Determinants of Sustainability of Community Seed Banks in Nicaragua:

A Duration Analysis Approach

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1. Introduction

Common bean *(Phaseolus vulgaris)* is widely produced and consumed in Nicaragua and is strategically important for food and nutritional security of both the rural and urban poor. The increases in bean production seen by this country over the past two decades is due to an increase in area cultivated rather than an increase in yield, which was estimated to be 643 kg per hectare for the country in 2011 (Quiroz Cortez el al. 2009, MAGFOR 2009, Schmidt et al. 2012). Large shares of bean producers in Nicaragua are smallholder farmers.[1] In 2011, 64% of producers cultivated beans on less than 20 manzanas (equivalent to 34 acres or 14 hectares)[2], 50% on less than 10 manzanas and 34% of farmers cultivated beans on less than 5 manzanas (INIDE 2012). One way to increase bean yields of smallholder farmers is to use certified seeds of improved varieties (Remington 2002). Long-term investment in research by the national program in collaboration with international researchers has resulted in the development and release of many disease resistant bean varieties with a potential to increase bean grain yield in the country. However, access by small holder bean producers to the certified seeds of improved bean varieties remains a major constraint. According to the *Instituto Nicaragüense de Tecnología Agropecuaria* (INTA), due to the lack of availability and access to certified seeds, the use of this type of quality seed has remained low even among farmers who receive training on implementing practices to increase yield (MAGFOR 2009, Sain 2011, Carter et al. 2012). The Nicaraguan Ministry of Agriculture estimates that in 2008-09 agricultural season only 6.2% of

[1] Compared to many developing countries in Asia and Africa, the definition of smallholder farmer in Nicaragua based on the size of land holding may seem out of range. However, Berdegué and Fuentealba (2011) and Carmagnini (2008) point out that given the conditions of rural Nicaragua, a family cannot maintain its sustenance on less than 5.6 hectares (8 manzanas). MAGFOR considers farmers to be small scale if they cultivate less than 50 manzanas for all crops (Hallensleben 2012).

[2] One manzana is equal to 0.7 hectares and equal to 1.7 acres

bean production area was planted with certified seeds, and in the past seven years, even though the use of certified seeds has increased, it has never surpassed 15% of area planted to beans in Nicaragua (MAGFOR 2009, UNISEM personal communication).

Due to low profitability, private seed companies have had little interest in marketing certified bean seed directly to farmers. Instead, the private sector's contribution to the formal seed system has focused on selling the certified seed to government agencies and NGOs to feed into their free or highly subsidized seed distribution programs. This model of seed production by the for-profit private sector, and its purchase and distribution to the farmers by government and NGOs at less than the economic price is not sustainable over the long run. Moreover, this approach only reaches a limited subset of bean producers in the country (MAGFOR 2009).

Recognizing that 'access to good quality seed' is one of the limitations in increasing bean productivity, the government of Nicaragua has started several initiatives to improve access to quality seed by farmers in rural areas. One of these initiatives is to promote the community seed bank (CSB) model to produce '*Apta* seeds,' or Quality Declared Seeds (QDS) of basic grains, including beans. A CSB is a formalized, but not a legally registered, organization whereby community members come together to produce seeds to meet their own current needs, save seeds for future seed security, and sell excess seeds to generate revenues to cover production costs. The CSB oversees community-level production, marketing, distribution, and storage of quality seeds (i.e., QDS). These QDS are produced from registered seeds using the agronomic practices of 'seed' production, but are not certified as 'seed'. In other words, the seeds are produced by the farmers under the aegis of a community organization with technical guidance from INTA and distributed to other farmers within or outside the community.

While work has been done to study the various types of CSBs (Lewis and Mulvany 1997), the profitability of community based bean seed production (Katungi et al. 2011) and provide case studies that suggest factors that lead to sustainability of CSBs (Vernooy et al. 2015, Witcombe et al. 2010, ICRISAT 2010, Van Mele et al. 2011, Tripp et al. 2001, Sentimela et al. 2004), no known study has provided an empirical analysis of the factors associated with sustainability. This study documents the experience of CSBs in Nicaragua in the context of the Bean Technology Dissemination (BTD) project and studies the sustainability of this form of local seed production and its role in a possible integrated seed system. The BTD project was a donor funded project tasked to disseminate quality seeds of improved bean varieties to smallholder farmers. It used CSBs to multiple *Apta* seeds (i.e., QDS) to reach a more than 20,000 farmers in Nicaragua from 2011 to 2014.

The paper proceeds as follow—Section 2 provides the model and methodology used in the study, Section 3 describes the data and provides descriptive statistics from the study, Section 4 provides the results from the duration analysis, and Section 5 concludes the paper with a discussion of policy implications.

2. Methodology

The methodology of duration analysis, also known as survival analysis, aims at understanding the factors that explain the time that passes (i.e., duration) before a certain event occurs (Greene, 2012). In the current study, the event of interest is the end of the CSBs' participation in the BTD project. Thus, during the project phase (2011-2014), the CSB can be in one of two states, (1) participating in the BTD project or (2) having withdrawn from the BTD project. The only way to leave the initial participation state, often called a 'spell' in duration analysis literature, is to leave the BTD project.

The decision to withdraw from the BTD project can be modeled using a utility model. The members of the i^{th} CSB evaluate their collective utility after each year t of the BTD project from two alternatives j=1, 2. They could continue in the BTD project, j=1 or withdraw from the BTD project, j=2. The CSB also makes this decision with the *tecnicos* or extension workers from INTA. If an alternative project, say soil conservation, better mets the needs of the farmers or community, the extension worker could suggest changing the CSB to a group of farmers implementing soil conservation practices.

The decision is made as a group, although an individual may choose to leave the CSB in any given year. The individual's decision to leave the CSB would impact the size of the CSB as well as human capital assets associated with that individual's age, experience and education.

The model developed by Carletto et al. (1999) to explain the technology adoption decision and entrance into non-traditional markets is useful in modeling the determinants of CSB sustainability. Carletto's model includes two analytical components-- the analysis of time to adopt a new technology or market, and the duration of participation in the nontraditional market before withdrawal. In the setting of our study, 'technology' is defined as 'the production of QDS bean seed using the community seed bank model.' The analysis of time to adopt a new technology as done by Carletto et al. (1999) is not applicable in the current study because the decision to adopt the technology (i.e., production of QDS bean seed using the CSB model) and the new market (seed sales to neighbors/local community) had already been made before the start of the BTD project. The second/complementary part of Carletto's adoption analysis, i.e., the duration of participation in the nontraditional market before withdrawal, is however, applicable and used as a basis to model the determinants of CSB sustainability in this study.

Like the farmers in Carletto's farm-household choice model, the risk-averse decision makers of a CSB, will maximize their utility and thus choose to withdraw from the BTD project if the change in utility, ΔU, from leaving the project is positive. This utility function is expressed as a function of several factors (explained below) that positively or negatively influences the change in utility:

$$\Delta U = \Delta U(-A, -L/A, -p_x, -FK, -HK, -SK, -T_{CSB}, \pm t_s, \pm D_v) \qquad (1)$$

The factors included in equation 1 build on the model from Carletto et al. (1999), notation used by Hernandez-Barco (2012) and the review of the literature. *A* represents land assets, which are associated with access to credit, adoption of technology and slower withdrawal from adopted technology through the risk factor. CSBs that produce seed on land owned by members are expected to be able to obtain financing should it be needed to cover emergency inputs to prevent crop loss. Bean seed harvest is particularly vulnerable to post harvest losses in the event of a rainy harvest season. Likewise, the more than proportional decline in absolute risk aversion associated with increased land assets indicates that land assets are expected to be associated with longer participation in the BTD project.

The size of the CSB is an indication of available labor *L* (per unit of land asset) that its members can supply. Hired labor is assumed to be less efficient and thus increase production costs. The expected price p_x of seed sales is negatively associated with withdrawal from the BTD project. The price comes from repayment of seed loans to community members and thus is not dependent on grain prices.

Three sources of capital are negatively related to withdrawal from the CSB. Farm productive assets *FK* include sources of transportation (pick-up trucks, mules, oxen, horses) and tools (backpack sprayers, grain/seed drying areas, silos for seed storage). Human capital assets

HK include leadership age and experience as well as gender and education. And finally social capital assets, *SK* are measured by the type of CSB (individual vs community based), share of CSB members that are related of other members and operational formality (i.e., number of meetings, written by-laws, recording minutes of the meeting, having a seed production and marketing plan). Training received by the CSB leadership and members could fall either under human capital (representing knowledge or education) or social capital (i.e., operational formality and connectivity to INTA).

Two time measurements are included in the model. The years of previous collective organization of CSB members prior to CSB formation T_{CSB} and the survival time t_s between entering BTD project and withdrawing from the project.

Finally, the village or community effects D_v include measures of remoteness such as distance to city (market), infrastructure, and public services. Regional effects are also included in the model to include regional level heterogeneity in the approaches used by the INTA regional offices to operationalize the CSB model.

Since we are interested in the survival time in years, equation 1 is manipulated to express t_s as a function of the independent variables.

$$t_s = t_s(+A, +L/A, +p_x, +FK, +HK, +SK, +T_{CSB}, \pm D_v) \qquad (2)$$

The Accelerated Failure Time (AFT) models of duration analysis provide results allowing for a comparison of survival times between different CSBs and covariates. Specifically, how covariates accelerate the time that passes between the beginning of the study and the time of failure or CSB withdrawal from the BTD project.

