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Farmer-led Seed Enterprise Initiatives to Access Certified Seed for Traditional African Vegetables and its Effect on Incomes in Tanzania

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Abstract

Farmers need access to certified seed stocks for efficient production of traditional African vegetable seed. However, access to quality certified seed is constrained by several factors. Primary data from four selected regions of Tanzania was analyzed to examine the causal linkages among traditional African vegetable farmers' decisions to participate in farmer-led seed enterprises and their access to quality certified seeds. The effect of farmers' access to certified traditional African vegetable seed on revenue generated from their seed sales in the study locale was assessed. This study concludes that farmers' revenue from traditional vegetable seed sales is positively and significantly influenced by access to certified seed. Indeed, access to certified seed can be increased, if farmers participate in farmer-led seed enterprises, and if they have more frequent contact with village extensionists. Relevant policy actions and recommendations for improving farmer-led seed enterprises are offered.

Keywords: smallholder market participation, traditional African vegetables, African indigenous vegetables, contract farming, quality declared seed, certified seeds

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Introduction

In most Sub-Saharan African countries, diets of African consumers are often deficient in essential micronutrients and vitamins, resulting in widespread malnutrition. Increasing consumption of traditional African vegetables such as amaranth (*Amaranthus* spp.), African eggplant (*S. aethiopicum, S. anguivi* and *S. macrocarpon*), African nightshade (*Solanaceae*), and jute mallow (*Corchorus* spp.) ensures staple-based diets are balanced and provide both food and nutrition security (Yang et al. 2009; Keatinge et al. 2011; Afari-Sefa et al. 2012; Keding et al. 2012; Keatinge et al. 2015). In recent years, the demand for traditional African vegetables has increased but limited availability and accessibility of quality seeds of preferred varieties has constrained the ability of farmers to deliver improved produce to consumers (Afari-Sefa et al. 2013). Most vegetable producers are thus seed-insecure (McGuire and Sperling 2011). Most traditional vegetable species are open-pollinated and farmers can easily save seed over many seasons, thereby discouraging commercial investment in seed production (Karanja et al. 2013). There are several other reasons why farmers utilize poor quality vegetable seed in their fields. These include lack of information about quality seed production methods, lack of availability of improved varieties of seeds, lack of updated market information and support systems, and lack of credit to purchase farm inputs. Poor infrastructure raises the cost of inputs and lowers revenue from crop sales (Daniel and Adetumbi 2004; Ellis-Jones et al. 2008; Thomas et al. 2008; Minot 2011).

Good quality certified seed enhances crop yields and their subsequent contribution to food security, the value of the product in the market, and economic growth (Lanteri and Quagliotti 1997; Daniel and Adetumbi 2004; Toenniessen et al. 2008; Louwaars and De Boef 2012; Keatinge et al. 2015). Increasing smallholder access to good quality inputs is often desirable for addressing yield gaps and increasing output, as most farmers would otherwise resort to using farmer-saved seed (Gildemacher et al. 2011). To improve the accessibility of certified seed from formal seed markets, some studies have proposed that national seed regulatory agencies shift their role from direct supervision of seed production toward technical and policy support for the development of a wider range of seed provision options (Tripp 1997; Tripp and Rohrbach 2001). In addition to the urgent need for seed policy reforms, Daniel and Adetumbi (2004) suggest that vegetable seed supply systems can be improved when breeders and seed producers regularly assess consumers' preferences and factor them into their participatory breeding and seed supply systems. Almekinders et al. (1994) identified the potential of local informal seed markets for improved seed supplies in developing countries when they are properly integrated with the formal sector.

David (2004) argues that farmer-led seed enterprises might offer a sustainable solution to accessibility of good quality and certified seed, but scaling up this approach in Eastern and Southern Africa remains a challenging task. However, in Tanzania, Afari-Sefa et al. (2013) found that community seed producers have a lower average input cost and higher returns than contract seed growers, and note that seed companies operate in a dynamic business environment and have profit-oriented motives that might contravene development objectives. The authors investigated two farmer-led seed enterprise models (FLSE) namely, contract seed production with private seed companies (formal seed system) and the community-led Quality Declared Seed (QDS) production systems (semi-formal system). The QDS system is regarded as an improved

alternative seed supply system that caters for regional specific varietal preferences and provide opportunities for establishing linkages with formal institutions to produce good quality seed and meet farmers' complex and diverse seed requirements. However, the authors suggested that because the majority of farmers obtain seed from informal sources, strengthening informal seed production systems by integrating them with semi-formal and formal seed systems must be seen as an urgent priority if the supply-side bottleneck is to be successfully addressed.

In the 1980s, many African farmers obtained their inputs and agricultural credit from semi-formal markets or state-owned commodity marketing boards, but these have failed to deliver good quality inputs and services mostly due to inefficiency in delivery systems. Therefore, during the 1990s several African countries including Tanzania liberalized their seed markets. In East Africa, the liberalized seed trade primarily benefited commercial staple crops such as maize; additional investment was required to develop seed markets for other crops (Rohrbach et al. 2003). In countries across the region, particularly Tanzania, many traditional African vegetables are well-adapted to local agroclimatic conditions and are highly valued in local markets. However, the informal markets and networks that smallholders rely on to obtain seed of these crops typically fail to provide reliable, good quality cultivars (Karanja et al. 2013). Ellis-Jones et al. (2008) estimated that 70-75 percent of traditional vegetable seeds come from the informal sector, whereas the semi-formal and formal seed sector together constitute 25-30 percent. Weinberger and Msuya (2004) estimated that the share of traditional vegetable seed sold in the formal market is about 10 percent, with about 15 hectares under formal seed production. Informal seed markets thus play a vital role in the buying and selling of vegetable seed. The Tanzanian government is trying to improve the efficiency of the vegetable seed value chain through semi-formal and formal seed markets via various policy reforms. Yet formal markets are an increasingly important source for affordable certified quality seed and other input services in Tanzania (World Bank 2012).

