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Full Length Research Paper

Analysis of adoption spell of improved common bean varieties in the central rift valley of Ethiopia: A duration model approach

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This paper assesses the spread and farm household level determinants of adoption lag of improved common bean varieties in the central rift valley of Ethiopia with descriptive, parametric and non-parametric duration models. Results of descriptive method indicated that 83% of the total respondents were adopters of improved beans varieties with uneven adoption pattern. Non-parametric duration analysis showed that speed of adoption of beans was rapid in the early years and wanes eventually. Compared to male headed households, female headed households were found to be slow to adopt improved bean varieties in the early periods of awareness about the technologies. Parametric duration models suggest that the size of cultivated land, proximity to extension office and remoteness to fertilizer market hastened adoption, while dependency ration and livestock ownership contributed to increase in the adoption spell. In general, results imply that to influence the adoption behavior of smallholder beans farmers, policies and strategies should be made to account for the demographic, asset and institutional factors associated to the particular crop.

Key words: Adoption spell, adoption pattern, improved common beans, duration model.

INTRODUCTION

Common bean (*Phaseolus vulgaris*), also known as haricot bean, is one of the important cash crops in Ethiopia. The crop has significant place in food security owing to fast maturing characteristics that enable households to get cash income required to purchase food and other household needs when other crops have not yet matured (Legesse et al., 2006). Ethiopia has become one of the major exporters of common beans since the 1990s, mainly due to the export oriented policy focus in trade, particularly the functioning of the Ethiopian Commodity Exchange and the foreign demand for common beans.

Following its national significance, a number of improved varieties have been released and popularized among smallholder farmers of Ethiopia since early 1960s. In spite of the agricultural extension and research efforts in disseminating the improved technologies, the pace of adoption among smallholder farmers has been less significant. Adoption studies point out that the reason for such a scenario can be attributed to household, market, policy and institutional characteristics (Bekele et al., 2005; Katungi et al., 2011). However the time dimension has not been given due emphasis by previous adoption studies and this study hypothesizes that the speed of technology adoption could be influenced by the lag between adoption and knowledge about the technologies which may be attributed to farmer, technological and environmental attributes that could need further scrutiny. Therefore, the main objective of this study is to assess the time gap in adopting improved common bean varieties and factors governing this gap among farm households living in the moisture stress part of Ethiopia. The results of this study are expected to contribute to designing of appropriate agricultural policies that enhance dissemination and adoption of improved common bean technologies and contribute to national

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agricultural development targets. It has also a particular relevance to smallholder farmers elsewhere struggling to thrive under drought prone environment.

METHODOLOGY

Data and sampling

This paper depends on the farm household baseline survey data that were collected from the central rift valley area of Ethiopia where rainfall is erratic and drought has been one of the most important factors threatening agricultural production. The data were collected from 232 farm households that were drawn randomly through a multi-stage sampling procedure. The procedure involved selection of three districts; namely, Shalla, Adamitulu-Jido-Kombolcha and Dugda, based on the distribution of common bean land area and producers. Three peasant associations were drawn randomly from each district from which the total sample is selected randomly. Pre-tested semi-structured questionnaire involving socio-economic, institutional and environmental characteristics was used to solicit data from the identified respondents by trained enumerators.

The analytical model

This study utilizes duration model. The model was first used in social sciences to study factors influencing unemployment spells (Lancaster, 1978) and later adapted in various studies, such as, adoption of financial system (Hannan and MacDowell, 1984), economics and marketing (Kiefer, 1988), agricultural technology adoption (Fuglie and Kascak, 2001) and impact (Dadi et al., 2004; Pornpratansombat et al., 2011).

Hazard-based duration models that are flexible for many real-world situations are ideally suited to modeling duration data (Yannoutsos, 2009). Such models focus on an end-of-duration occurrence (such as end of technology adoption) given that the duration has lasted to some specified time (Kiefer, 1988; Hensher and Mannering, 1994).

The framework of the study was constructed over the duration model and it assumes that when farmers are exposed to new technologies, the expected completed duration of their time of adopting the technologies (adoption spell) of most interest depends upon the probability of receiving information about the particular technology and the probability of internalizing the technology.

The probability that a common bean farm household will adopt the technology will be determined by the perception and capacity of the individual household to adopt the technology and the availability and marginal benefit of the technology. This research scopes on the status of farmers adoption of improved varieties, once the information about the technology has been available to the farmer which will be considered as the start year (t = 0). The spell comprises the time difference between the first year the farmers received the information about common bean variety and the year that the farmer adopted the variety.

