Drivers of Indivisible Technology Channel Access and Service Provision among Small and Medium Sized Food Processing Firms in Tanzania

Jason Snyder, David Tschirley, and Thomas Reardon
Department of Agricultural, Food, and Resource Economics
Michigan State University
Contact: snyde138@msu.edu

Selected Paper prepared for presentation at the 2017 Agricultural & Applied Economics Association Annual Meeting, Chicago, Illinois, July 30-August 1

Introduction

Economic growth and urbanization has led to a rapid increase in the purchase of processed foods in East and Southern Africa (ESA) among all segments of society, with overall demand through markets projected to increase 7% to 8% per year over the next three decades (Tschirley et al., 2015a). This presents a major opportunity for the local food processing industry and for the economy as a whole. However, seizing this opportunity depends on the ability of the local food industry to compete with food imports, requiring investment in the capital (e.g., human and physical) and technology necessary to cater to the evolving preferences and requirements of both a rising middle class of consumers and a modernizing retail sector.

Trienekens (2011) classifies three types of food systems: (1) an "A-system" which is characterized as low income, local, and traditional with mainly small firms and many links in the supply chain, (2) a "B-system" which has a mix of small and medium size firms (SMEs) and networks of collaborating firms, many of which engage in value added production and are linked to supermarkets, and (3) a "C-system" which is designed for export and is characterized by large economies of scale and high value added production. The focus of this paper is on A and B food systems, and more specifically, on the role of and opportunities for SMEs within them.

Much has been discussed about SMEs and their role in the process of economic development and employment generation. There is a rapid "churning" of micro firms (referred to as "mice") entering and exiting the industry, and, hence, not contributing greatly to net growth, and the occasional emergence of "gazelles", small firms that experience rapid growth and productivity gains (Li and Rama, 2015). It has been noted that one of the factors that may constrain SMEs growth are credit constraints that prevent investment in adequate technology (Nichter and Goldmark 2009). Other factors that may influence technology adoption include the efficiency of capital markets (Parente 1994), contractual incompleteness with suppliers (Acemoglu et al., 2007), risk and uncertainty (Dercon and Christiaensen, 2011), human capital, farm size, labor availability, tenure arrangements, complementary input supply constraints (as reviewed by Feder et al., 1985), gender (Doss and Morris, 2000), and social learning (Conley and Udry, 2010). Less discussed in particular are means of access to indivisible technology that do not necessarily require ownership. In this paper we look specifically at the determinants of channel choice that firms in a Tanzanian maize flour market use to access indivisible technology, either through ownership (and perhaps also providing services), or alternatively through milling service markets.

One main strand of literature that is pertinent to this issue relates to indivisible technology adoption at the farm level. Griliches (1957) showed that the technology rate of diffusion for hybrid corn in the United States followed an S-curve, starting with a few early adopters, followed by a rapid increase in adoption, followed by an eventual slowing down by straggling firms. David (1966) linked the diffusion of indivisible "lumpy" technology (tractors) in the United States to a threshold level of capital accumulation. However, it was shown by Olmstead and Rhode (2001) that tractor diffusion in the United States and Canada was also made possible by an active services market. From 1905-1909 custom services accounted for 44% to 50% of total plowing (depending on the type of tractor). This not only allowed smaller farmers to gain access to tractor services, but it also encouraged slightly larger farmers (marginal adopters) to buy tractors with greater capacity than their own production required.

Recently, there has been a number of studies that have documented the emergence of machine rental service markets in developing countries (Feder et al., 1985; Yang et al., 2013; Reardon et al., 2014; Qanti et al., 2017). Using these as illustrative studies, Lu et al. (2016) provide a conceptual treatment of the demand and supply for custom machine services, emphasizing the theoretical "separation between technology adoption decisions and machinery ownership decisions".