Many studies (e.g. Shiferaw et al. 2008; Alene et al. 2008; Asfaw et al. 2012) have analyzed the causal linkages between adoption of improved seed varieties and machinery as well as the economic benefits attained from adopting improved seed varieties in sub-Saharan African countries. The conclusion of these studies is that adopting improved or certified seed varieties has contributed to the welfare of rural households. Some studies (e.g. Fischer and Qaim 2012; Boniphace et al. 2014) identified factors that constrain farmers' decisions to participate in seed markets. The authors conclude that transaction costs incurred by farmers when seeking price information and during produce sale transactions influence their decisions to participate in viable markets. Not surprisingly, the studies highlighted above focus mainly on cereals and pulses. Several other studies (Weinberger and Msuya 2004; Ellis-Jones et al. 2008; World Bank 2012; Karanja et al. 2013; Afari-Sefa et al. 2012; Afari-Sefa et al. 2013) analyzed the performance of vegetable seed markets and policy reforms in East Africa. However, there has been limited research to explicitly examine the causal linkages among farmers' access to certified traditional African vegetable seed and the revenue generated from their seed sales.

This study aims to (i) examine the causal linkages among farmers' decisions to participate in farmer-led seed enterprises and farmers' access to certified traditional African vegetable seed within four regions of Tanzania, and (ii) measure the effect of accessibility of certified traditional African vegetables on revenue generated from the traditional African vegetable seed sales in

Tanzania. The research questions underlying our study include: Do farmers' decisions to participate in farmer-led seed enterprises improve accessibility to certified traditional African vegetable seed? Does increased accessibility to certified seed lead to increases in revenue from seed sales? These hypotheses were tested using an endogenous treatment effect model complemented by a two-stage instrumental variable model, both of which are explained in more detail in the econometric framework of the methods section.

Seed Policies and Regulations in Tanzania

Following the liberalization of seed trade in the late 1990s, Tanzania introduced several policies and regulations to improve quality certified seed supply and distribution systems, and the production and marketing of crops including: Plant Protection Act of 1997, Plant Breeders Act 2002, Seed Act 2003, Seed Regulation 2007, Protection of New Plant Varieties (Plant Breeders' Rights) Regulations (2008). Despite the modest achievements gained from these policies and regulatory acts, explicit variety release requirements and procedures, seed certification standards, and conditions for import and export of vegetable seeds remain largely unclear. The regulations do not clearly differentiate between seed of staple crops and those of horticultural crops, especially vegetables. In the guidelines and procedures, priority is given to staple crops rather than vegetables. However, a concerted advocacy effort by AVRDC – The World Vegetable Center and its national partners to increase awareness of the value of traditional vegetable crops among government regulators resulted in the release for the first time in 2010 of seven new varieties of traditional vegetables in Tanzania (AVRDC 2011, Afari-Sefa et al. 2012).

To improve seed quality and a more secure seed supply in deficit areas, the Tanzanian government introduced the Quality Declared Seed (QDS) program, which was developed by the Food and Agriculture Organization of the United Nations (Food and Agriculture Organization 2004). The objective of the QDS program is to improve the availability of quality seed to farmers in seed deficit areas such as Central Tanzania. Most of the country's private seed companies operate from northern Tanzania, a considerable distance from potential customers located in central Tanzania; thus, they seldom can deliver seed in a timely manner. The QDS functions most effectively where formal seed markets are not active and government resources are too limited to reach target farmers.

As a part of the seed regulatory process, the government has established an independent institute known as the Tanzania Official Seed Certification Institute (TOSCI) to regulate seed businesses in accordance with the Seed Act of 2003. TOSCI certifies seed of registered cultivars for official trading in Tanzania. There are three major steps involved in producing certified seed: technical, administrative, and legislative. The technical aspect requires cultivars to be registered according to relevant eligibility criteria. New cultivars must then undergo National Performance Trials (NPT) and certain tests to release new varieties, namely Distinctness, Uniformity and Stability (DUS) to demonstrate that the new variety adds value in terms of productivity, adaptability and tolerance/resistance to pests and diseases. Administrative steps include registration of seed growers, applications and certification services, and monitoring of seed trading. TOSCI follows legislative guidelines to complete the first two steps (Afari-Sefa et al. 2013).

The Tanzanian government has established an independent body called the Agricultural Seed Agency (ASA) with the key mandate of promoting the use of improved seed as well as promoting private sector participation in seed production, processing and marketing. Although ASA encounters logistical and resource bottlenecks, its policies and regulations have changed the seed production and marketing system in Tanzania (Ministry of Agriculture and Co-operatives 1997). Despite the improved policies and interventions to address spatial and time gaps in its seed supply system the country is still beleaguered by low production and productivity of vegetables. This is due to limited use of inorganic fertilizers, quality seed, and pesticides; inefficient input distribution systems; poor infrastructure facilities; and climate change (Rohrbach et al. 2002).

Vegetable Seed Systems in Tanzania

A seed system is defined as "an interrelated set of components including breeding, management, replacement and distribution of seeds" (Maredia et al. 1997; Thiele 1999). Vegetable breeding is mainly done at the Horticultural Training and Research Institute, Tengeru (HORTI-Tengeru) and to some extent at Sokoine University of Agriculture and other agricultural research institutes. Due to the lack of research investment, no breeding programs are currently underway at HORTI-Tengeru. Therefore, AVRDC – The World Vegetable Center Eastern and Southern Africa, based in Arusha, Tanzania, contributes by breeding improved cultivars of global and African traditional vegetables to suit farmers' needs and consumers' preferences. Although AVRDC provides germplasm and the requisite plant breeding and seed production expertise, HORTI-Tengeru is the most active participant in the varietal release process for all public cultivars. Several private companies are involved in varietal development and release, albeit with a strong focus on hybrids; these companies need to emphasize exclusivity in plant varietal protection rights to ensure they can re-coup their investments and accrue profits (Nazeem et al. 2010).