Parametric, semi-parametric and non-parametric duration models have been used to study the duration for occurrence of an event and the associated factors (Aryasepehr et al., 2002). Parametric models are more efficient in their use of data because they do not reject what happens to covariates where adoptions occur. Functional forms that have been used for parametric duration models include the exponential, Weibull, Gompertz, logistic, lognormal and log logistic probability distribution (Cleves et al., 2010). Among all of them, the two most commonly used are the exponential and Weibull distributions. However, some studies in marketing have used Gompertz distributions (Jain and Vilcassim, 1991; Vilcassim and Jain, 1991).

The Weibull's hazard function is more popular (Jain and Vilcassim, 1991) since it is more flexible in that it posits exponential change in the hazard function, which is an advantage when duration dependence is not linear as in the exponential function. The Gompertz model is useful for monotone hazard rates that either increase or decrease exponentially with time. Therefore this study has evaluated the two models in terms of their adequacy to explain the distribution of the data. The Weibull distribution is characterized by the hazard function:

$$h(t) = \lambda P t^{p-1};\ \lambda > 0\ and\ p > 0$$

$$\lambda = e^{x\beta}$$

Where λ is the location parameter and p is the shape parameter because it determines whether the hazard is increasing, decreasing, or constant over time; x = covariates included in the duration (that is, common bean adoption spell) model, and β = coefficients to be estimated.

Thus, the Weibull model exhibits an increasing hazard rate when $p > 1$ while the hazard rate would be decreasing if $p > 1$. When $p = 1$, it exhibits a constant hazard rate and collapses to the exponential distribution model.

The survivor function for Weibull model can be defined as:

$$S(t)=e^{(-\lambda t)p}$$

The hazard rate ($h(t)$) of Gompertz model can be defined as:

$$h(t) = \lambda e^{\gamma t}$$

Table 1. Descriptive statistics of explanatory variables (n=232).

S/N	Variable	Mean	Std. Dev.	Expected sign
1.	Dependency ration (Age)	131.39	99.23	+
2.	Sex of head (1=male)	0.88	0.33	+
3.	Education level (head)	3.41	3.38	-
4.	Farming experience (beans)	12.41	10.80	-
5.	Livestock (TLU)	6.65	5.80	-
6.	Cultivated land (ha)	2.39	1.72	-
7.	Fertilizer use (1=yes)	0.71	0.45	-
8.	Access to credit (1=yes)	0.20	0.40	-
9.	Training index	0.54	0.23	+
10.	Distance market fertilizer (minute)	55.13	50.65	+
11.	Distance to Extension office (minute)	32.97	29.65	-
12.	Social capital	31.99	55.28	-
13.	Price of beans	4.45	0.92	-

Source: Survey data (2011).

where $\lambda = e^{x\beta}$ and γ is a shape parameter; x = covariates included in the duration (that is, common bean adoption spell) model and β = coefficients to be estimated.

The survivor function is:

$S(t) = e^{-\lambda\gamma^{-1}}(e\,\gamma t - 1)$

- If γ <ˆ 1, then the hazard is monotonically decreasing with time.
- If γ >ˆ 1, then the hazard is monotonically increasing with time.
- If γˆ = 1, then the hazard is flat and we have the exponential model.

RESULTS AND DISCUSSION

Descriptive analysis

Table 1 shows the summary of hypothesized factors influencing the duration adoption of common bean varieties. About 88% of the sampled respondents were male and 12% were female. Similarly, analysis of adoption by gender indicated that about 79% (female) and 84% (male) headed households were adopters. The mean age dependency ratio was found to be about 131 indicating that there is higher proportion of dependents per 100 working-age population and is a burden in supporting the population. The average farming experience of farmers with beans was 12.4 years. The level of education of the respondents was 3.4 years. The respondents owned about a 2.4 ha cultivated land and about 6.65 tropical livestock units (TLU). About 71% of the households used chemical fertilizer in beans production and only 20% of the respondents had access to credit. At the time of the survey, the average price of maize seed was 4.45 Birr/kg (equivalent to 0.23 USD/kg). The average walking distance to input market and extension office was about 55 and 33 min. More than 50% of the farmers had training in beans production. In terms of social capital, the respondents had about 32 people that can support them in critical time.