The decision to own a machine in the presence of a rental market can also be viewed as a decision to vertically integrate the means of production. This leads to the second pertinent strand in the literature, transaction cost economics (TCE). TCE arose out of Coase's (1937) discussion on the boundary of the firm, an analysis of the "make or buy decision" (i.e., the decision to coordinate some aspect of production within the firm, or to contract it out to another firm in the market). Williamson (2005) characterizes this as a governance decision that is driven by three main factors associated with transaction costs: asset specificity (or the difficulty of redeploying the relevant assets outside of a specific relationship), uncertainty or the potential for disturbance in the transaction relationship, and the necessary frequency of the transaction relationship. Demsetz (1988) broadens this decision to encompass all of the relative costs of external contracting versus in-house production (including management, transaction, and production costs within and across both firms). The TCE framework has been applied to many types of analyses, ranging from hospital services (e.g. Coles and Hesterly (1998)) to viticulture (e.g. Olmos (2010)). A meta-analysis of TCE empirical studies by David and Han (2004) suggested that only asset specificity corresponded consistently with theory, while uncertainty much less so, and frequency of transaction was surprisingly understudied.

A third strand sets the larger context in which rental markets are viable and vertical integration is possible. Above we discussed Trienekens classification of food system stages. Similarily, Sonobe and Otsuka (2011) outline a model on the stages of industrial cluster development based on a number of case studies in both Asia and Africa. It begins with the *initiation stage*, followed by a *quantity expansion phase*, in which success and high profit margins in the formation of the market induce an influx of competitors (imitating the relatively low technology product) into the market, thereby leading to an increasing number of low productivity firms clustering together, competing, collaborating, and gradually decreasing profit margins.

In successful clusters, the opportunity arises for certain companies to invest in further innovation and scale in order to regain profit margin. This marks the beginning of the *quality improvement phase* which is associated with a consolidation of firm activity and increasing productivity, greater product sophistication, and evolving marketing strategies (including branding and vertical integration) among lead firms. The lead firms may actually find it more lucrative to leave the cluster at a certain point in order to develop an independent brand and avoid congestion. In a study of the Chilean wine cluster, lead firms are described as possessing "advanced absorptive capacities" and acting as "technological gatekeepers", controlling the flow of knowledge and technology within the cluster (Giuliani and Bell, 2005). In a study of a Chinese hosiery cluster, they act as links between the cluster and regional and international markets (Akoorie and Ding, 2009). Sonobe and Otsuka point out that progressive cluster development is in no way guaranteed, and many industrial clusters, especially those located in many African countries, are stuck in a low productivity equilibrium.

In the literature there is a scarcity of studies on the determinants of the means of indivisible technology access and/or the make or buy decision when there is a presence of a machine services market among SMEs in developing countries. The extant analysis of machine service markets in the agri-food system are focused on the farm sector, neglecting post-farm segments of the food system. This is important because while the agri-food system occupies a significant share of GDP and employment in many developing countries, much of its relative growth is occurring in the post-farm sectors (Wilkinson and Rocha, 2009; Tschirley et al., 2015). Furthermore, the general trend in developing countries worldwide appears to follow a "J-curve" of increasing market concentration after an initial proliferation of small firms (Reardon, 2015). However, it has been shown that the presence of a machine rental or resale market is associated with lower market concentration (Kessides, 1990) and lower industry size dispersion (Kessides and Tang, 2010). This is because it makes entry easier (greater "market contestability”) by decreasing the “sunkeness” of investments or alternatively, increasing the “mobility and fungibility” of capital

In order to address this scarcity, we will explore the following research question: what are the incentives and capacities of maize flour brand owners to either operate their own milling machinery (and perhaps sell milling services) or to simply purchase milling services? The paper proceeds as follows. First we describe the research context and conceptual framework, including key variables and hypothesis for analysis. Second, we describe the data collection and empirical strategy. Finally, we present and discuss the results, including implications for policy.