AVRDC develops new vegetable lines and releases the lines as varieties in collaboration with public sector partners such as HORTI-Tengeru in Tanzania (Afari-Sefa et al. 2013; Dinssa et al. 2015). AVRDC researchers multiply and maintain breeder seed[1], which is then sent to the Agricultural Seed Agency (ASA), an independent public entity, for further multiplication and preparation of foundation seed[2] for distribution to private seed companies. Private seed companies in turn multiply the foundation seed to obtain commercial certified seed for sale to farmers in domestic, regional and international markets. As of January 2015, there were 23 seed companies procuring foundation seed of different crops (including vegetables) from ASA[3], most through contracts with farmers. To increase timely access to adequate foundation seed for the production of certified seed by the private sector, AVRDC introduced an online ordering

[1] Breeder seed is defined as "Seed that is produced by a breeding unit in small quantities for multiplication to reach the desired volumes for sale to farmers" (Minot et al. 2007)

[2] Foundation seed is defined as "seed produced by a public or private enterprise mandated multiplication unit, technically one breeding generation after breeder seed". It requires subsequent multiplication by private seed companies before being sold to farmers as formal certified seed (Minot et al. 2007). In Tanzania, ASA has the national mandate for providing foundation seed of publicly released and maintained varieties to private seed companies.

[3] List of 23 companies received from ASA, Morogoro, Tanzania

platform, "VegOneX" in May 2015 (http://asa.worldveg.org/). Seven companies have registered to use VegOneX and now order foundation seed from ASA through this platform.

In areas where private companies are not able to provide seed to farmers in a timely manner, ASA produces commercial seed that is sold directly to stockists and to seed growers as certified seed. Farmers may receive seed from other farmers through exchange or seeds saved from their own fields. Some farmers receive seed from nongovernmental organizations as part of development project or via emergency aid relief. Within the seed supply and distribution system, TOSCI has authorized district inspectors who handle quality control for all actors/stakeholders involved in the supply chain system.

Materials and Methods

Study Sites

A survey of ninety farm households that cultivate traditional African vegetables for seed production were selected in four administrative regions of Tanzania: Arusha, Tanga, Morogoro, and Dodoma (Figure 1). The survey was conducted between January and May 2013. Study regions, districts, wards, and villages were selected using a multistage procedure based on a combination of project deliverable requirements, the importance and volume of traditional vegetable produced in various wards and villages, the extent of market access, and interviews with key informants and officials from the Ministry of Agriculture.

The Arusha region falls under the Northern Highlands agroclimatic zone with an altitude of 1400 m and experiences bimodal rainfall of 760–1200 mm per annum (usually from October-December and March–May). The temperature in Arusha region varies between 5–30 ^{o}C. The Tanga region (Lushoto district) is located within the Western Usambaras, with an altitude ranging from 1000–2100 m, characterized by steep slopes and narrow valleys (Vainio-Mattila 2000) with a relatively high population density of 210 persons/km of agricultural land. Land use is a combination of traditional subsistence farming and modern cash crop production.

Subsistence crops such as maize, field beans, bananas, cassava and sweet potatoes are grown on hillsides, while vegetables are mostly grown in valley bottoms (Vainio-Mattila, 2000). Compared to most other agroclimatic zones of the country, the Lushoto study site enjoys a relatively cool climate with temperatures ranging from 18-23 ^{o}C, with the maximum occurring in March and minimum in July, and high rainfall of 600–2000 mm per annum. The area is characterized by high rainfall variability. The Morogoro region has a coastal climate with temperatures ranging from a minimum of 19 ^{o}C to maximum of 30 ^{o}C, mean annual precipitation of 854 mm, and an altitude of 366–549 m. The Dodoma region study site in central Tanzania has a semi-arid (savanna) type of climate with a unimodal rainfall regime of 500-700 mm per annum, usually starting as early as mid-November in some places and ending around mi-May, followed by a long dry season (Stigter et al. 2005). The rainfall is relatively low in amount and rather unpredictable in frequency. The unreliability of rainfall in these regions imposes a pattern of risk aversion in traditional farming. During the long dry season, persistent desiccating winds and low humidity contribute to high evapotranspiration and soil erosion (Afari-Sefa et al. 2015).