Following Cleves et al. (2010) AFT models or ln (time) models follow the parameterization:

$$\ln(t_j) = \mathrm{x}_j\beta_{x,} + \epsilon_j \quad (3)$$

but instead of assuming a distribution of t_j, a distribution is assumed for

$$\tau_j = \exp(-\mathrm{x}_j\beta_x)t_j \quad (4)$$

and since $t_j = \exp(-\mathrm{x}_j\beta_x)\tau_j$

$$\ln(t_j) = \mathrm{x}_j\beta_{x,} + \ln(\tau_j) \quad (5)$$

When $\exp(-\mathrm{x}_j\beta_x) = 1$, then $\tau_j = t_j$ and time is "normal" but when $\exp(-\mathrm{x}_j\beta_x) > 1$ time passes faster so the event occurs sooner and thus time is accelerated. Likewise, when $\exp(-\mathrm{x}_j\beta_x) < 1$ time passes slower so the event occurs later and time is decelerated.

For our current analysis, the lognormal distribution model is used, $\tau_j \sim lognormal(\beta_0, \sigma)$ with the conditional survival function

$$S(t_j|\mathrm{x}_j) = 1 + \Phi\left\{\frac{\ln t_j - (\beta_0 + \mathrm{x}_j\beta_x)}{\sigma}\right\} \quad (6)$$

The parameters, β_x, estimated in the AFT model give the proportional change in duration (survival) time given a one unit change in the explanatory variable, all else held equal.

3. Data and Descriptive Statistics

The data for this study comes from the survey of community seed banks conducted in 2012 in Nicaragua. All the 207 CSBs that had participated in the BTD project in 2011-2012 (i.e., the first year of the BTD project) were targeted for this survey. Table 3.1 presents the total number of CSBs targeted for the survey included in this study by region. Multiple attempts were made by the authors through requests to national INTA employees to obtain the surveys from all 207 CSBs, however, there remained 53 non-respondent CSBs. Table 3.2 presents the distribution of the surveyed CSBs by region and type of CSB.

For the current study, CSBs self-identified as one of the three types defined below. Classic CSBs resemble closely to the structure described in the manual above and was defined for this study as follows:

> The CSB is made up of several members of the community (partners or members) and bean seed is grown in an area of approximately one manzana (possibly only one field) with one promoter. The members of the CSB make decisions about which seed variety to use (beginning in 2012), what input to use, who should receive seed (loan), and how to secure repayment of grain (loan repayment).

David (2004) pointed to trust and previous work experience in groups as reasons to use the classic model and in their absence, to choose an individual option. In this study, the individual seed banks were defined as follows:

> The CSB is made up of one individual who grows the seed and makes decisions, sometimes with the help of INTA, as to who should receive the seed (loan).

Additionally, parceled CSBs were formed and resemble the structure David (2004) mentioned allowing a farmer, or farmers here, to focus on production and incorporate a collective process to post-harvest activities. The definition of parceled CSB used in this study is as follows:

> The CSB is made up of several members of the community (partners or members) and bean seed is grown on several lots with several promoters. The members of the CSB make decisions about which seed variety to use (beginning in 2012), what input to use, who should receive seed (loan), and how to secure repayment of grain (loan repayment).

Over the course of the BTD project, INTA staff submitted reports listing the CSBs that continued to operate in the final two years of the project as well as a selected group of CSBs that were supported in the 2014 agricultural season (after the official end of the BTD project). Information on which CSBs failed during the BTD project years 2 and 3, and which continued after the end of the BTD project is used in the duration analysis to determine which characteristics of the CSB are associated with variations in the CSBs failure rates and time of operation.

Table 3.1: Total number of CSBs targeted for the survey versus those that completed the survey and included in this study

Region	Total number of CSBs targeted	Number of CSBs that returned the completed survey (sample size for this study)
Centro Norte	41	37
Centro Sur	40	40
Las Segovias	44	29
Pacifico Norte	62	28
Pacifico Sur	20	20
Total	207	154

Table 3.2: Distribution of surveyed CSBs by region and type

	Type of Seed Bank			
Region	Classic	Parceled	Individual	All
Centro Norte	37	0	0	37
Centro Sur	0	10	30	40
Las Segovias	15	11	3	29
Pacifico Norte	7	21	0	28
Pacifico Sur	13	7	0	20
Total	72	49	33	154

Table 3.3 Summary Statistics of variables used in the duration analysis: Differences across types of CSBs in community level characteristics, membership and operating procedures

	Type of Community Seed Bank						
	Classic		Parceled		Individual		TOTAL
# of Observations	72		49		33		154
Mean Years participation in BTD	2.07	a	2.22	a	1.61		2.02
# of Years (% Yes)							
1 Year	38.89	~	26.53	~	69.7	~	41.56
2 Years	29.17	~	30.61	~	12.12	~	25.97
3 Years	18.06	~	36.73	~	6.06	~	21.43
4 Years	13.89	~	6.12	~	12.12	~	11.04
CSB Organizational Structure							
# Years operation at beginning of BTD	0.24	a	0.31	a	0		0.21
# of CSB members	9.35	a	7.51	a	1		6.97
CSB or Community members had voice in use of seed produced (% Yes)	81.94	a	79.59	a	45.45		73.38
Number of monthly meetings	1.41	a	1.37	a	0		1.09
% of CSB members attending meetings	82.38	a	89.38	a	0		66.96
Meeting Minutes Recorded (% Yes)	54.17	a	61.22	a	0		44.81
CSB has written bylaws (% Yes)	54.17		73.47		0		48.70
% of CSB members with Immediate family members in CSB	40.71	a	31.42	a	0		29.03
% of CSB members with Extended family members in CSB	22.86		11.03	a	0	a	14.20
Community Characteristics							
Distance to paved road (KM)	14.21	a	12.52	a	8.24	a	12.40
Travel time to Municipal Seat in private car (minutes)	25.86	a	25.57	a	28.64	a	26.36
PCA of Community Level Development[1]	-0.10	a	0.30	a	-0.23	a	0
Leadership Characteristics							
President older than 30 (% Yes)	95.83	a	83.67		96.97	a	92.21
President's Gender (% Male)	90.28	a	87.76	a	84.85	a	88.31
Promoter's Gender (% Male)	87.50	a	85.71	a	84.85	a	86.36
President is Promoter (% Yes)	65.28	a	48.98	a	100		67.53
President’s years of education	5.58	a	7.29	b	5.73	ab	6.16

Notes:

[1] PCA means Principal Components Analysis

Types of CSBs that share a letter are not significantly different at the 10% level

~ indicates that a significance tests across groups has not been performed for these variable

Tables 3.3, 3.4 and 3.5 provide summary statistics of the variables included in the duration analysis. Since one of the objectives of this study is to characterize the differences and similarities between the CSB models, the statistics are presented by the three types of CSBs—classic, parceled and individual. The dependent variable in duration analysis is calculated as the duration of time (i.e., number of years) from a starting point (in this case the start of the BTD project) to the occurrence of an event (in this case the withdrawal of a CSB from the BTD project). The weighted average of the 'duration' variable (i.e., number of years participating in the BTD project) is lowest for Individual CSBs at 1.6 years and highest for Parceled banks at 2.2 years (Table 3.3). Individual banks as a group had a statistically different weighted average years of survival at a 10% level than the other two CSB types.

Characteristics of Individual Banks

There are several statistically significant differences in the descriptive statistics for individual banks compared to the other two types of CSBs (Table 3.3 and 3.4). As mentioned above, one such variable is the duration of BTD participation, the dependent variable in this study. Years of operation prior to the beginning of the BTD project was zero for individual banks, not from lack of seed production experience, but from not previously using the CSB operational structure.[3] The percent of promoters that are also the presidents of their CSBs, percent of CSB members related to another CSB member, and the variables related to CSB meetings are not relevant to individual seed banks due to the nature of this type of seed bank (Table 3.3). Training related to formation and organization of the CSB also did not occur for individual banks (Table 3.4). Additionally, less than half of the individual seed banks reported

[3] The survey instrument did not capture years of individual seed production experience, the relevant variable of interest for individual seed producers.

having a voice in the decision of use of seed (Table 3.3) due in part to INTA's seed distribution plan given the climatic and geographic conditions in the *Centro Sur* region.

Organizational Structure of CSBs

Comparing classic and parceled CSBs in regards to indicators of organizational structure, there were only two variables that were statistically different (Table 3.3). A higher percentage of extended family members participated in classic CSBs than parceled CSBs and a higher share of parceled CSBs had written bylaws than the classic CSBs. Written bylaws are a good indicator of both following the CSB formation protocol given by INTA but also the organizational disciple of administering and planning required in a business orientated enterprise with several partners. No significant difference was detected in the number of meetings per month, average attendance per meeting and documenting minutes of the meetings between the two types of banks.

Community characteristics

No statistically significant differences were found between the three types of CSBs in the index of community development,[4] distance to paved road and travel time to town in a private vehicle. While these community level characteristics did not differ between types of CSBs, there were regional differences between the five INTA administrative regions which are controlled for below in the duration analysis.

In rural Nicaragua, age is closely associated with farming experience as urban to rural migration is rare. Most rural Nicaraguans would state that they have been farmers since they were born. Likewise, with age comes responsibility as community leadership roles are less likely to be held by youth. The presidents of over 95% of classic and individual banks were

[4] A principal component analysis (PCA) of 14 community level characteristics (reflecting the infrastructure and amenities present/absent in the community) was used to generate this index of community development. Lower numbers represented communities with less access to public services and amenities. See section B9 of the survey included in the Appendix for a complete list of community level characteristics comprising the PCA index.

older than 30 years of age. Only 84% of presidents of parceled CSBs were older than 30 years representing a statistically significant difference compared to the other two types of CSBs.

