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Modeling the Diffusion of Crossbreed Cow Technology in Sri Lanka using Duration Analysis

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ABSTRACT

Livestock plays an important role in the Sri Lankan economy and the smallholders significantly contribute to dairy production. This study is carried out to analyze the adoption of crossbred cow technology by smallholder dairy farmers. Duration analysis is used to examine the impact of time-varying and time-invariant variables on the speed of adoption of crossbreed by smallholders. Three models frequently used in literation: Cox, Exponential and Weibull Proportional Hazard models are estimated using a sample of 401 farmers spanning 8 districts in the country. The empirical results highlight the importance of farming system, extension services, society membership, and geographical zones on accelerated adoption. However, higher transaction costs, experience, higher costs of production delays the time to adoption.

KEYWORDS: Cox model, Crossbred cow adoption, Duration analysis, Exponential model, Weibull model

INTRODUCTION

Milk production in Sri Lanka has significant potential in growing, because local demand is higher than production. Consumption of dairy products has increased since the 1977s with the open economics policies (Ranaweera, 2009). The policy on dairy development is aimed at producing 50% of country's requirement of milk by the year 2015. To achieve this target milk production needs to be increased in significant proportions. One way of achieving this is by popularizing the crossbred cow technology. Apart from increasing national production, crossbreeding will increase farmer incomes making it a poverty alleviation strategy.

A crossbreed is an animal with purebred parents of two different breeds, varieties, or populations while crossbreeding is the process of breeding the animal with the purpose to create offspring that share the traits of both parent or producing an animal with hybrid vigor. Traits such as reproduction, growth, maternal ability, and end product influence the productivity and profitability of the dairy production.

Cross breeding programs are implemented in farms across the country to suit each agro ecological zone. Despite the effort, the performance of sector is far below the expected targets. Adoption of technology is a process based on sequence of individual decisions, after which innovation is either accepted or rejected, which can be defined as the process by which the use of an innovation is spread throughout a productive system (Karshenas and Stoneman, 1995). Adoption of such improved technology creates awareness, changed attitudes and provides favorable conditions for farm.

At the simplest level, there is a considerable gap in knowledge of which technology are being used, what level it has been adopt, where, and by whom. In this context, the aim of this research is to analyze the adoption behavior over time, for crossbred technology and provide information that can improve future policies to encourage adoption.

METHODOLOGY

Duration Analysis

Duration Analysis (DA) is a statistical method that has been used to analyze adoption processes of agricultural technologies (Alcon *et al.*, 2011). It attempts to relate a set of covariates to time-to-event (which is time to adoption in this case) data. Length of a spell (time-to-event) is started with the entry (start of dairy farming) and end after a new state (adoption of a crossbred) is achieved. Interest here is to estimate the effect of covariates that shorten/extend this time to adoption. In this context, two things are important: the survival function and the hazard rate.

The survival function, which is denoted in (1), gives the probability that the event in question has not occurred at time 't'. In relation to the present study, the survival function gives the probability of a farmer not adopting a crossbred at the end of the study period.

$$S(t) = Pr(T \geq t) = 1 - F(t) \qquad (1)$$

Where, S(t) gives the probability that a spell is of length at least 't', that is, the probability that the random variable T exceeds t.

The distribution of T is characterized differently in the Hazard function, which is sometimes called the instantaneous occurrences of the event. The Hazard function can be given by (Dadi *et al.*, 2004):

$$ht = \lim_{\Delta t \to \infty} \left(\frac{pr(t \le T < t + \Delta t\_T \ge t)}{\Delta t}\right) \quad (2)$$

The numerator of (2) gives the conditional probability that a crossbred will be adopted in the interval, (t, t+d_t) given that a crossbred has not been adopted before. The denominator is the size of this interval. When the width of this interval approaches zero this can be called the instantaneous rate of occurrence (=adoption). This can be stated as:

$$= \lim_{\Delta \to 0} \frac{F(t+\Delta) - F(t)}{\Delta S(t)} \quad = \frac{F(t)}{S(t)} \quad (3)$$

Where, S(t) is the Survival function and F(t) is the continuous probability density function.

Parametric Model

The most commonly used parametric model in duration analysis is the Proportional Hazard model and it takes the following form:

$$h(t, X, \theta, \beta) = h_0(t, \theta)\, g(X, \beta) \quad (4)$$

Where, $h_0(t, \theta)$ is the baseline hazard, $g(X,\beta)$ is the scaling factor, and θ, β are parameters to be estimated (An and Butler, 2012).

There are three types of proportional hazard models in literature: the Cox, Exponential and Weibull models. The Exponential model is characterized by a constant hazard function, h(t) =λ where the parameter λ is more than zero, implying that the time does not influence the hazard rate. The Weibull model is defined by the hazard function $h(t) = \lambda p t^{p-1}$ with $\lambda > 0$ and P>0. If P>1, then risk increases over time. If P<1, risk declines over time. If P=1, this model collapses to an exponential model where, risk is constant over time (Alcon *et al.*, 2011).