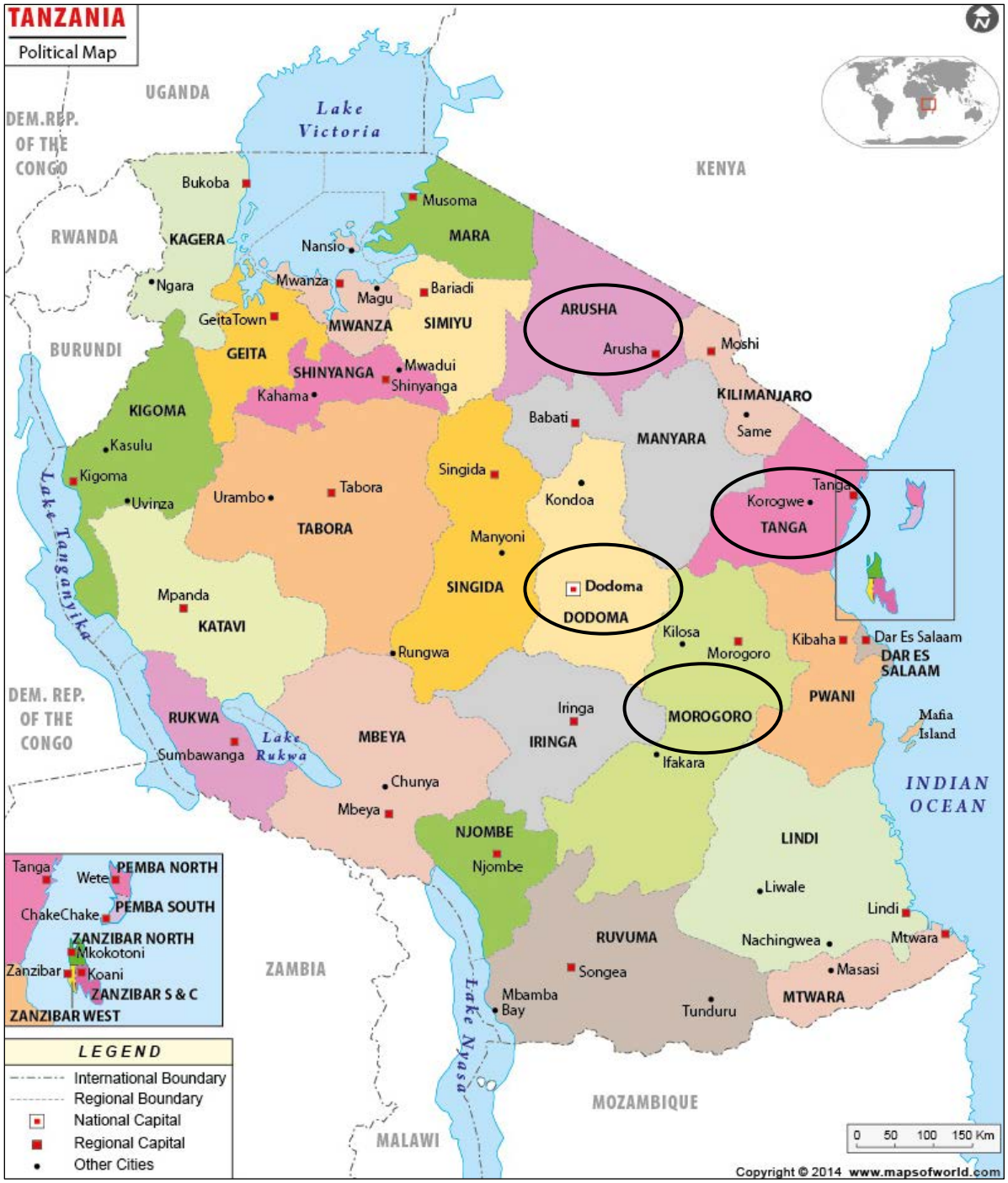

Figure 1. Survey regions cultivating traditional African vegetables for seed production include: Tanzania: Arusha, Tanga, Morogoro, and Dodoma.

Study Approach and Data

The primary survey was undertaken in three stages: pre-pilot, pilot, and main survey. In the pre-pilot survey, the survey team met with several clusters of farmers to learn about their agricultural activities. Based on the pre-pilot survey, a structured questionnaire was developed and pre-tested with a few farmers selected for the pilot survey. The questionnaire was then revised and

implemented for the main survey from March-May 2015. For the main survey, 90 sampled farm households were selected for one-on-one interviews with the guidance of village executives, extension officers, and local opinion leaders. The 12-month cropping year reference period for primary data collection was from March 2012 to February 2013.

Econometric Model

A household's vegetable seed income can be modeled as a sequential decision. Typically, a household first decides to choose a treatment (accessibility of certified vegetable seeds) which then endogenously impacts on its outcome (vegetable seed income). The decision on the household's accessibility of certified seed is endogenous in the sense that there might be some unobserved characteristics that influence both the accessibility of certified vegetable seed and vegetable seed income. This implies that ordinary least-squares regression cannot identify the average treatment effect, and hence an alternative and more robust identification strategy should be employed. To control for endogenous sample selection bias, this study adopted a standard treatment effect model from the causal modelling literature in econometrics (Heckman 1979, Maddala 1983). To validate the robustness of the treatment effect model while complementing the ensuing results, we also estimated a two-stage or extended Instrumental Variable (IV) model. To this end, a household's decision on accessibility of certified seed can be denoted as an unobserved latent variable such that:

$$P_i^* = \delta_0 + \delta_1 X_i + \delta_2 Z_i + u_i \text{ where the observed decision is}$$

$$(1) \quad P_i = \begin{cases} 1 \text{ if } P_i^* > 0 \\ 0, \text{ otherwise} \end{cases}$$

The farm household then chooses to have better accessibility of certified vegetable seeds in terms of timely availability, with lower prices if $P_i^* > 0$ where X_i and Z_i are exogenous covariates and u_i is random error term. The outcome of interest equation is written as

$$(2) \quad Y_i = \beta_0 + \beta_1 P_i + \beta_2 X_i + \varepsilon_i$$

where P_i is a dummy variable indicating whether or not a household have better and timely access to certified vegetable seeds at lower prices[4]. Thus we have a continuous outcome variable (vegetable crop income) and a limited dependent binary treatment variable (accessibility of certified vegetable seeds). Consistent with addressing variable endogeneity issues, we suppose that u_i and ε_i are correlated. To jointly estimate (1) and (2), we then assume two errors follow the bivariate normal distribution.

The estimation of the two step model under the bivariate normality assumption, proceeds as follows:

[4] Farmers were asked three questions: (i) Do you encounter any bottlenecks in the timely availability of certified seed? (ii) Do you encounter any bottlenecks in obtaining quality seed? and (iii) Do you have any concerns regarding the price of seed? If the farmer reported for all questions that they did not experience any bottlenecks for accessing certified under these constraints, then it is recorded as 1, otherwise 0.

a. Estimate a Probit regression of P_i on X_i and Z_i.
b. Use the fitted model to calculate the predicted Inverse Mill's Ratios. For participants this would be $\hat{\lambda}_i = \frac{-\phi(\hat{\delta}_0 + \hat{\delta}_1 X_i + \hat{\delta}_2 Z_i)}{\Phi(\hat{\delta}_0 + \hat{\delta}_1 X_i + \hat{\delta}_2 Z_i)}$ where $\phi(.)$ is the standard normal density and $\Phi(.)$ is the standard normal cumulative density.
c. Regress Y_i on P_i , X_i and $\hat{\lambda}_i$.

The two-step estimator was implemented in STATA Software Package. A significant coefficient of Inverse Mill's Ratio would imply that the error terms are correlated.

Y_i is the revenue generated from the vegetables by a household as a dependent variable, which is a continuous outcome variable in the endogenous treatment effect model.