Econometric analysis

Before and after fitting the models, appropriate diagnostic tests including multicollinearity, heteroscedastisity and model specification were made on the data and hypothesized variables. Results of test for multicollinearity showed no serious problem (Belsley et al., 1980). Robust estimation method was employed to correct for minor heteroscedasticity. One variable (TLU) was transformed to square root form.

Kaplan-Meier estimates of the survival functions for adoption of common beans varieties are presented in Figures 1 to 4. Figure 1 indicates the Kaplan-Meier estimate that discontinuities or jumps at the observed beans variety adoption times. The speed of adoption of beans was rapid in the early years and slugged as the number of years from first awareness increased (Figures 1 and 2). Generally, male farmers were more likely to adopt beans varieties quicker than their female counterparts (Figure 3). However, the adoption trend converged for both sexes as the time from awareness increased.

From the smoothed adoption curve (Figure 4), it can be observed that adoption was rapid in the beginning, decreased to 7 years and rose up again afterwards. This early rapid adoption may be attributed to innovators and early adopters that are relatively earlier in adopting new ideas than other members of a system (Rogers, 2003). While the rise in adoption in later years might be due to

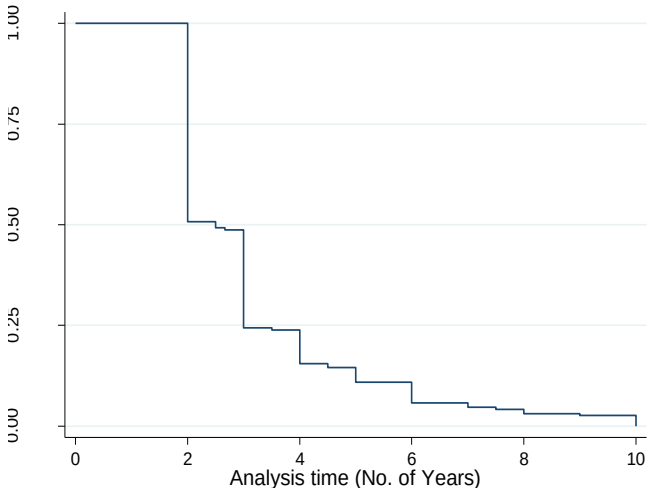

Figure 1. Kaplan-Meier survival estimate.

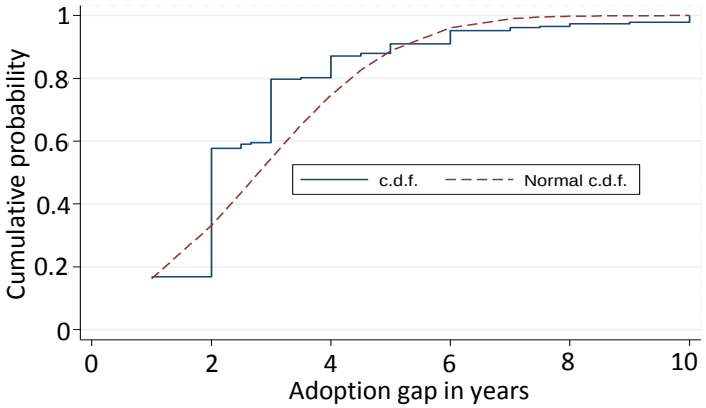

Figure 2. Cumulative adoption.

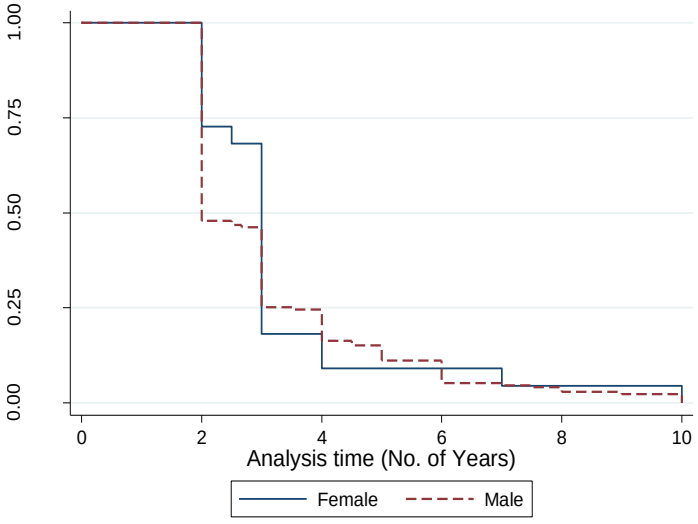

Figure 3. Adoption time by gender.