In addition to time, evaluating the explanatory variables that influence the distribution of durations is interest. Thus, the hazard function can be made to condition on a vector of explanatory variables x. The estimated β in Equation 4 indicates the direction and proportional effects of unit changes in the relevant explanatory variables on the conditional probability of adoption at time t (Dadi *et al.*, 2004). In this research all three (Cox, Exponential and Weibull) models are estimated.

Data Source

Smallholder dairy sector is purposely selected as they are contributing significantly for national milk production. Data used here has been collected in 2009 for a previous study (Edirisinghe, 2010). Data were collected from smallholder dairy farmers from 8 districts in Sri Lanka from a sample of 401 farmers. Stata 11 statistical software is used to estimate the Proportional Hazard model.

RESULTS AND DISCUSSION

Description of the Sample

Descriptive statistics of the 401 sample of cattle farmers are depicted in Table 1 and variables are explained in the Table 2. Most of the respondents are in the intermediate and dry zone respectively 40% and 38%. Majority of respondents are male (76%) with the average age of 46 years.

From total respondents' considerable amount are belonged to the category of secondary education (75.8%) while average experience of farmers is 14 years. Out of total respondents 63% are unemployed and 27% are employed. Comparatively most of farmers are engaged in cattle farming as part time (71%) and others are as full time (29%).

Table 1. Descriptive of the sample

Variables	Mean	SD	Min	Max
ELE	265.8	414.2	-8	1915
AGE	46	11.3	20	73
EXP	14	10	0.3	58
TIM	13	13	0	120
HED	9	9.9	1	112
EXT	9	10.8	0	100

Note: SD=Standard Deviation, ELE= elevation, EXP= experience, TIM= time taken for market, HED=herd size, EXT= extension services

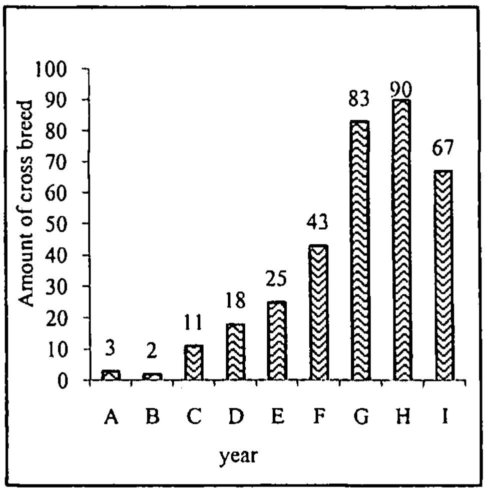
Majority of farmers carry out a semi intensive (54%) farming system while 44% of the farmers' rear animals in extensive systems with the average herd sizes are nine. About 89% of them have 1 to 15 animals. The average farmer lives 13 minutes away from the market although 86% take the 1 to 30 minutes to accesses the market. Out of total farmers 86.3% are agreeing with the suitability of the crossbreed cows. Majority of farmers has a membership with the milk cooperation (76%) and others do not have the membership. Most of the farmers do not use the milk society as an information source (58%) while 42% use the milk society. 79% of farmer visit the veterinary service with the average days of nine while 63% attend to the training programs.

Table 2. Variable description of the model

Variables	Category	Percentage
Wet	Wet zone	22
Intermediate	Intermediate	40
Dry	Dry zone	38
Gender	Male (1)	76
	Female (0)	24
Employment	Unemployment	63
	Employed	27
Education	No schooling	3.5
	Primary	21.7
	Secondary	75.8
Experience	<1	2
	1-25	85
	26-59	13
Working time	Full time (1)	29
	Part time (0)	71
Selling time	1-30	84
(minute)	30<	16
Management	Intensive(1)	4
System	semi intensive(2)	54
	Extensive(3)	42
Information	Yes(1)	42
	No (0)	58
Perception	Agree(1)	86.3
	Disagree(2)	12.2
	Neither(3)	1.5
Society	Yes(1)	76
membership	No (0)	24
Credit	Yes(1)	31
	No (0)	69
Training	Yes(1)	63
	No (0)	37
Extension	1 -10	79
	>11	21
Failure time	Adopt	86
	Not adopt	14

Out of the total sample 342 adopt with the technology and 59 not adopt. Adopters are 86% from the sample. The duration is the length of time to adopt the innovation. There is no clearly defined date for the adoption to the innovation. Earliest year is 1965 maximum duration 45 years. Some farmers adopt at 1965 but some are not adopt until 2009. Average duration is nine years.

In Figure 1 shows that number of adopters and the timing of adopters. In here adoption is increased in gradually with the period of time and it has sigmoid shape. The tapering occurs when the adoption of new farmers declines. At this point growth is slow or negligible, and is sustained by existing farmers who continue to adopt the technology.