Context

The Tanzanian maize flour processing industry has elements of both the A and B systems in Trienekens’s framework, and could likely be classified to be in the *quantity expansion phase,* with slight movement towards the *quality improvement* stage in Sonobe and Otsuka’s (2011) framework. First, there are an abundance of firms of many different sizes, but producing a very similar product (i.e., maize flour in a polypropylene sack), albeit with differentiated branding. Second, there is a robust market for the provision of milling machine services that are used by both consumers and other firms. The larger firms are generally most likely to own machinery and either provide milling services and/or mill only for themselves. Those firms that have their own brand and also provide milling services could be characterized as the “technological gatekeepers” who are fully embedded within the cluster and control the flow of knowledge and technology. On the other hand, those firms that own machinery and only mill for themselves may be symptomatic of the early Sonobe and Otsuka’s (2011) quality improvement phase, in which certain firms may have incentive to become more autonomous and eventually leave the cluster. The smaller firms appear most likely to purchase milling services, and may perhaps be described as the “mice” in the “quantity expansion phase” that that are chasing profit margins and vying to become the new “gazelles” of the industry.

Conceptual Framework

The conceptual framework has some similarities to the TCE framework developed by Masten et al. (1991) in which the choice of governance form hinges on the relative transaction costs of internal organization and market exchange. However, our framework differs in a few important ways: (a) we are also incorporating the decision to sell services, and, thus, focusing more on relative profitability instead of relative costs, (b) given the study of SMEs in a developing country context, we are accounting for explicit constraints to internalizing production (own milling), emphasizing how the presence of a rental services market may lower barriers to entry into the industry; and (c) in our study there is a high degree of homogeneity of both the product (maize flour) and the production process (maize milling). For this reason, relationship specific asset specificity does not appear to be significant a factor in determining the organizational choice of firms. The most consistently visible product difference is the label on the packaging which differentiates the brand and is applied post milling, but even this is relatively standardized. Hence, this is not a standard TCE formulation with a focus on asset specificity.

We will assume that the owner of each brand-owning firm faces an operational decision {A,B,C}. They can (A) purchase machine capacity M to both produce their own brand and sell milling services, they can (B) purchase machine capacity M to only produce for their own brand, or (C) they can outsource this stage of the production process (i.e., just choose to purchase milling services). Firms that only provide milling services, and hence are not brand owners, will be excluded from this analysis. We assume that the owner uses backwards induction to choose an initial path, i.e. they determine before-hand the expected utility of the profit maximizing outcome of each decision and then they choose the optimal profit maximizing outcome, as shown in figure 1.