The effect of accessibility of certified vegetable seed (treatment variable) on vegetable seed income (outcome variable) was measured by the endogenous treatment effect model. The first step involves measuring the casual linkages between respondents' participation in farmer-led seed enterprises and accessibility of certified vegetable seed. The second step measures the effect of accessibility of certified vegetable seed (treatment variable) and vegetable seed income along with other explanatory variables.

Two explanatory variables—gender and age of the household head—affected both the treatment variable and outcome variable. Afari-Sefa et al. (2012) highlighted that when farmers participate in farmer-led seed enterprises, they have better access to certified quality seed, thereby improving their crop income. Other studies (Almekinders et al. 1994; World Bank 2012) also observed that the formal seed marketing system can provide better access to certified seed in many developing countries. Batt (2008) argues that receiving frequent extension services influences farmers' access to certified seed. Therefore, this study included two explanatory variables that might influence the treatment variable: farmers' participation in farmer-led seed enterprises and farmers' frequent contacts with village extension workers.

Other variables that directly influenced the outcome variable in our model were net cultivated area and irrigated area. Rajendran et al. (2015) argued that net cultivated area represents total area under irrigation and unirrigated land, which explains farm size as well. It implies that the larger the farm size, the greater the opportunity to apply new technologies and have a better output value. The implication is that medium and large farms derive more gains from application of more capital than do small farms, and also depend on the possibility of a larger share of irrigated land to total land size. Based on a household survey from five administrative regions in Tanzania, irrigated land area influences output value, particularly the value of vegetable production; hence, the inclusion of irrigated area as an independent variable is required.

Accessibility of credit by farmers also influences farmers' crop income (Diagne and Zeller 2001). In our study, this variable was measured as a dummy variable, where farmers receiving credit for their agricultural activities are assigned a value of 1, otherwise zero. As a complement to the endogenous treatment effect model, this study also estimated an extended Instrumental Variable (IV) model to account for the possibility of inconsistent parameter estimation due to endogenous regressors in the main treatment effect model. In the IV model, individual characteristics such as head of household, collective household characteristics such as family

size, accessibility of credit by farmers, and agricultural characteristics including irrigated area under cultivation are exogenous regressors or instruments. Farmers' participation in farmer-led enterprises is an excluded instrument or exogenous variable excluded from the regression. Accessibility of certified seeds is an endogenous regressor that is being instrumented.

Results and Discussion

It is important to understand the number of sales transactions through various types of seed distribution channels existing across the different farm size categories and regions. Farm size was categorized as marginal, small-, medium- and large-scale farmers. Smallholder farmers were defined as marginal and small-scale farmers that own or/and cultivate less than 2.0 hectare of land. Medium-scale farmers were defined as farmers that own or/and cultivate between two and four hectares of land. Large-scale farmers were defined as farmers that own or/and cultivate more than four hectares of land.

Marginal, small- and medium-scale farmers constituted 96% of the sample (Table 1). Out of the 90 farm households surveyed, 15% and 33% were engaged in contract farming and QDS systems, respectively, while 52%, including smallholders, sold their seed through the informal system. The high percentage of smallholders selling seed through semi-formal and formal systems may indicate a preference for low risk factors associated with formal sub-sector arrangements compared with the informal seed marketing system. This indicates that the share of seed sold through the informal system is larger than the semi-formal and formal marketing systems in the study region, which validates the findings of Wekundah (2012) and Shiferaw et al. (2008).

Within the Arusha region, it was observed that although almost all types of seed marketing channels exist, the major seed distribution channel was through contract farming. The survey results show all respondents in Dodoma region produce and sell their seeds under the QDS system. In Tanga and Morogoro regions, only the informal seed marketing system was active. This reflects the comparative advantage Arusha has over other regions in Tanzania in attracting private seed companies.

Table 1 shows the share of sales transactions by farm size, regions for each seed marketing channel (column percentage); and shares of sales transaction by marketing channels under each farm size category and regions (row percentage).

Table 2 provides details of land ownership and cultivated area for all crops and vegetable seed by farm size under identified marketing channels. Small and medium farm categories accounted for most of the land volume (61%), which indicates that small- and medium-scale farmers play an important role in seed production. In the contract farming system, there is little difference between net operated and net irrigated area, which indicates that contract companies prefer farmers who have irrigation facilities to grow their crops.

Table 1. Farms by Size, Marketing Channel and Region

By Farm Size Category	No of HH*	Formal system (Contract grower)	Semi-formal system (QDS)	Informal system (Farm-saved seed)	Overall (% of HH*)
Marginal farm (0> to 1 ha)	24	31 (17)	27 (33)	26 (50)	27 (100)
Small farm (>1 to 2 ha)	32	38 (16)	27 (25)	40 (59)	36 (100)
Medium farm (>2 to 4 ha)	30	23 (10)	40 (40)	32 (50)	33 (100)
Large farm (above 4 ha)	4	8 (25)	7 (50)	2 (25)	4 (100)
Total	90	100 (15)	100 (33)	100 (52)	100 (100)
By Regions					
Arusha	18	100 (72)	10 (11)	6 (17)	20 (100)
Tanga	19	-	-	40 (100)	21 (100)
Morogoro	25	-	-	53 (100)	28 (100)
Dodoma	28	-	90 (100)	0	31 (100)
Total	90	100 (15)	100 (33)	100 (52)	100 (100)

Note. Figures in parentheses indicate row percentage. In the farm size category, size of area mentioned in the bracket is a range of landholding size by various farm categories. * Household (HH)

Table 2. Land Ownership and Cultivated Area for all Crops and Vegetable Seed by Farm Size under Each Marketing Channel