While there was no statistical difference between the three types of CSBs in gender of the president and promoter, the presidents' of parceled CSBs had more years of education than classic CSBs. On average presidents of parceled CSBs completed more than 7 years of formal education while classic CSB presidents completed less than 6 years. The years of education of presidents of individual banks were not statistically different than the other two types of CSBs.

Land Use in CSB Seed Production

Table 3.4 provides a summary of seed production inputs by types of CSBs. There was a large and statistically significant variation in ownership of land used for seed production between the three types of CSBs. While 81% of classic CSBs used land owned by a CSB member, the share was much lower among parceled (61%) and individual (15%) CSBs. Around a quarter of the classic and parceled CSBs rented land and were not significantly different, while only 3% of individual CSBs rented land. Some CSBs with multiple seed plots reported using CSB member land and renting it from another farmer, while some individual CSBs did not report using either source of land. Other sources of land possibly used by individual CSBs could be borrowed land (without paying rent) or a crop sharing agreement where the land owner provides the land and the seed bank (producer) provides the labor with the agreement of splitting the harvested production. Unfortunately, these other options were not included in the survey, and thus it is difficult to determine if and how many of the CSBs that did not report using their own land or rented land used these alternate sources of land or whether they simply did not respond to that question (and thus we potentially have the problem of missing data).

Labor use for seed production

In terms of labor input, as expected, the classic CSBs reported statistically higher use of CSB members for labor than the parceled and individual CSBs. While low use of hired labor by classic banks was expected because CSB members provided labor, it was surprising that individual seed banks did not hire labor and instead mostly relied on household members for labor input. The similarities of seed production between the parceled and individual banks explain the lack of statistically significant difference in the use of CSB member labor. In the case of individual banks, the operator him/herself is in charge of production but for parceled banks they could have access to additional CSB members providing labor.

Assets and access to facilities used for seed production

The CSBs also vary in terms of assets and access to facilities (Table 3.4). Number of silos is an important variable for CSBs because an additional silo provides the opportunity to store an additional variety of seed or grain while still maintaining the varietal distinction. Parceled CSBs had a significantly higher number of silos compared to classic and individual CSBs. Although the share of parceled banks that received silos from the BTD project was higher than the other two types, the difference is likely due to existing silo ownership prior to the BTD project. Some silos were inherited by CSBs from the MCC project in the *Pacifico Norte* region and 43% of parceled CSBs are in the *Pacifico Norte* region.

Backpack sprayers are an important tool used to apply inputs. Although there was no statistical difference between the three types of CSBs, over 76% of classic CSBs and 53% of parceled CSBs had this tool, while only 9% of the individual banks reported access to a backpack sprayer. If one CSB member had the tool, it is assumed that the CSB would have access to that tool. Therefore, the individual banks might be at a disadvantage compared to the classic and parceled if they are unable to borrow the tool from neighbors.

An area for drying seed is used during post-harvest treatment of seed. Twenty percent of parceled CSBs had access to a drying area while only 3% of parceled CSBs and no individual banks indicated having access to a drying area (Table 3.4).

Table 3.4 Summary statistics of variables used in the duration analysis: Differences across types of CSBs in seed production inputs

	Type of Community Seed Bank						
	Classic		Parceled		Individual		TOTAL
# of Observations	72		49		33		154
Land							
Land used for seed production (MZ)	1.19	a	1.00	a	0.99	a	1.09
Seed produced on CSB member land (% Yes)	80.56		61.22		15.15		60.39
Seed produced on rented land (% Yes)	23.61	a	28.57	a	3.03		20.78
Labor							
CSB members provided labor (% Yes)	90.28		69.39	a	69.70	a	79.22
Hired workers provided labor (% Yes)	12.50	a	57.14		0	a	24.03
Assets/facilities							
# of Silos	1.83	a	3.39		1.09	a	2.17
CSB received Silo from BTD Project (% Yes)	30.56	a	67.35		12.12	a	38.31
CSB has access to backpack sprayer (% Yes)	76.39		53.06		9.09		54.55
CSB has access to seed/grain drying area (% Yes)	2.78	a	20.41		0	a	7.79
CSB has access to transportation (pickup/mule/ horse/ox) (% Yes)	73.61	a	83.67	a	90.91	a	80.52
CSB has access to animal transportation (mule/ horse/ox) (% Yes)	73.61	a	83.67	a	69.70	a	75.97
Human Capital							
CSB trained in Formation and Organization (% Yes)	88.89	a	95.92	a	9.09		74.03
CSB trained in Seed Marketing (% Yes)	25.00	ab	36.73	b	12.12	a	25.97
CSB trained in Seed Production (% Yes)	90.28	a	95.92	a	90.91	a	92.21

Notes:

Types of CSBs that share a letter are not significantly different at the 10% level

A source of transportation is important to increase efficiency of moving plants or grain from the field to the drying area. There was no statistical difference between CSB types for the percent of CSBs with access to animals or a pickup for transportation.

Human capital in seed production

As mentioned above, few individual seed banks received training on CSB formation and organization while the levels of this training were not significantly different for classic (89%) and parceled (96%) CSBs. Training on seed marketing, a skill deemed very important for sustainability as per the literature, was received by 37% of parceled banks, 25% of classic banks and 12 % of individual banks. There was no statistically significant difference between the classic CSBs and the other two types of banks, but the share of parceled banks receiving this training was significantly higher than individual banks (Table 3.4). Finally, seed production training was received by 92% of the CSBs and did not significantly differ among the types of CSBs.

Output and efficiency indicators in Seed Production

As reported in Table 3.5, there are also differences and similarities in the output and efficiency indicators across the three types of CSBs as measured by yield, number of beneficiaries, loan repayment and meeting the varietal diversity needs of the communities served by these banks in the first year of their operation under the BTD project. On average, CSBs of all three types used one manzana (0.7 hectares) to produce a little over 1200 pounds of seed per manzana and marketed seed to just fewer than 29 (clients) beneficiaries per manzana. There was no statistical difference in potential yield[5] among the three types of CSB. The similarity in size,

[5] Potential yield is the highest yield achieved by a CSB during the BTD project. For CSBs that withdrew from the BTD project after Year 1, yield and potential yield are the same.

number of clients served, and yield can be attributed to recommendations by the BTD project and a similar input package distributed across types of CSBs.

Table 3.5 Summary statistics of variables used in the duration analysis: Differences across types of CSBs in seed production output indicators

	Type of Community Seed Bank						
	Classic		Parceled		Individual		TOTAL
# of Observations	72		49		33		154
Output and Efficiency Indicators							
Year 1 Yield (QQ/MZ)	11.05	a	14.07	a	12.78	a	12.38
Yield potential (QQ/MZ)	15.75	a	17.67	a	14.00	a	15.98
% of production distributed to beneficiaries	43.37	a	57.89	b	50.18	ab	49.45
# Beneficiaries per MZ Seed Production	25.16	a	30.86	a	33.45	a	28.75
% of Beneficiaries Fully Repaying (2lb per 1lb)	23.76		55.74	a	54.04	a	40.43
Recovery rate (repaid/seed distributed)	0.49		0.88	a	1.18	a	0.76
CSB supplied variety demanded (% Yes)	29.17		63.27	a	57.58	a	46.10

Notes:
Types of CSBs that share a letter are not significantly different at the 10% level

Despite the similarities, parceled CSBs disseminated a statistically larger percentage of their seed production (58%) to beneficiaries than classic CSBs (43%). The percent of production distributed to beneficiaries of individual CSBs did not differ than the other two types of CSBs.

At the BTD project level, repayment terms for beneficiaries were established to be two pounds of grain for each pound of seed received from the CSB. The two-for-one scheme was to differentiate the value of seed compared to grain and recover production costs. Agreement with this price was not universally shared by CSB leaders and INTA staff. The *Centro Norte* region, where 51% of the Classic CSBs are located, had an extremely low compliance rate of only 1% due to a regional implementation of a one pound of grain repayment for each pound of seed received. The classic banks' repayment rate as measured by compliance with the two to one guidelines was half that of the parceled and individual banks (Table 3.5). Similarly, the recovery rate of seed was only 49% for classic CSBs and 7% for the Centro Norte region compared to 76% among all CSBs. As mentioned, regional differences are controlled for below.

In year 1 of the BTD project, the CSBs had few options of varieties to offer to their communities. Most CSBs received registered seed of only one variety, INTA Rojo[6], because that was the main variety available from INTA and it was considered to be widely adapted to different conditions across the country, was resistant to diseases, and fetched a decent market price for grain[7]. But the availability of one main variety for seed production throughout the country implied that the location specific demand for diverse bean varieties was not met by all CSBs. Less than a third of classic CSBs offered a variety that was among the highest demanded seed varieties in their community. Supplying a demanded variety was higher among parceled (63%) and individual (58%) CSBs (Table 3.5).

Seed Quality

Unfortunately, not all CSBs provide reliable data on seed quality indicators such as germination test results, humidity at time of storage and seed purity after post-harvest treatment (the percent of seeds free of lumps or divots, fungus, germinated, contrasting or seed of other varieties)[8]. The data from the subset of CSBs that did provide seed quality data reveal that CSBs are widely distributed across quality standards as measured by acceptable humidity level (at most 15%), seed germination rate (minimum 80%), and purity (minimum 97.5%). Only 18% of CSBs met all three quality standards and seed purity was the most difficult standard to achieve.

[6]A little over 83% of CSBs received INTA Rojo. Other varieties produced by CSBs in year 1 of the BTD project were INTA Sequia (12% of CSBs) and INTA Matagalpa (5% of CSBs).