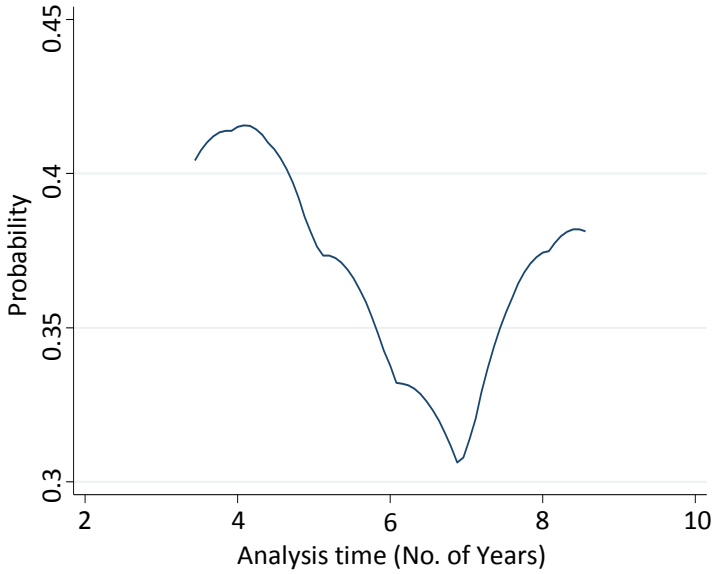

Figure 4. Smoothed adoption curve.

access to more full information about the technology over an elapse of time that would reduce uncertainty, there is increase in the expected discounted benefits by avoiding irreversible investment when it is not worthwhile (Sunding and Zilberman, 2000).

The two parametric duration models (Gompertz and Weibull) were statistically significant at 1% level. Comparison of the two models using Akaike Information Criterion (AIC) revealed that Weibull model fits the data better as shown by the lowest AIC (AIC = 317.6) (Bozdogan, 1987). In the Weibull model (Table 2), a negative coefficient generally reflects a shorter pre-adoption spell and increase in the probability of adoption, while a positive coefficient indicates longer pre-adoption spell and lower probability of adoption.

The Weibull model was estimated on the sample of 232 respondents where 83% were non-censored (that is, adopters of different beans varieties). Results of the Weibull model showed that five out of twelve variables were statistically significantly influencing time to adopting haricot bean varieties. Accordingly, the size of cultivated land and the length of distance from fertilizer market positively and significantly affected earlier adoption, while dependency ration, ownership of livestock and distance to extension office affected it negatively. In this study, we found that the size of cultivated land played a significant (P<5%) role in shortening of the time to adoption of beans varieties. Farmers who have larger size cultivated land area were able to take up the beans varieties quickly (14%) compared to their counterparts. The result is in line with several previous empirical works conducted in Sub-Saharan Africa (Katungi et al., 2011; Olusegun et al., 2014).

Results of the duration model revealed that dependency ratio and early adoption were negatively related (P<5%). Households with higher dependency ration take longer time to adopt new beans varieties. This is mainly due to smallholder farmers dependency on family labor for different farm activities; as a result the quality and quantity of household labor are expected to affect adoption decisions (Takane, 2008; Bagamba et al., 2009). The result is consistent with that of Adetola (2009) and Kassie et al. (2010), who found negative relationship between the dependency ratio and adoption of irrigation technologies and improved groundnut varieties respectively.

The negative relationship (ME=0.572) between Livestock ownership (sqrtTLU) found was unexpected as often times the ownership of livestock enhanced adoption of improved technologies; this is because access to more resources increase farmers risk bearing ability (Nkonya et al., 1997). However Murage et al. (2012) found late adoption of technologies among livestock owners. The reason for this behavior may be that livestock becomes a substitute farm income source to bean growing and as livestock holdings increase, farmers may become reluctant to adopt common beans early. Furthermore, smallholder farmers in Ethiopia prefer cereal residues to common beans for cattle feed and beans may have to be given less priority.