By Farm Size Category	Formal system (Contract grower)	Semi-formal system (QDS)	Informal system (Farm-saved seed)	Overall
Land ownership and cultivated area size (ha) under each marketing channel				
Total own area	1.5 (1.5)	2.0 (1.3)	1.6 (0.9)	1.7 (1.6)
Net operated area (NOA) for all crops	2.0 (1.9)	1.9 (1.2)	1.6 (0.9)	1.7 (1.2)
Net operated irrigated area (NOIA) for all crops	2.0 (1.9)	0.4 (0.3)	0.8 (1.0)	0.8 (1.0)
Area under vegetable seed cultivation	1.7 (1.1)	0.4 (0.3)	0.6 (0.5)	0.7 (0.7)
NOA by farm size category under each marketing channel		**Land Size (ha)**		
Marginal farm (0-1 ha)	0.7 (0.2)	0.6 (0.2)	0.5 (0.3)	0.6 (0.3)
Small farm (1-2 ha)	1.5 (0.2)	1.4 (0.3)	1.3 (0.2)	1.4 (0.3)
Medium farm (2-4 ha)	2.8 (0.7)	2.6 (0.5)	2.5 (0.5)	2.6 (0.5)
Large farm (above 4 ha)	7.7 (0.0)	4.9 (1.1)	4.5 (0.0)	5.5 (1.6)
Overall	2.0 (1.9)	1.9 (1.2)	1.6 (0.9)	1.7 (1.2)
% of NOA under each marketing channel (weighted by household)		**(Share %)**		
Marginal Farm (0-1 ha)	11	8	8	9
Small Farm (1-2 ha)	29	20	33	29
Medium Farm (2-4 ha)	32	55	50	51
Large Farm (above 4 ha)	30	17	6	14
Overall	100	100	100	100

Note. Standard Deviation in brackets

Table 3 depicts the basic socioeconomic characteristics of farm households. Out of 90 sampled farm households, 38% were headed by women. Interestingly, contract farming had the highest level of women's participation. The average age of respondents was 45 years.

Table 3. Basic Socioeconomic Characteristics of Farm Households

By Farm Size Category	HH	Formal system (Contract grower)	Semi-formal system (QDS)	Informal system (Farm-saved seed)	Overall
By Gender					
Female-headed	35	54 (20)	47 (40)	29 (40)	38 (100)
Male-headed	56	46 (11)	53 (29)	71 (61)	62 (100)
		100	100	100	100
Age Group of Respondent					
0-35 years	23	15 (9)	27 (35)	27 (57)	25 (100)
35-50 years	39	38 (13)	57 (44)	35 (44)	43 (100)
50 above	29	46 (21)	17 (17)	38 (62)	32 (100)
		100	100	100	100
Level of Education					
Number of Years	90	5.5	7.1	7.3	7
Family Size					
Number of People	90	4.8	5.9	5.6	5.6

On average, contract farmers had comparatively lower levels of education compared with QDS and non-QDS farmers.

Marketed surplus as a percentage of output is higher in contract farming (98.4%) than in QDS and informal systems (Table 4). QDS and informal systems had relatively smaller marketed surplus, implying that farmers sell their produce in the market under these systems and also keep their own seed for production in subsequent seasons, to exchange with neighboring farmers, or to give out to neighbors and relations as gifts. Farmers who produce under the contract seed model system tend to sell more of their produce compared with farmers who produce seed under the QDS and informal systems; however, contract farmers received higher crop income per ha/season than those under the QDS and informal systems (Table 4).

Farmers' self-perceptions about social norms, perceived control, and adoption of new agricultural technologies under different seed marketing systems are presented in Table 5. The values were measured using a 5-point Likert scale, where the set of ordinal scale perceptions of respondents were elicited under three major psychological indicators: attitude, social norms, and perceived control. *Attitude* includes an individual's evaluation of a given innovation. *Subjective norm* measures his or her perception of how important the opinions of others are regarding an identified innovation.[5] An innovation may not be adopted if it is against the prevalent cultural norm or has a negative effect on neighbors. *Perceived behavioral control* measures an individual's perception of his voluntary control of the adoption process. Even if a given

[5] Feder and Savastano (2006) analyzed how opinion leaders' views on a technology affect adoption of the technology by others.

innovation appears attractive and acceptable to others, individuals may not adopt it if it requires behaviors that are difficult to control, such as saving cash for use in the next season.

Table 4. Traditional African Vegetable Seed Yield and Marketed Surplus

				Marketed Surplus		Income from Seed Crop Sales	
Farm Size	**No. of HHs**	**Area Operated under Seed**	**Seed Production (kg/ha^{-1})**	**Seed sold (kg/ha^{-1})**	**As % of Output**	**per house hold /season (USD)**	**per ha/ season (USD)**
Formal system (Contract Farming)	13	1.6	174.7	172.0	98.4	587.3	907.1
Semi-formal system (QDS)	30	0.6	354.8	182.6	51.5	216.7	892.6
Informal system (Farmer saved seeds)	47	0.7	59.8	34.3	57.4	59.2	209.1
Overall	90	0.8	175.2	107.7	61.5	186.6	576.5

For this study, we have adopted the ten statements used by Hansson et al. (2012) with slight modifications to capture latent variables on the three psychological indicators. We asked respondents to evaluate their agreement with each of the 10 statements on a 5-point Likert scale, with 1 indicating strong disagreement and 5 indicating strong agreement (Table 5).

Following aggregation of the results, the Kruskal Wallis test was applied to understand the statistical significance of farmers' self-perception indicators among seed marketing channels. The results for all three statements of attitude were statistically significant among the three marketing channels. This implies that farmers' attitudes toward a new agricultural technology differs among three main identified seed marketing channels (formal, semi-formal and informal channels). Scores for social norms and perceived control did not vary statistically across the different marketing channels, except for the first statement under each perception indicator. Farmers with high scores for attitude and perceived control were not concerned about what other farmers think (social norms).

Overall, the study results suggest that attitude, social norms and perceived control differ among farmers who participated in seed marketing and distribution channels—contract farming, QDS, and informal (Table 5). Farmers from the formal and semi-formal seed sectors had better self-perception about adopting new technologies than farmers from informal seed sector. Farmers from the formal and semi-formal seed sectors had better social systems to diffuse their knowledge to neighbor farmers. These farmers also had better access to technologies due to their positive attitude toward adopting new technologies. Table 6 presents results regarding the relationship between farmers' decisions to participate in farmer-led seed enterprises and their access to certified seed, and the subsequent effect on vegetable seed income. Overall, farmers' participation in farmer-led seed enterprises and their frequent contacts with village extension agents were positively and significantly associated with accessibility of certified seed (treatment variable). Seed companies also provide extension services to their contract farmers, thereby increasing the frequency of extension and advisory services to contract seed growers.