[7] The price for grain of a category of land race or *Criollos* varieties call *Rojo Seda* is largely assumed to be higher than INTA Rojo, however, no market prices were collected for this study.

[8] See Arraya and Fonseca (2007) for details of seed purity criteria in Central America.

Figure 3.1: Quality of Seed as Measured by Germination Rate

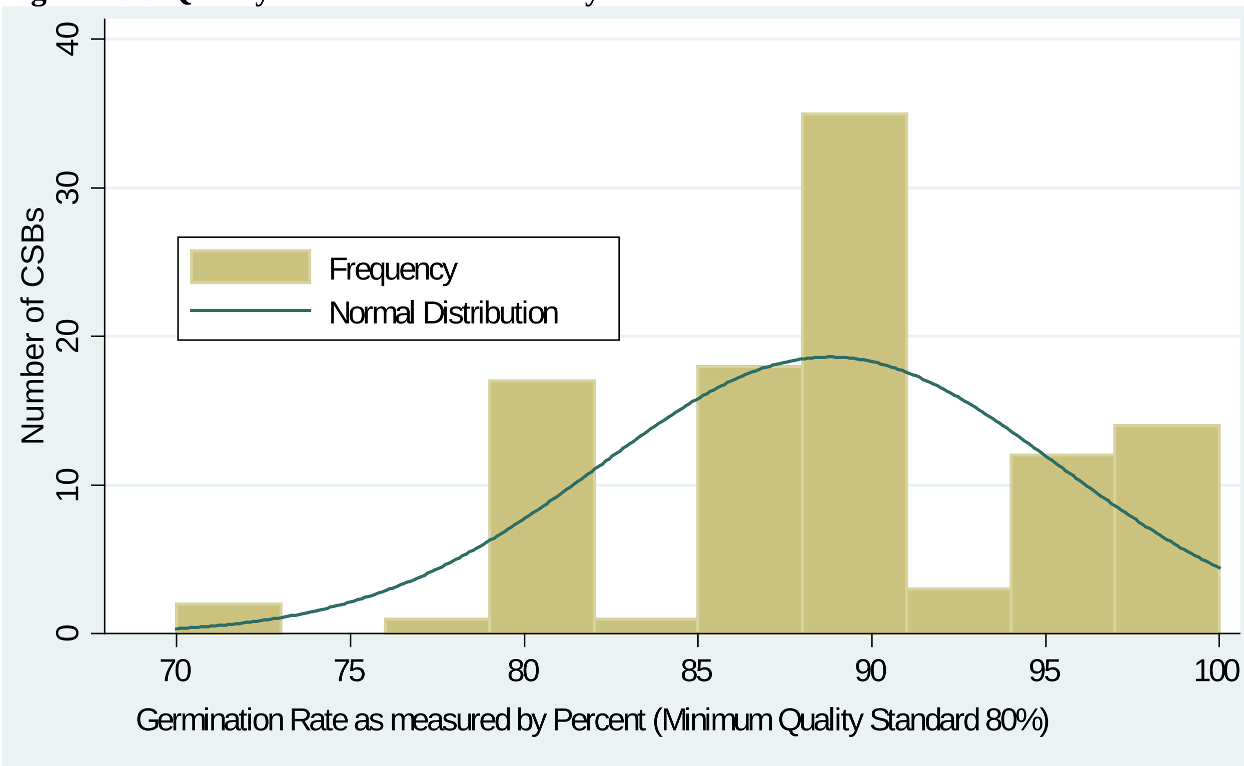


Figure 3.2: Quality of Seed as Measured by Humidity

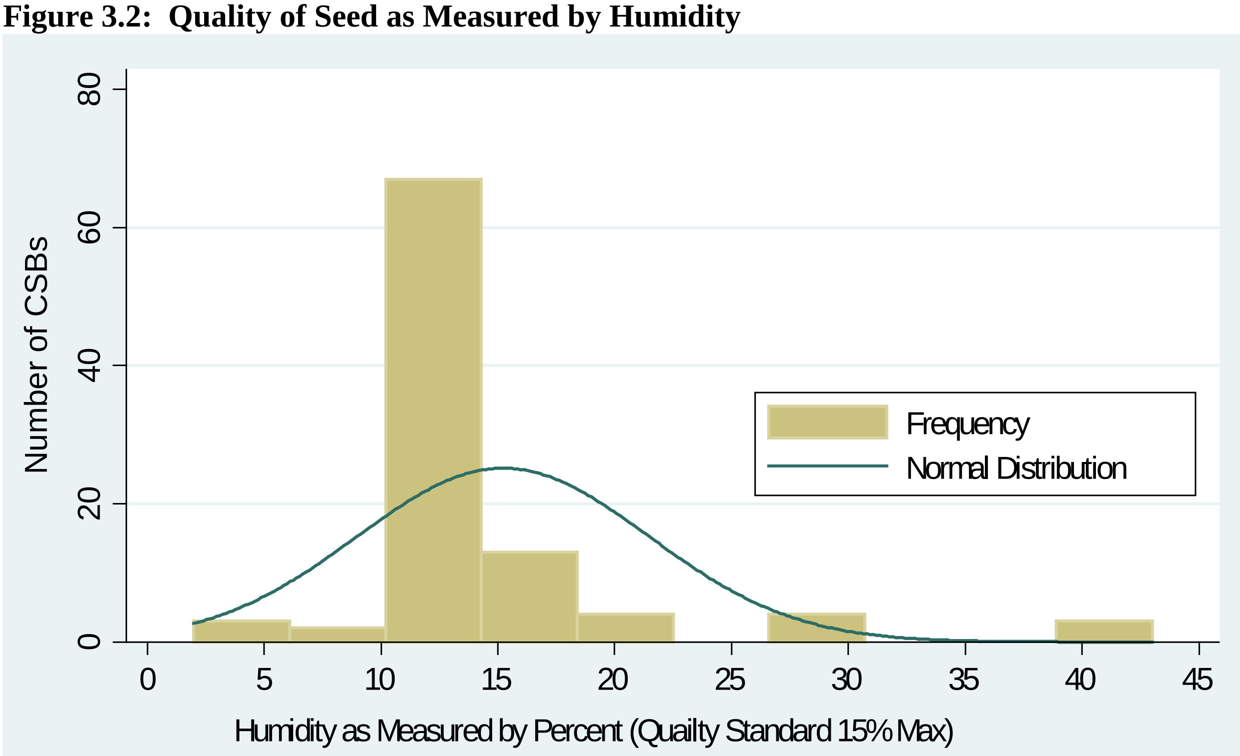


Figure 3.3: Quality of Seed as Measured by Seed Purity

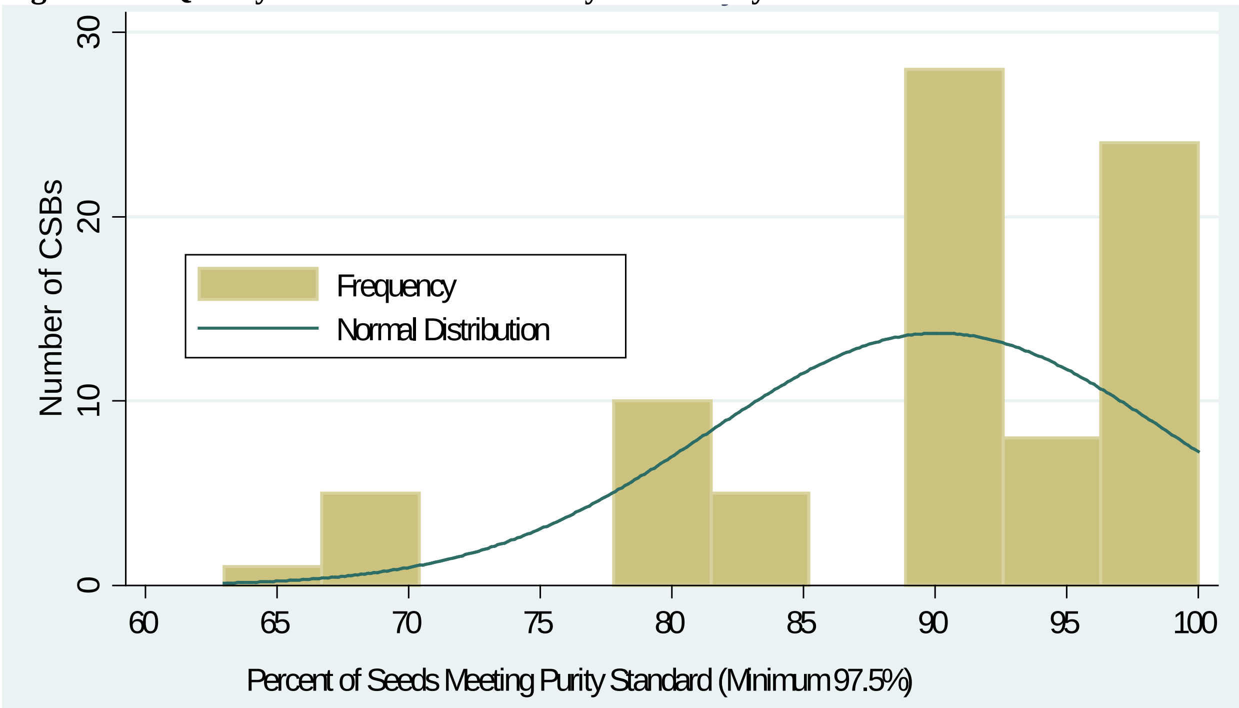
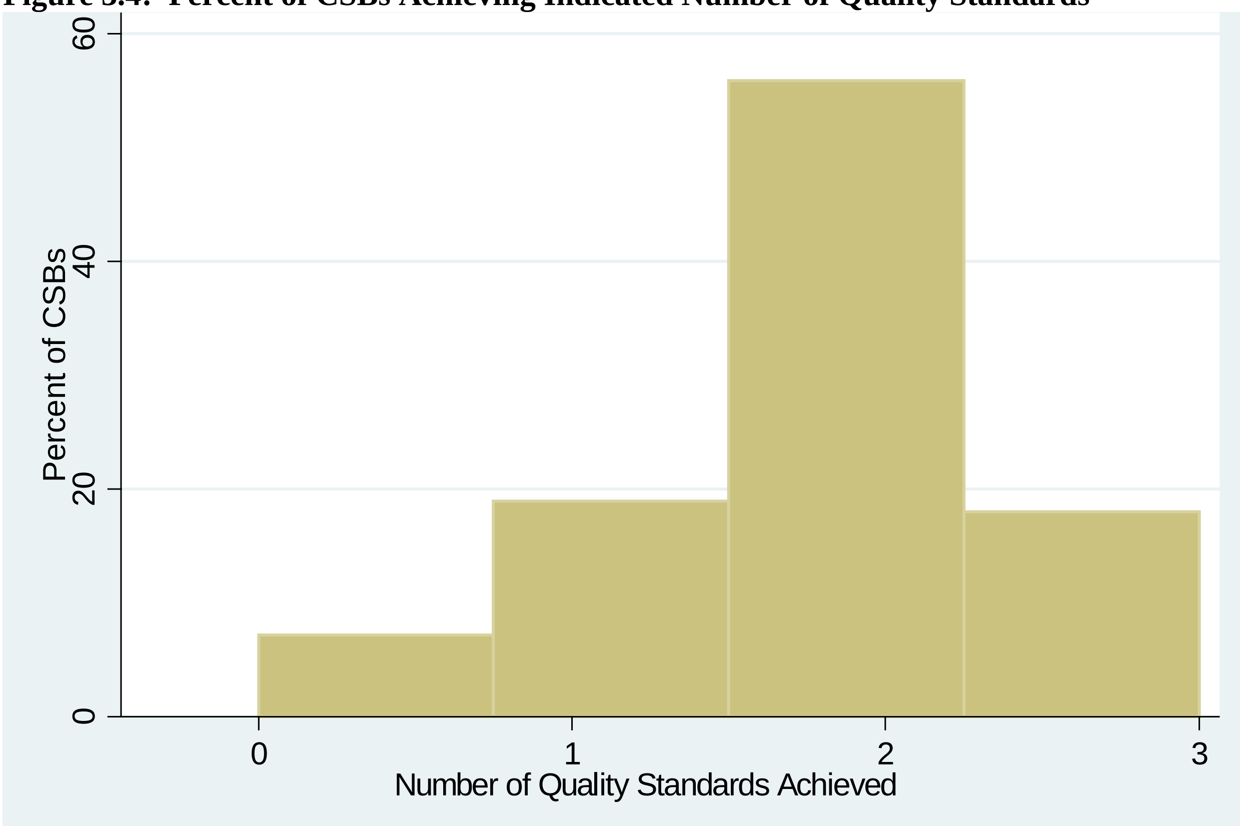


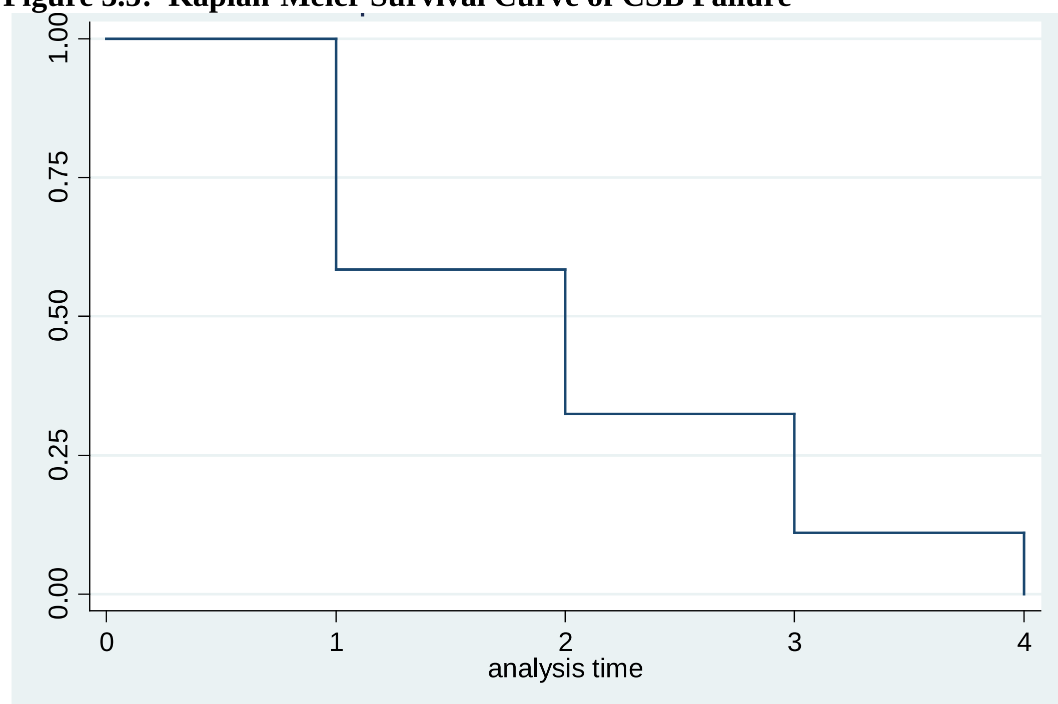
Figure 3.4: Percent of CSBs Achieving Indicated Number of Quality Standards



Non-parametric technique of duration analysis

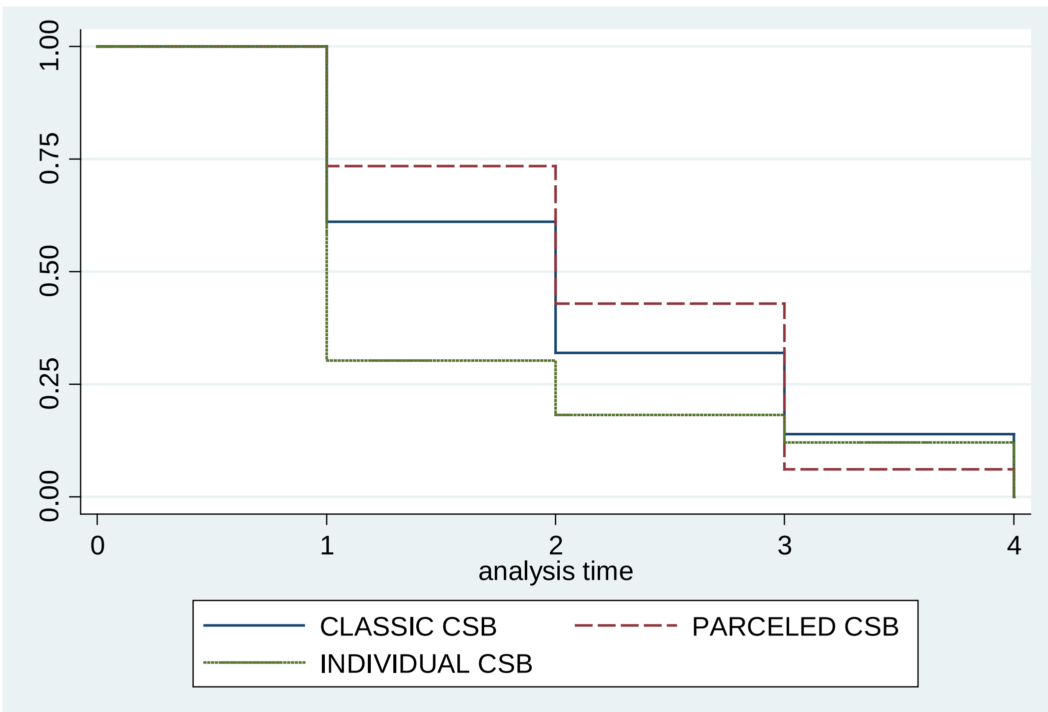
Before using the AFT duration analysis regression to explain the survival time of the CSBs, a non-parametric technique of duration analysis is helpful to visually observe the data and different subgroups of the data (Kleinbaum & Klein 2012). The non-parametric technique used in this study is the Kaplan-Meier Survival (KMS) curves. Additionally, the log-rank test is used to test if multiple KMS curves are different. Figure 3.5 gives the KMS survival probabilities for each year of the BTD program.

Figure 3.5: Kaplan-Meier Survival Curve of CSB Failure



The horizontal axis represents the years of the BTD project. For example, t=0 is at the beginning of the BTD project and t=1 is the end of year 1, t=2 is the end of year 2, and so on. The agricultural year in Nicaragua begins with the rain in May, thus t=0 is May 2011, and t=1 is May 2012 when the first year of the BTD project ended and the second year began. The vertical axis represents the percent of CSBs still operating, thus at *t*=0, the curve's *y*-value is 1 because none of the CSBs had failed. After year 1 of the BTD project or between *t*=1 and *t*=2, the function has the value of 0.58 because 58% of the CSBs remained in the BTD project. The speed of leaving the BTD project (or ending the spell) is highest at the beginning and slows near the end.