Note: A=1965-1970, B=1971-1975, C=1976-1980, D=1981-1985, E=1986-1990, F=1991-1995, G=1996-2000, H=2001-2005, I=2006-2010

Figure 1. Adoption time of crossbred cows by farmers

The Kaplan-Meier estimate of the steps survivor function is plotted in Figure2. The horizontal axis represent the 44 years between the first adoption year 1965 and the year of survey 2009 is scaled in artificial time, from 0 to 50. The value is decrease gradually in the first interval. There are adopters in each consecutive 10 years giving an evenly spaced step, after there are long periods with no adoptions and accordingly the Kaplan-Meier survivor function does not change. The last change in the value of the function occurs when the last of the 342 adoptions occurs, at t =43.

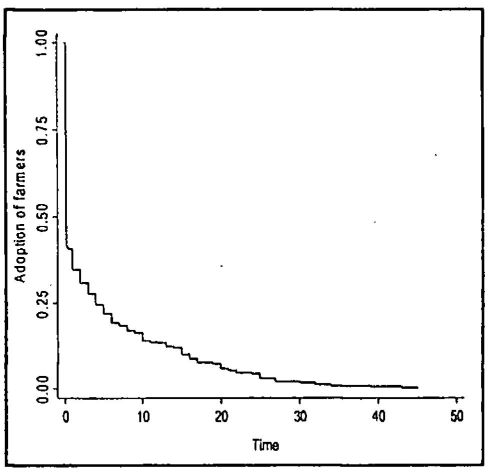


Figure 2. Kaplan-Meier survival estimates

Outcomes of the Cox Regression Model

In Table 3 results of all three models estimated: Cox, Exponential and Weibull are reported. Cox model is the more general model. A hazard ratio greater than one denote that the variable has positive impact on the likelihood of the adoption (or the likelihood of no adoption spell ending) and vice versa.

Table 3. General duration models

Variables	Cox model	Exponential	Weibull
Wet	1.38(0.013)	1.15(0.515)	1.11(0.619)
Intermediate	1.43(0.000)	1.99(0.000)	1.77(0.000)
Elevation	1.00(0.307)	1.00(0.264)	1.00(0.326)
Age	1.01(0.100)	1.00(0.428)	1.01(0.472)
Gender	0.99(0.872)	1.07(0.642)	1.05(0.733)
Employment	1.03(0.149)	1.02(0.644)	1.01(0.622)
Education	1.03(0.083)	1.02(0.318)	1.02(0.345)
Experience	0.92(0.000)	0.89(0.000)	0.91(0.000)
Working time	1.01(0.875)	1.01(0.965)	0.98(0.899)
Time to market	0.99(0.579)	0.99(0.305)	0.99(0.433)
Management system	1.16(0.047)	1.26(0.044)	1.21(0.100)
Herd size	1.01(0.089)	0.99(0.962)	0.99(0.931)
Cost	0.99(0.049)	0.99(0.487)	0.99(0.519)
Income	1.00(0.433)	1.00(0.102)	1.00(0.143)
Perception	0.76(0.013)	0.61(0.008)	0.65(0.022)
Society membership	1.58(0.000)	2.04(0.000)	1.88(0.001)
Information	0.85(0.033)	0.96(0.758)	0.95(0.711)
Credit	0.96(0.546)	0.89(0.419)	0.91(0.473)
Training	1.00(1.000)	1.02(0.894)	1.00(0.973)
Extension	1.01(0.015)	1.01(0.204)	1.01(0.223)
Log likelihood	-1467.66	-562.33	-549.10

Note: All coefficients are reported as Hazard ratios Significance levels at 0.05 and reported in parentheses are for the hazard ratio

In terms of location, wet and intermediate zone (1.38 and 1.43) has higher rate of adoption with compared to dry zone. That is, farmers in wet and intermediate zones have high probability of adopting crossbred technology sooner than dry zone farmers.

Management system (1.16) has a positive hazard rate show that the intensive farming system has a higher probability of adoption than the other farming system. Farmer, who has the society membership (1.58), adopt sooner than farmers who are not members of dairy societies.

Also an extension service significant and positively impact on the adoption of cross bred technology. As well as education (1.03) is also significant and positively impact on the adoption of farmers. With the higher education farmers has the higher adoption rate. Also herd size (wealth) significantly impact the duration taken to adopt.

Age, full time working in the farm, government employment, and have positive impact of the adoption but were not significant.

The farmer who believe the conventional farming can sustain productivity, experience, cost of production, perception on cross bred cows, information taken from the milk society have lower hazard ratio. Gender, time taken to market, credit is found to have a negative and impact on adoption but failed to show significance. The high impact of intermediate zone is shown across the three as well as the society membership. Similarly, experience and perception of the farmers is significant in all models but negatively impact adoption, in other words, delays adoption of crossbreds.

CONCLUSIONS AND POLICY IMPLICATIONS

The result of the study shows that the Adoption of farmers speeds up with their education, farming system they adopt, herd size, society membership, extension services and the area of the farms are situated while experience, time to market (transaction costs), costs of production and perception delays adoption.

It is therefore, prudent to improve extension services, knowledge of farmers, and strengthen the institutional innovations such as dairy societies. Further, reductions in transaction costs of selling, finding ways to reduce costs of production is important. Further, extension service can look at reducing negative perceptions of farmers to speed up adoption rates.

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