Table 5. Surveyed Farmers' Psychological Constructs on Attitude, Social Norms and Perceived Control, by Marketing Channel.

Farmers' Self-perception Indicators	Semi-formal system (QDS)	Formal system Contract grower	Informal system Farm-saved seed	Overall
Attitude		**Average** [a]		
I consider myself as a progressive farmer	4.1	4.2	3.6	3.8*
I like to try new agricultural technologies	4.4	4.7	4.2	4.3*
I actively seek information from others	4.4	4.2	4.1	4.2**
I like new ideas in general	4.4	4.4	4.2	4.3
Average	4.3	4.4	4.0	4.2
Social Norms				
Other farmers think I am a progressive farmer	4.0	3.7	3.6	3.7***
Other farmers ask my opinion about agricultural technologies	3.9	4.0	3.8	3.8
Other farmers will not object my farming activities	3.9	3.8	3.4	3.6
Average	3.9	3.8	3.6	3.7
Perceived Control				
It is easier for me to collect information about technology	3.6	3.4	3.1	3.3**
I have good and constant contact with village extension officers	4.0	4.3	3.8	3.9
I can adopt new agricultural technology if it is profitable	4.4	4.5	4.3	4.4
Average	4.0	4.1	3.7	3.9

Note. a 5-point Likert scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neither, 4 = Agree, 5 = Strongly Agree.
* Indicates significance at 1% level; ** 5% level; *** 10% level and statistically significant difference among three marketing channels; test of equality using Kruskal Wallis test.

The accessibility of certified seeds is an endogenous treatment. Bratti and Miranda (2010) noted that if treatments are not randomized, and there are unobservable characteristics affecting the treatment variable, it will in turn affect the outcome variable (revenue generated from vegetable seed sales). Such unobservable characteristics are usually related to the individual characteristics of the household head (i.e., gender and age) and collective household characteristics such as family size. The individual characteristics of the household head significantly influences the accessibility of certified seeds but not the outcome variable, vegetable seed income. This means that female-headed households have less likelihood of having access to certified seed in comparison with male-headed households. However, vegetable seed income was not influenced by female-headed households. Similarly, age of the household head significantly affects accessibility of certified vegetable seed, which implies that older farmers have less likelihood of having better access to certified vegetable seed compared to young farmers. There are unobservable characteristics that directly influence the outcome variable rather than the treatment variable. These include access to credit and the net operated irrigated area. Farmers' vegetable seed income can be improved if farmers receive credit for their farm operations during the production season while simultaneously increasing their cultivated and irrigated land area.

In sum, based on the sign of the coefficient of access to certified vegetable seed and its standard error value, the study concludes that farmers' vegetable seed income is positively and significantly influenced by access to certified vegetable seed. The interpretation of the estimated results can be done in two ways. First, the direct interpretation of the coefficient (2.281) of accessibility of certified vegetable seed variable shows that holding all other independent variables constant, the log of revenue generated from vegetable seed sales is expected to increase by 2.3 times if farmers can increase their access to certified seed (Table 6). However, this method of interpretation has been criticized by several studies (e.g., Halvorsen and Palmquist 1980; Kennedy 1981; Giles 1982; Van Garderen and Shah 2002; Giles 2011). Therefore, this study also presented a second method of interpretation based on Kennedy (1981) approach[6], which is similar to an approach suggested by Van Garderen and Shah (2002). Based on the approach of Kennedy (1981), the coefficient of access to certified vegetable seed, the revenue generated from vegetable seed sales is expected to increase by 17.6% if farmers can increase their access to certified seed. Since the coefficient of the Inverse Mills ratio (Lambda) is significant at the 10% probability level, the treatment effect (i.e., access to certified seed) significantly impacted on farmers' vegetable seed income at the 10% probability level after correcting for endogeneity in the estimates. The results highlight that increasing access to certified vegetable seed significantly and positively affects farmers' vegetable seed income, along with improved credit access and increased net operated irrigated area.

Results from the extended Instrumental Variable (IV) model are presented in Table 7. The IV model is used to validate the results of the endogenous treatment effect model, and was estimated in two sequential steps. First, the causal relationship between accessibility of certified vegetable seeds and farmers' participation in farmer-led enterprises is measured such that access to certified vegetable seed is identified and assumed to be the most suitable instrument that has an effect on the outcome variable. Unobserved characteristics that influence this instrumental variable are designated as "excluded instruments". This study hypothesized that excluded instruments, including farmers' participation in farmer-led seed enterprises and frequency of contact with village extension agents, have positive influences on access to certified seed. The Sargan statistics are significant at the 5% probability level, indicating that the assumed excluded instruments are valid, uncorrelated with error, and correctly excluded from the equation. We also performed an endogeneity test of endogenous regressors (i.e., accessibility of certified seed), and results indicate the presence of endogeneity in the model. The IV model also provides results of an "under and weak identification test," which indicates that the excluded instruments are relevant (statistically correlated with the endogenous regressors) and implies these variables positively and significantly influence access to certified seed.

[6] Kennedy (1981) suggested the following formula for producing almost unbiased estimates and measures percentage change from the estimated coefficient in the model:100 {[exp(*b)/exp(0.5V(b))*]-1]} where *b* is the relevant parameter estimate and *V(b)* is the variance of the parameter estimate. Since in this study the estimated coefficient of access to certified seed as a dummy variable and measured in the log-linear regression framework, we used the Kennedy (1981) approach for the interpretation of the coefficient of access to certified seed.