Figure 3.6: Kaplan-Meir Survival Estimates by CSB Type



The KMS curves in Figure 3.6 indicate that the survival functions are not equal for all three CSB types. The log-rank test confirms with Chi squared(2)=4.96, *p*-value 0.0835, so at a 10% level we reject the null hypothesis that the survival functions of the three types of CSBs are equal. A second common test with the same null hypothesis is the Wilcoxon test and it confirms the results of the log-rank test at a higher level Chi squared(2)=10.84, *p*-value 0.0044. Since regional heterogeneity is anticipated, we can test for difference in survival curves while controlling for regional differences using a Wilcoxon test stratified by the five INTA regions. The results reveal the same conclusion, Chi squared(2)=6.11, *p*-value 0.0471, the null hypothesis, that the three survival functions are equal, is rejected at a 5% level.

4. Results

To fit the model, first all of the variables considered important from the literature review are included. These variables are included in Tables 3.3, 3.4 and 3.5 above. A likelihood ratio test justifies the omission of non-significant variables with less than unity *t*-ratios in the final model. The null hypothesis is that the coefficients of the omitted variable are jointly not equal to zero. By failing to reject the null hypothesis, the preferred models have only removed a set of explanatory variables that jointly equal zero from the full model.

Two AFT models, the log-normal and log-logistic were estimated. Comparison of the models to determine the best model is performed by comparing the estimated log-likelihood (higher is better) and two post-estimation information criterion (lower is better)—the Akaike information criterion (AIC) and Schwarz's Bayesian information criterion (BIC). Additionally, the significance levels of the coefficients are considered when comparing different models.

It has been assumed that each CSB, after controlling for all observable differences, are homogeneous. If they are not homogeneous, the results of the determinants of sustainability, or variables, in the duration analysis will be affected. Also, the share parameters could be wrong (we had concluded that risk of failure increases with time). Although heterogeneity can come from misspecification of functional forms, it can also occur due to unobserved variation between CSBs. A frailty model includes an additional multiplicative term, with assumed mean of 1 and constant variance estimated as theta from the data. When the estimated frailty is greater than 1, than the CSB (or group in Shared Frailty below) has an increased hazard and decreased probability of survival compared to the other CSBs (or groups in Shared Frailty below). A likelihood-ratio test that theta is equal to zero, indicating no heterogeneity, is preformed using the preferred log-normal model with a frailty distribution of gamma. No individual heterogeneity was detected; indicating that after controlling for observable differences in CSBs, no individual CSB experienced any increased or decreased hazard of failure.

Although heterogeneity has been controlled for between CSBs in our model, there still may be unexplained differences between the INTA administrative regions. Just as frailty models accounted for individual differences, shared frailty models account for differences in survival functions from unobserved factors. If we have not controlled for all of the differences between regions, once again our shape parameters and duration analysis results will be affected. We anticipate regional heterogeneity because of the unique seed production history of each region detailed in section 3 above. While including dummy variable for all but one of the regions controls for these differences through the fixed effects method, it is now necessary to test and adjust the models for the presence of heterogeneity.[9]

The results indicate that at an 8% confidence level we reject the null hypothesis that the shared heterogeneity parameter *theta* is equal to 0. The results with regional heterogeneity effects removed are presented in Table 4.4.

[9] Two alternative methods to remove the regional heterogeneity effects were considered. These alternatives were to stratify by region and to use VCE clusters by region. Only small changes in coefficients and significance levels were observed.

Table 4.4 Log Normal (AFT) Duration Analysis results with Heterogeneity Removed

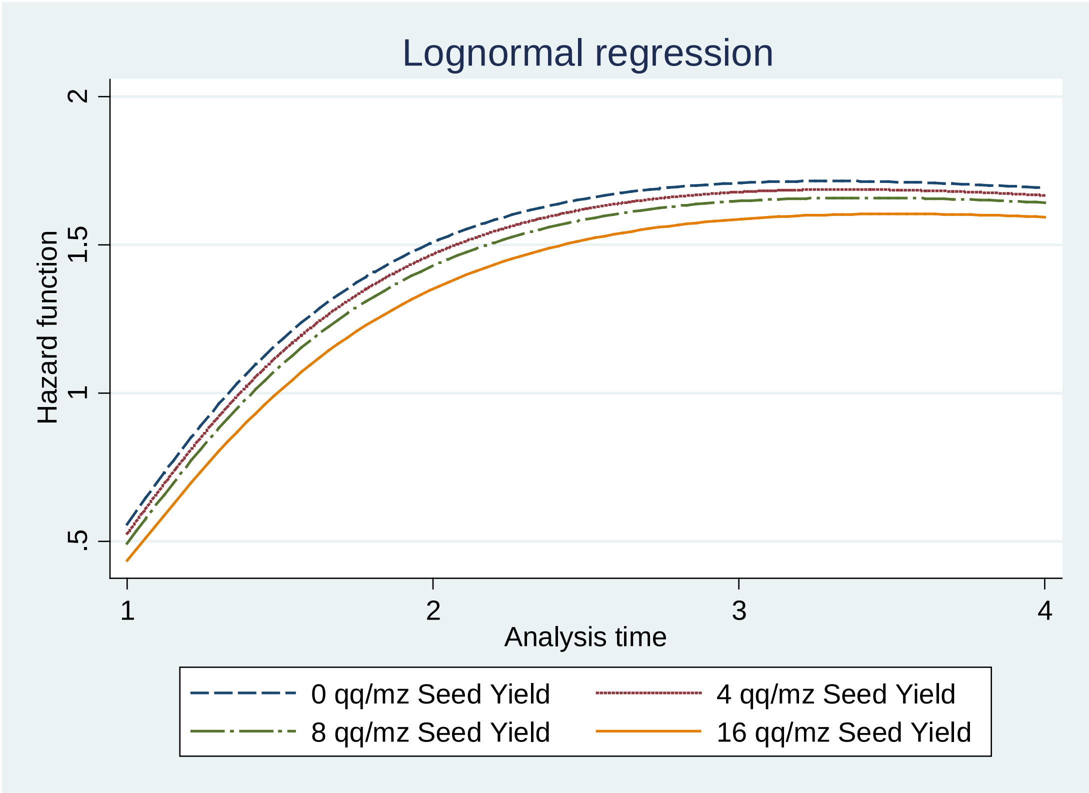
Variables	Coefficient		Std. Err.
1=Meeting minutes recorded	0.251	***	0.095
% CSB members with immediate family member in CSB	-0.231		0.143
Travel time to city in private car (minutes)	0.001		0.002
1=President's Age>30	0.420	***	0.160
1=President is male	0.248		0.216
1=CSB has Horse, Mule or Ox	0.186		0.227
Interaction President male and CSB has animal	-0.148		0.238
# of Years of President's Education	0.020	*	0.012
1=seed produced on CSB member land	-0.088		0.087
# of Silos	0.059	**	0.021
1=access to backpack sprayer	0.158	*	0.093
1=trained in CSB formation	-0.158		0.125
1=trained in seed marketing	0.258		0.191
Max Yield (yield potential) (qq/mz)	0.028	**	0.005
1=trained in seed marketing*yield	-0.022	**	0.010
# of beneficiaries/mz	-0.005	***	0.002
% of beneficiaries repaying 2x1 lbs	0.251	**	0.114
1=Parceled Bank	-0.109		0.107
1=Individual Bank	-0.290	*	0.164
Constant	-0.626	*	0.329
Shape Parameter	σ=0.390		0.029
Shared Frailty Parameter	θ=0.083		0.092
LR test of θ=0	χ2=2.02		p-val=0.077
Log likelihood	-78.230		
Restricted LL	-113.214		
Frailty Distribution	Gamma		
AIC	200.461		
BIC	267.274		

Note: ***, **, and * indicate significance levels of 1%, 5%, and 10% respectively

The results from Table 4.4 reveal that an additional beneficiary for a CSB producing seed on a plot of one manzana, and all else held equal, decrease the time to failure by 0.5%. As repayment compliance rates increase by 10%, time to failure is 2.5% longer. An additional silo delays time to failure by 5.9% while CSBs with presidents aged 31 and older survive 42% longer than CSBs with presidents aged 30 or younger. An additional year of CSB president's education decreases failure time by 2%. Individual banks fail 29 % faster than classic CSBs. CSBs that meet, and record meeting minutes survive 25% longer than CSBs that do not record meeting minutes. CSBs with access to a backpack sprayer survive 16% longer than those without the device.

The results indicate that a one unit (qq/mz) increase in yield for a CSB without marketing training and holding all else equal, will decrease failure time (and thus increase survival time) by 2.8%. The same one unit increase in yield for a CSB with marketing training and holding all else equal, will decrease failure time by 0.6%. The implication is best seen graphically in the figures below.

Figure 4.1: Hazard Functions of CSBs with Training at Four Seed Yield Levels



Figures 4.1, 4.2 and 4.3 show the hazard rates at four levels of seed yield (0 qq/mz, 4 qq/mz, 8 qq/mz and 16qq/mz) for CSBs trained (Figure 4.1) in seed marketing and CSBs without seed marketing training (Figure 4.2). When the eight hazard curves are plotted together in Figure 4.3, it becomes clear that CSBs with training have lower hazard curves than CSBs with the same level of yield but without training at levels of yield up to 15 qq/mz. The data from yield in year one of the BTD project reveals that 37% of the CSBs produced 8 qq/mz or less, 33% produced between 8 and 15 qq/mz, and 30% produced more than 15 qq/mz. Training reduces the variation in hazard functions and is clearly beneficial for CSBs with less than 15 qq/mz yield. Given the variation in seed production possible even with a package of technical inputs, seed marketing training is an important determinant of success of CSBs.