The effect of increase in walking distance (minute) to fertilizer market/source on the speed of adoption of common beans varieties has been positive (ME = -0.007). This may be due to the role of the crop as legume, that is, legume crops reduce the rate of soil fertility decline by fixing nitrogen in the soil and enhance crop yield (FAO, 2014). Therefore when farmers do not have access to fertilizer markets, they tend to grow these

Table 2. Estimates of Weibull and Gompertz model for the adoption of beans varieties.

_t	Weibull				Gompertz	
	Haz. Ratio	Std. Err.	ME	Std. Err.	Haz. Ratio	Std. Err.
Dependency ration (age)	0.998	0.001*	0.003	0.001**	0.998	0.001*
Sex of head (1=male)	1.122	0.319	-0.166	0.369	1.111	0.268
Education level (head)	1.013	0.028	-0.019	0.035	1.012	0.024
Farming experience (beans)	0.997	0.009	0.004	0.010	0.997	0.008
sqrtTLU	0.673	0.129**	0.572	0.329*	0.791	0.132
Livestock (TLU)	1.043	0.035	-0.061	0.057	1.017	0.031
Cultivated land (ha)	1.140	0.062**	-0.189	0.073**	1.125	0.052**
Fertilizer use (1=yes)	1.163	0.239	-0.218	0.277	1.140	0.197
Access to credit (1=yes)	1.357	0.328	-0.440	0.279	1.281	0.252
Training index	1.112	0.500	-0.153	0.453	1.072	0.406
Distance to fertilizer market (minute)	1.005	0.002**	-0.007	0.002***	1.004	0.001*
Distance to extension office (minute)	0.993	0.003**	0.010	0.005**	0.995	0.003**
Social capital	1.001	0.001	-0.001	0.002	1.001	0.001
Price of beans	1.091	0.105	-0.126	0.117	1.084	0.090
_cons	0.051	0.035***	-	-	0.102	0.063*
n	232					
/ln_p (/gamma)	0.767	0.045			0.288	0.031
P	2.153	0.097				
1/p	0.464	0.021				
Prob> chi2	0.000				0.000	
Wald chi2(14)	39.06				40.97	

Source: Survey data (2011).

crops to nourish the soil. In addition, legumes are cheap source of fertilizer to resource-poor farmers that have limited access to chemical fertilizer and credit (Rahman et al., 2013). As expected, the duration of adoption and access to extension service (distance to Extension office in minutes) were related negatively, showing that access to extension information is vital for early adoption. Generally, access to extension is one of the major sources of agricultural technology and innovation (Feder and Zilberman, 1985).

SUMMARY AND CONCLUSION

The contribution of new agricultural technology (improved agricultural practices, crop varieties, inputs and associated products such as crop insurance, improved varieties, fertilizer, irrigation, etc.) on household food security and commercialization can only be realized when the use of the new technology is widely adopted. However, the adoption pattern of proven technologies has remained uneven particularly among the poor smallholder farmers living in the drought prone areas of Ethiopia. Moreover, the speed of adoption of these technologies was rather found to be very slow and irregular. Therefore, analysis of the duration of adoption and its determinants was critical and the adoption duration framework which allows the timing of an event to be explored was applied to meet this objective.

Results of the non-parametric duration analysis on haricot indicated that speed of adoption of beans was rapid in the early years and wanes eventually. Sex of the household was found to be one of the factors as female headed households were found to be indeterminate to adopt improved common bean varieties implying the need for the design of gender oriented technology promotion strategy. Results of the parametric duration model showed that the size of cultivated land and the length of distance from fertilizer market had accelerated adoption, while dependency ration, ownership of livestock and distance to extension office have affected and slugged it. The fact that land size has a negative impact on adoption spell implies that during the early stage of promotion of newly released common bean varieties, agricultural extension strategies may need to target farmers with larger farm holdings to encourage wider demonstration effect among the smallholder common bean producers.

The findings also suggest that promotion of the varieties to areas where access to fertilizer is limited might help to improve soil fertility decline and enhance crop yield due to the leguminous nature of the crop. In addition to the increasing access to extension

information, family planning and creating employment opportunities might be essential to enhance the adoption of haricot bean varieties among smallholder farmers in moisture stressed areas. Contrary to many adoption studies, we found out ownership of livestock to be a delaying factor in haricot beans variety adoption which may be due to the consideration of livestock as a substitute income source to bean growing and low comparative advantage of common beans straw as cattle feed. Further studies may be needed to establish the appropriate relationship between duration of adoption and livestock holding.

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