Table 6. Linear Regression with Endogenous Treatment (Two-step Estimator)

Variables	(1) Log of Traditional African Vegetable Income	(2) Accessibility of certified seeds (Dummy) (1=No bottlenecks; 0=Otherwise)
Female (Dummy) (1=Female; 0=Otherwise)	0.472	-0.659**
	(0.407)	(0.337)
Age of Household Head (Number of Years)	0.00599	-0.0269***
	(0.0192)	(0.0133)
Family Size (Number person in the household)	0.0991	0.0914
	(0.0978)	(0.0695)
Access to Credit (Dummy) (1=received credit for agricultural activities; 0=otherwise)	0.775*	
	(0.487)	
Net Operated Irrigated Area (Ha)	0.311***	
	(0.142)	
Accessibility of Certified Seed (Dummy) (1=No bottlenecks; 0=Otherwise)	2.281**	
	(1.363)	
Farmers' Participation in Farmer-Led Enterprises (Either Contract farming and/or QDS system=1; 0=Otherwise) (Dummy)[a]		0.555**
		(0.318)
Have good contacts with village extension workers (Likert Scale 1-5) 1=Strongly Disagree; 5=Strongly Agree)		0.295**
		(0.160)
Lambda (Inverse Mills ratio)		-1.458**
		(0.844)
Constant	9.500****	-0.720
	(1.196)	(0.844)
Observations	81	81

Note. Standard error in parentheses **** p<0.01, *** p<0.05, ** p<0.10, * p<0.15; Footnote for a: base group is informal system (farm-saved seed)

Table 7. IV (2SLS) Estimation with Endogeneity Test

Variables	(1) Log of Traditional African Vegetable Income
Accessibility of Certified Seed (Dummy) (1=No bottlenecks; 0=Otherwise)	2.216**
	(1.308)
Female (Dummy) (1=Female; 0=Otherwise)	0.440
	(0.390)
Age of Household Head (Number of Years)	-0.000511
	(0.0172)
Family Size (Number person in the household)	0.106
	(0.0947)
Access to Credit (Dummy) (1=received credit for agricultural activities; 0=otherwise)	0.972*
	(0.594)
Net Operated Irrigated Area (ha)	0.528***
	(0.238)
Constant	9.587****
	(1.131)
Observations	81
Under identification test (Anderson canon. corr. LM statistic):	6.632***
Weak identification test (Cragg-Donald Wald F statistic):	3.255
Stock-Yogo weak ID test critical values:	
10% maximal IV size	19.93
15% maximal IV size	11.59
20% maximal IV size	8.75
25% maximal IV size	7.25
Sargan statistic	15.751****
Endogeneity test of endogenous regressors:	4.974***
Instrumented:	Accessibility of certified seeds (Dummy) (1=No bottlenecks; 0=Otherwise)
Excluded instruments:	Farmers' Participation in Farmer-Led Enterprises (Either Contract farming and/or QDS system)
	Have good contacts with village extension workers (Likert Scale 1-5) 1=Strongly Disagree; 5=Strongly Agree)
Duplicates	Female (Dummy) (1=Female; 0=Otherwise)
	Age of Household Head (Number of Years)
	Family Size (Number of Persons in the Household)

Note. Standard error in parentheses **** p<0.01, *** p<0.05, ** p<0.10, * p<0.15

Based on the results from the endogenous treatment effect model and extended IV model, the income of farmers from traditional vegetable seed sales is positively and significantly influenced by access to certified seed. However, access to certified seed tends to be influenced by farmers'

participation in farmer-led enterprises and through frequent contacts with village extension workers. As per any other rational behavior, a farmer decides whether or not to participate in a farmer-led seed enterprise. If the farmer makes this decision randomly, we could ignore that not all crop incomes are realized, and use an ordinary least squares regression to fit a crop income model. Such an assumption of random participation, however, is unlikely to be true; a farmer with a low crop income may be unlikely to choose to participate in farmer-led seed enterprises, and thus the sample of observed crop income is biased upward. Therefore, farmers may choose not to participate in farmer-led seed enterprises when their crop income from an informal system is greater than their income from a formal or semi-formal system. Therefore, crop income and farmers' participation have a simultaneous effect. However, this study hypothesized that if farmers participate in farmer-led enterprises, then they can have better access to certified seed, which influences revenue generated from their vegetable seed sales. This finding could be linked to consumer preference for produce attributes from diverse marketing outlets that would drive the seed supply system for farmers to demand quality certified seed for production.

Conclusion

In Tanzania, vegetable seed growers encounter three critical bottlenecks in the seed supply and distribution system: (i) seed quality, (ii) spatial and timely availability of certified seed, and (iii) affordability of certified seed. These factors directly influence the revenue generated from seed sales. Several studies have concluded that farmer-led enterprises can provide better access to certified seed to overcome these bottlenecks, while other studies indicated that farmers' participation in farmer-led seed enterprises can enhance their incomes. However, few studies have analyzed the simultaneous effect between farmers' participation in farmer-led seed enterprises, their access to certified seed, and the consequent effect on income accrued from seed production and sales. Our studies empirically quantified the effect of accessibility of certified seed on farmers' crop income among vegetable seed growers in Tanzania. Farmers' revenue generated from vegetable seed sales can be increased by 2.3 times if their access to certified seed can be increased while simultaneously improving the frequency of their contact with village extension agents. Female-headed households were found to have less access to certified seed in comparison with their male counterparts. We recommend that women's participation in farmer-led enterprises be encouraged through the formation of women's groups or by creating targeted extension programs to improve their access to certified seed. Our study results show that young farmers have a better likelihood of accessing certified seed than older farmers. Thus there is a need to encourage vulnerable youth in Tanzania to participate in farmer-led seed enterprises to generate employment while enhancing their income for improved livelihoods. The results suggest that both contract farming and QDS farmer-led seed enterprise models are effective for generating higher income for farmers in the study locale.

There is a need for government and development partners to promote and boost public-private partnerships that will ensure better access to inputs for production of certified seed, provide better access to extension services for smallholders, and increase revenues from certified seed production from farmer-led seed enterprises. The government should provide an enabling policy environment and incentives to scale up farmer-led seed enterprises, particularly for traditional African vegetables. Awareness campaigns about the nutritional benefits of these crops will further stimulate and increase demand while attracting investors and agribusiness practitioners into the sub-sector.

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