Figure 4.2: Hazard Functions of CSBs without Training at Four Seed Yield Levels

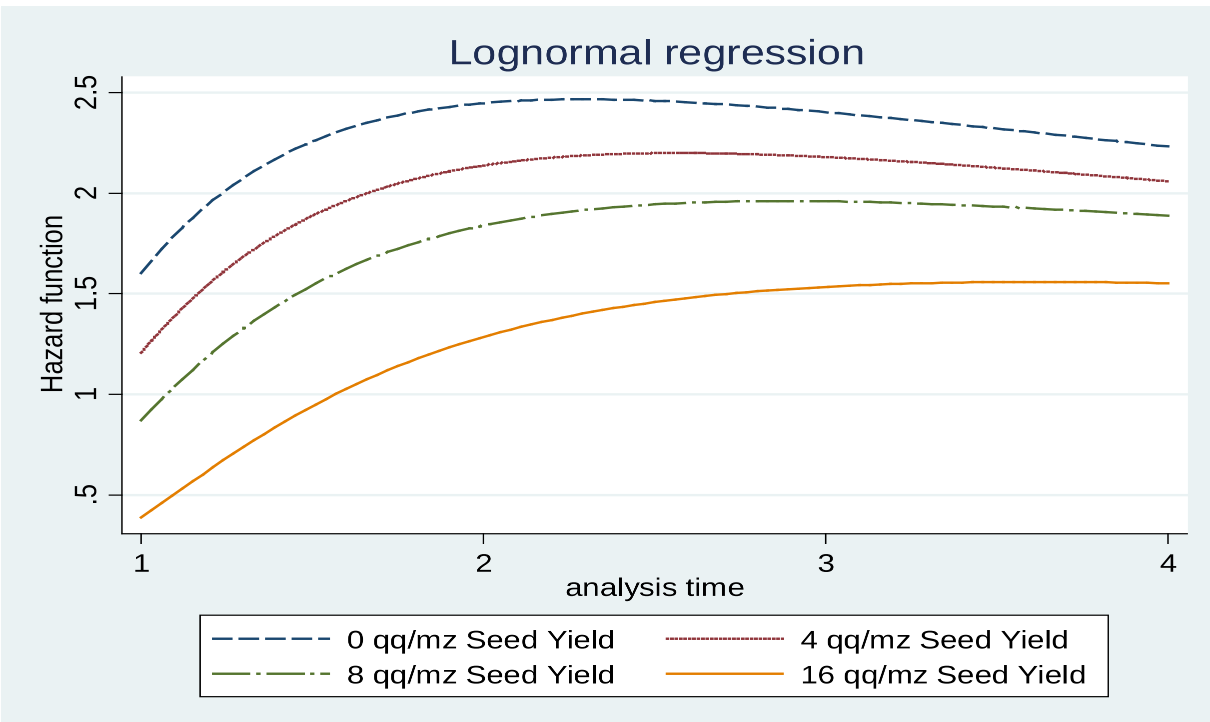
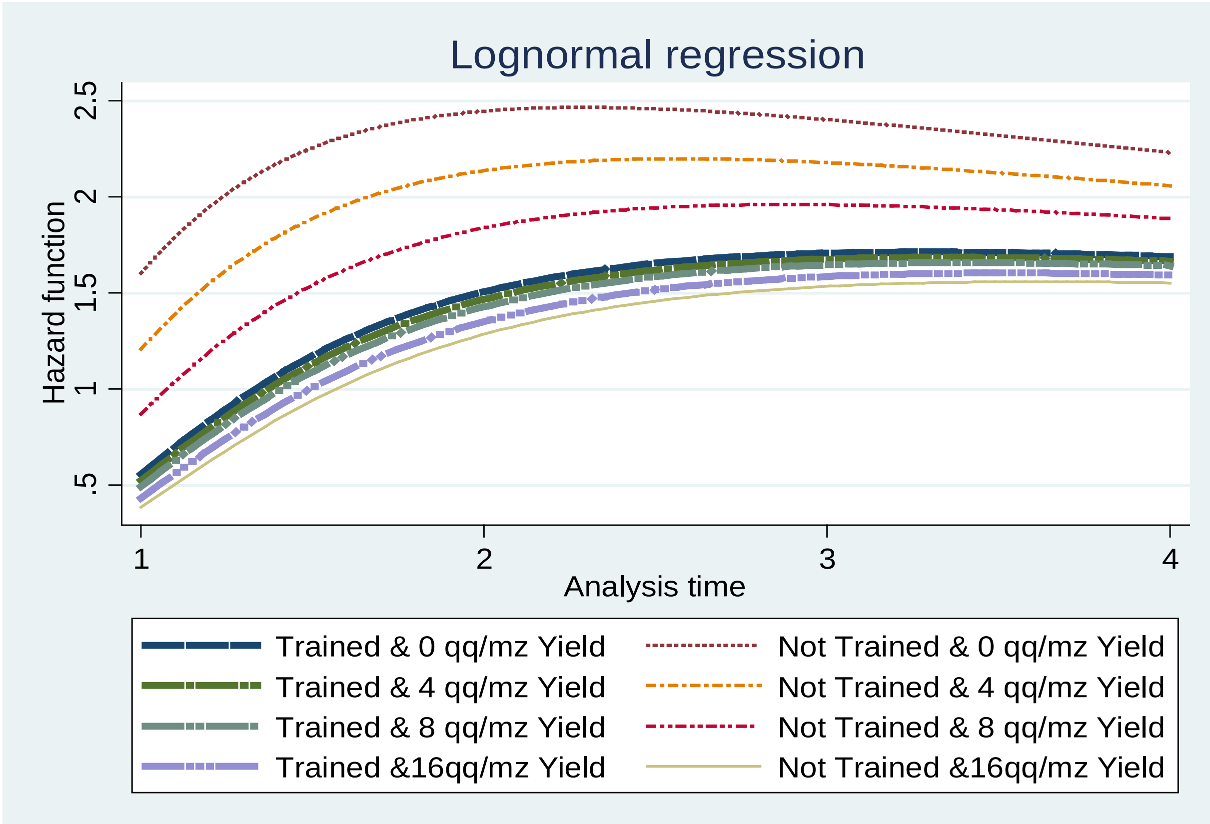


Figure 4.3: Hazard Functions of CSBs with and without Training at Four Seed Yield Levels



Additional Potential Source of Bias

Because continuation in the BTD program in each year is not only a CSB level decision but also decided by INTA's regional or national staff or the extension worker one could argue that survival in Year 4 was an exogenous decision of the CSBs based on funding at best but also potentially political connections. To ensure that inclusion of year 4 is actually modeling BTD participation or survival and not a decision of INTA staff, duration analysis of a truncated data set with the same number of observation but "failure" of the 17 CSBs that had previously survived until Year 4 occurring in Year 3 reveal small changes in the coefficient values but minimal changes in significance level. Additionally, when the 4^{th} year was included by right-censoring the 17 CSBs in year 3, similar results were obtained.

5. Conclusions

Eight main results are found from the duration analysis of the CSBs in Nicaragua. Each has implications for future iterations of CSB projects but also larger scale seed enterprises focusing on the production and distribution of improved variety of bean seed.

First of all, the analyses show that type of CSB does matter. Individual seed banks may provide a good contract farming option to NARS and extension programs for meeting project driven seed requirements, but based on the evidence from this study, they do not provide a sustainable model for a community based seed production system. Individual CSBs, as implemented in the BTD project, failed 29% faster than the classic CSBs. As against this, there was no statistically significant difference in the survival rate between the parceled and the classic CSB models.

Recording the minutes of the meeting is found to be one of the determinants of sustainability and indicates the importance of formality of operations and documenting decisions within community groups in the longevity of community based seed organizations. Evaluating the hazard functions of parceled and classic CSBs (similar to Figure 5.4 below) indicate that the importance of recording meeting minutes was the same for both types of CSBs.

A second finding is that training on seed marketing is a determinant of CSB sustainability. As Witcombe et al. (2010) found in Nepal, marketing training was necessary to build demand, establish partnerships and ultimately self-finance improved variety seed production. The results from the CSBs in Nicaragua suggest that in the first years of seed production, the impact of training is noted through an interaction term with yield as shown in Figure 4.3 above.