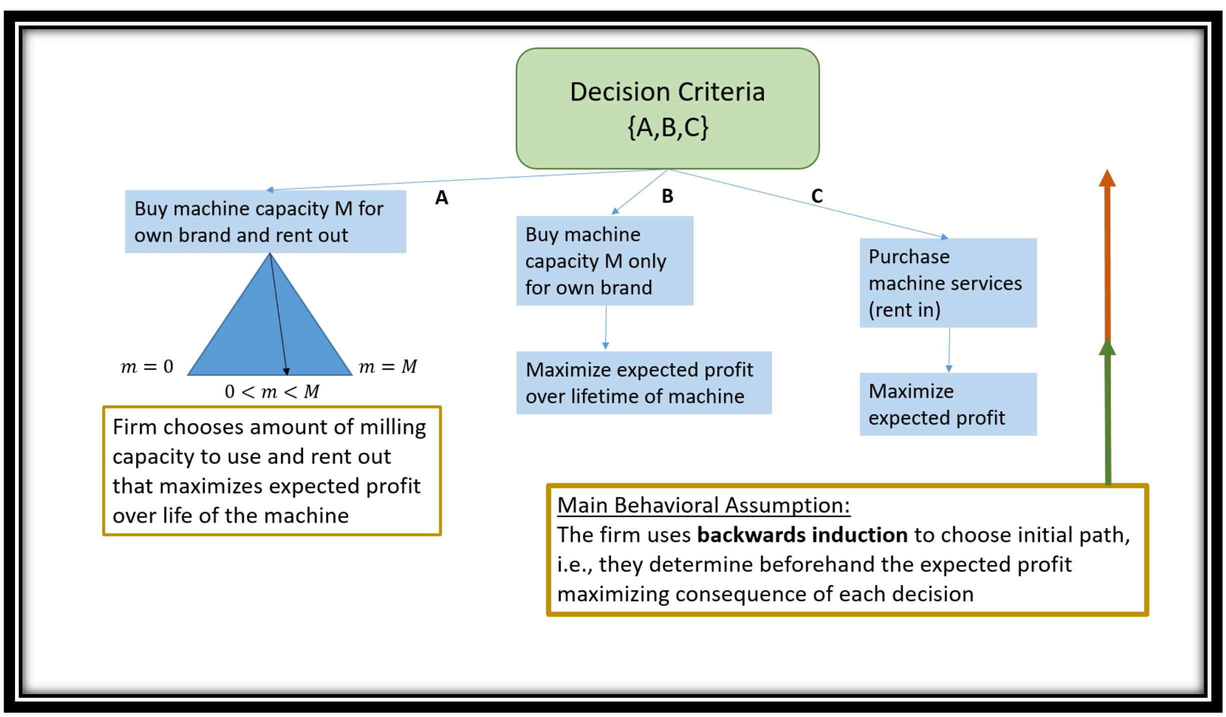

Figure 1. Conceptual Framework

Specifically, the entrepreneur has the following expected discounted utility of profit function in each case:

$$Max_{(m^t,s^t)_{t=0}^T} E_0 U[\sum_{t=0}^T \beta^t [P_q^t h(X^t(m^t,s^t),K^0) - P_M^t - P_K^t + P_r^t s^t - C(P_x^t, X^t(m^t,s^t),K^0)]]$$

s.t. $m^t + s^t \leq$ M (1)

$$Max_{(m^t)_{t=0}^T} E_0 U[\sum_{t=0}^T \beta^t [P_q^t h\left(X^t(m^t),\ K^0\right) - P_M^t - P_K^t - C(P_x^t, X^t(m^t),K^0)]]$$

s.t. $m^t \leq$ M (2)

$$Max_{(r^t)_{t=0}^T} E_0 U[\sum_{t=0}^T \beta^t [P_q^t h\left(X^t(r^t),\ K^0\right) - P_r^t r^t - P_K^t - C(P_x^t, X^t(r^t),K^0)]] \quad (3)$$

Where T is the lifetime of the machine, β^t is the discount factor at time t, m^t is a choice variable indicating the volume of milling for own-brand, X^t is a vector of other variable inputs (maize, labor, energy, machine upkeep, etc.) that go into the final product, K^0 is vector of the initial capital assets (human, social, physical) at start-up, P_q^t is the market price of firm output, P_M^t is the amortized cost of the machine, P_k^t is the amortized cost of other fixed capital, P_r^t is the rental rate of machine services, P_x^t is the vector of other input prices, r^t is the volume of milling services rented in, s^t is the volume of milling services rented out, h(.) is the production function, and C(.) is the variable cost of production.

For decision A, the business owner solves the problem in (1), choosing m^{t*} and s^{t*} in each period t over the lifetime of the machine T in order to maximize their expected utility of discounted profit, given the constraint that they cannot produce (for themselves and others) more than their total machine capacity M allows them. Similarly, for decision B in (2) and decision C in (3), they choose m^{t*} and r^{t*} in each case, respectively, that maximizes their discounted profit over the lifetime of the machine. Finally, given that they have solved the expected profit maximizing levels of m^{t*}, s^{t*}, and r^{t*} for each of the potential decisions, then the choice criteria is the following:

Choice {A,B,C} = *prob[[EU(π_i^*)] > {[EU(π_j^*)], [EU(π_k^*)]}];* (4)

where *EU(π_i^*)* is the maximized expected utility of profit for choice i ϵ {A,B,C}.

