relative investment requirements. All three variables were significantly correlated to AR_{94} and to the speed to current adoption ($Speed_{94}$). Considering the speed to completed adoption, the influence of relative investment was smaller while relative complexity and relative risk showed significant relationships. The regression models yielded significant results indicating a strong influence of relative complexity and relative risk.

The importance of complexity for adoption processes may be explained by the method that we used for calculation. The number of activities and the difficulty of decision making and performing these activities yield a composite index that indirectly reflects labor shortage, discomfort of work involved, and the availability human capital. As the survey indicated, many farmers face labor shortage, are poorly educated (Batz, 1998), and may hesitate to adopt technologies that require specific technical knowledge and/or additional labor input. This in turn leads to slow diffusion of complex technologies.

The high influence of relative risk on adoption parameters can be explained by the risky production environment. Diseases such as East Coast Fever and other tick born diseases are prevalent in the area causing considerable economic damage (Batz, 1998). The possible disaster associated with the loss of a cow makes farmers sensitive to such a risk and forces them to adopt technologies that reduce risk relative to the traditional technologies.

Having this information and knowing which technology characteristics proved to be important for farmers decision-making in the past allows planners in research and extension to determine which characteristics of new technologies lead to their adoption at a high speed and to a high ceiling in the future. Experts who are familiar with the farming systems. and with the old and new technologies would have to characterize the new technologies with respect to complexity, relative investment and risk characteristics using the approach described above. With this information, planners would advise to introduce technologies that do not increase management complexity of the system considerably and/or the risk to lose a cow.

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References

Adesina, A.A., Zinnah, M.E., 1993. Technology characteristics, farmers perceptions, and adoption decisions: A tobit model application in Sierra Leone. Agric. Econom. 9, 297–311.

Adesina, A.A., Baidu-Forson, J., 1995. Farmers perception and adoption of new agricultural technology: Evidence from analyses in Burkina Faso and Guinea, West Africa. Agric. Econom. 13, 1–9.

Alston, J.M., Norton, G.W., Pardey, P.G., 1995. Science Under Scarcity. Principles and Practice For Agricultural Research Evaluation and Priority Setting. Cornell University Press, Ithaca.

Anthony, G., Anderson, J.R., 1991. Modelling technology replacement over time for ex-ante analysis of agricultural research projects. Agric. Sys. 37, 183–192.

Batz, F.-J., 1998. Improving priority setting for livestock research by using technology characteristics for adoption assessment. Ph.D. Dissertation, Berlin.

Byerlee, D., de Polanco, E.H., 1982. The rate and sequence of adoption of improved cereal technologies: The case of rainfed barley in the Mexican Altiplano. Working Paper 82/4. Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico.

Fliegel, F.C., Kivlin, J.E., 1966. Farmer's perceptions of farm practice attributes. Rural Sociol. 31, 197–206.

Griliches, Z., 1957. Hybrid corn: An exploration in the economics of technological change. Econometrica 25(4), 501–522.

Metz, T.H., Kiptarus, J., Muma, M., 1995. A survey of smallholder dairy farmers in Kakamega, Uasin Gishu, Kiambu, Nakuru and Nyeri Districts. National Dairy Development Programme, Monitoring and Evaluation Unit, Nairobi.

Willke, H., 1991. Systemtheorie. Eine Einführung in die Grundprobleme der Theorie sozialer Systeme, UTB-Verlag, Stuttgart.