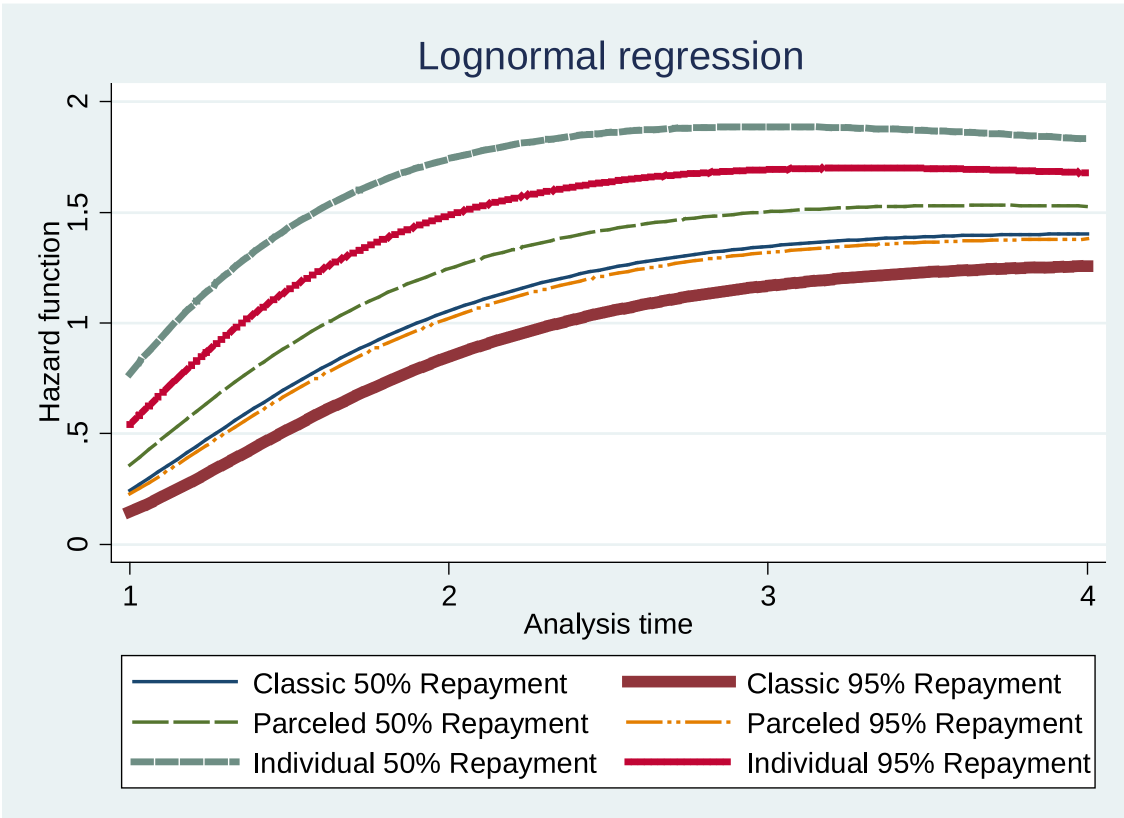
Hand in hand with marketing seed is providing the variety demanded by the community. The results from this study suggest that providing the demanded variety had no effect on sustainability. These results are expected to be different in the long run as CSBs that do not offer varieties that are demanded will not be able to generate revenue due to lack of sales. In the context of the BTD project, however, the CSBs changed the seed varieties available to farmers and a subsequent change in demand is expected. Calculations by the authors from the survey data of beneficiary farmers of the BTD project (Maredia et al. 2014) found that 85% of the CSB seed recipients had not previously used the variety they received[10]. It is not surprising, therefore, that failure rates were the same for CSBs that did and did not supply a variety demanded in their communities.

Third, cost recovery is often mentioned in the literature as necessary for sustainability. Two necessary business skills of CSBs offering seed purchase through loans to farmers is to judge the probability of repayment of each farmer at the moment of seed lending and successful reduction of seed loan delinquency through loan collection. Plotted for each type of CSB in Figure 5.4 are the hazard functions at 50% repayment and 95% repayment. The hazard function curves of all three CSB models shifted down proportionally with the increase in repayment rate from 50% to 95%. While the time to failure of parceled and classic CSBs where not statistically different as indicated in the results in Table 4.4, the difference is noted by comparing the two types of seed bank at the same repayment level. The classic CSBs have lower hazard function curves than parceled CSBs. In fact, the parceled CSBs needed a repayment rate of 95% to have a

[10] Just less than 85% of farmers receiving INTA Rojo, 72% receiving INTA Matagalpa and 96% of farmers receiving INTA Sequia reported planting the variety for the first time in 2011 or 2012 (Author's calculation).

lower hazard function curve than the classic CSBs with a repayment rate of 50% holding all else equal.

Figure 5.4: Hazard Functions at two Repayment Rates by Type of CSB



While increases in loan repayment rate have a positive relationship with sustainability, the number of clients (per unit area of seed production) had a negative effect on sustainability. The results indicate that CSBs face increased risk of failure when they lend seed to more farmers per unit of operation (i.e., when the intensity of seed operation is very high). The faster time-to-failure of CSBs with more clients per unit of land used for seed production indicates operational deficiencies and diminishing capacity of CSBs to manage a large number of clients. This result again emphasizes the importance of seed marketing training as well as training in business operations to increase the operational efficiencies of CSBs and their survival rates.

Fourth, quality of seed produced is important for CSB longevity. Only a subset of the CSBs provided seed quality data, but the results indicate a positive relationship between the CSBs that received positive and survival compared to CSBs that received mixed or negative feedback.

Fifth, number of silos is an important determinant of CSB sustainability. On average CSBs had just over 2 silos but only 38% of CSBs received silos in the first year of the BTD project. Although transportation of silos to remote communities might present considerable challenges when roads are in poor condition or do not exist in mountain communities, silos are a necessary asset for seed producing organizations and efforts to coordinate their delivery are rewarded in the form of longer time to failure in CSBs.

Sixth, CSBs with high concentrations of immediate family members (defined here as parents, children or siblings) had higher hazard ratios than CSBs with few or no immediate relatives in the Weibull proportional hazards models. Although no effect was found in the final heterogeneity removed model, efforts should be made to form CSBs that are more representative of the community by including members from different families rather than more members from a few families. This will increase the stakeholder base within a CSB, which can increase the community support as the bank will be viewed as an equitable source of seed for the entire community. The impact of extended family members (cousins, uncles and aunts, nieces and nephews) on sustainability was non-significant in all models indicating that in a village community where such relationships are likely to exist and perhaps unavoidable, this should not be a source of concern when forming a CSB.

Seventh, experienced leaders are an important determinant of survival. As stated earlier, age is often associated with experience and for the CSBs in the BTD project with presidents older than 30 year of age, failure occurred 33% later in time than CSBs lead by younger presidents. When plotted to compare differences in types of CSBs (similar to Figure 4.4), the effect of president's age had the same effect on all three types of CSBs. No effect was found for the age of the promoters, indicating that youth leadership in seed production and implementation of new technologies can be as effective as their older peers and should not be discouraged.

Female headed CSBs face additional challenges. Although no difference was found in the final model, there was evidence in earlier (albeit less robust models) that female led CSBs have higher failure rates and can benefit more from transportation assets. While this finding should not discourage policymakers implementing a project like BTD from including female leadership, it should be considered in the planning process, and efforts should be made to facilitate access to readily available and appropriate transportation and other assets. The identification of needed assets and their acquisition methods (i.e., renting, cash purchase and financing the purchase) should form part of the initial training.

Finally, a comprehensive needs assessment by extension worker or supervision staff should precede the implementation of project supported CSBs. Evidence of the importance of liquidity and access to (or ownership of) assets such as backpack sprayers and silos was found to be significant in the final model. Additionally, yield was a determinant of sustainability and thus liquidity to purchase inputs at the onset of disease or presence of pests to prevent crop failure should be a consideration to increase the viability and sustainability of a CSB.

The FAO-PESA (2011) guide to CSBs did not consider access to productive assets and financial services as important for choosing a community suitable for a CSB. The PESA guide lists the opposite as a community level condition for implementing a CSB in a given community as it should have little or no technical and financial assistance from other organizations. While the goal of reaching the most needed communities is noble (and demand for quality seed may be highest in such communities), project budgets will need to include purchase of such productive assets when they are not accessible in the community.

In conclusion, the results confirm much of the literature regarding factors contributing to the sustainability of community based seed production including the importance of training (seed marketing and business skills), ownership of productive asset (especially silos), experience of leadership, cost recovery, quality and quantity of seed produced, and operational formality in the form of conducting meetings and documenting decisions made at meetings with minutes. The two communal CSBs, supported during the BTD project, provided a production and delivery model that lasted longer than individual banks. The policy implication of these results is that CSBs present a more sustainable dissemination channel of improved variety seed to farmers than small scale contract-based seed production by individual farmers.

There remain several opportunities for future research on CSBs. First of all, a follow up survey and interviews with the leaders of the 154 CSBs included in this study and the INTA technicians and regional/national staff involved in the promotion of CSBs in Nicaragua can provide many missing pieces of information to explain the factors that went into their decision to continue and/or discontinue a CSB beyond project support. Secondly, reliable production cost data has been difficult to obtain despite efforts by the author and others. A study of community based seed production costs similar to Katungi et al. (2011) that value all aspects of seed production of *Apta* seed (i.e., QDS) in Nicaragua is needed to obtain a clear picture of the benefits to the CSB members and community as a whole. Finally, better knowledge of the determinants of purchase of replacement seed is needed to understand demand. While lack of access and affordability are often cited as the reason for low use of improved varieties, farmers that have technical training in bean grain production and increased resources from grain sales still have low rates of improved variety use in Nicaragua (Sain 2011, Carter et al. 2012). The literature is replete with studies that look at determinants of adoption of improved varieties (or decision to replace traditional/local varieties with new/modern varieties) (Feder et al. 1985, Mwangi et al. 2015). However, similar studies are needed to understand determinants of farmer behavior regarding replacement seeds post-adoption. Such information can help guide researchers, extension agents, policy makers and NGOs to better design sustainable seed production and distribution models in a developing country context such as Nicaragua.

Finally, it is important to identify the limitation to this study. Only the CSBs established in the first year of the BTD project that responded to the survey were considered for this study due to the data collection process. A more robust analysis would include the CSBs that began in the second and third year of the BTD project as well. Additionally, this study ended tracking the CSBs at the end of the BTD project in 2014. INTA employees insist that some CSBs continued to operate with or without external support after 2014. Information about all of the CSBs' survival or status in years following the BTD project was not available to include in this study. Had this information been readily available, it would provide valuable additional information regarding CSBs sustainability beyond the years of the BTD project. Given these limitations, the results and conclusions of this study should be used in the context of survival of a CSB within the BTD project timeframe only.

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