There a few elaborations to the formulation above. First, we are borrowing from the property rights literature (Grossman and Hart, 1986; Hart and Moore, 1990) in emphasizing that owners of machinery have the residual rights (preferred access) to the technology, and, hence, greater flexibility and strategic opportunity of use. We assume that this translates into lower variable costs per kg milled. In terms of notation, we use the following:

$$\frac{\partial C}{\partial X^t}\frac{\partial X^t}{\partial m^t} < \frac{\partial C}{\partial X^t}\frac{\partial X^t}{\partial r^t}; \quad (5)$$

Second, note that K^0 is also included directly in both the production function and the cost function. In other words, firm cost and productivity is influenced by capital accumulation, (e.g., physical, social, and human), and, therefore, may influence the relative payoffs of each decision. For example, if a business owner acquires a milling facility outside of their home, and, therefore, has more space to operate, it may increase the relative payoffs of purchasing a machine by having the necessary space to maximize its operational capacity.

Third, as mentioned earlier, ownership is a "lumpy" investment made viable via prior capital accumulation. There is mixed evidence for this in the literature. For example Lerner and Merges (1998) found that the distribution of control rights in the biotech industry was influenced partially by financial constraints. On the other hand, Bigelow and Argyres (2008) found capital constraints in the automotive industry were not a binding factor of producing engines in-house. However, in a developing country context with an abundance of micro-firms with limited capital hoping to access indivisible "lumpy" technology, this assumption seems credible. The practical viability of ownership[1] requires $K^0 \geq \overline{K}$, where $\overline{K}$ is a threshold level of initial capital. Fitting this into our model, we are assuming that if $K^0 < \overline{K}$, then the relative cost of the machine is high enough that the purchase would be unprofitable (although not impossible), and so therefore the probability of choosing choice A or B is zero and the probability of choice C is 1.

Key variables and hypotheses

The determinants of the decision {A, B, C} are defined below, coupled with a hypothesis on their direction of impact.

[1] If ownership is not "practical viable", we are not saying that it isn't theoretically possible to buy a machine, e.g. by taking a loan with a very high interest rate, but that it is too costly for it to every be profitable

1. Prior assets: proxied by the tons of own production at the start-up of the firm. Firms with greater initial assets are more likely to own machinery (see "threshold" literature described earlier) [A (+), B (+), C (-)].
2. Workspace: defined as a dummy variable equal to 1 if their main work premises is outside of the home. Micro-enterprises are more likely to have specialized premises at home (Bricas and Broutin, 2008). It is easier (due to space and zoning issues) to operate machinery in a space outside of the home [A (+), B (+), C (-)].
3. Formal or semi-formal financing: defined as a dummy variable equal to 1 if they received external financing from a least one formal or semi-formal institution, including a bank, grain wholesaler or trader, processor/business association, NGO or donor project, or Sacco or Upatu (rotating credit organizations). External financing is positively correlated with technology adoption (Correa et al., 2010) [A (+), B (+), C (-)].
4. Business networking (collaboration): defined as a dummy variable equal to 1 if they engaged in at least one of the following types of collaboration with other firms at start-up: (a) share or rent equipment, (b) share transport vehicles, (c) jointly bulk purchase maize grain (or other raw material input), (d) share employees, (e) share purchasing, technological, or marketing information, (f) outsource orders to fellow enterprises, or (g) fulfil large orders under a single brand. There are conflicting arguments as to the hypothesized effect. There is a literature on the impact of horizontal/vertical clustering on firm productivity (e.g. Long and Zhang, 2012) and the positive impact of social networks (Bandiera and Rasul, 2006) and social learning (Conley and Udry, 2010) on technology adoption. If they do own machinery, easier access to an output market channel via collaboration may lead to lower transaction costs (hence higher incentive) of marketing own production relative to providing services to others. On the other hand, collaboration may be conducive to repeated interactions with others in the value chain (i.e., potential renters or rental providers) which may lead to lower production costs of rental arrangements [A (?); B (+); C (?)].
5. Education: Defined as a discrete variable indicating the approximate years of education (based on general education categories). Human capital is conducive to technology upgrading (Sonobe and Otsuka, 2011) [A (+), B (+), C (-)].
6. Perceived market risk: Defined on a Likert scale (1 being low risk and 3 being high risk) asking how risky they perceived the external environment for their business due to factors outside of their control, like market demand, government regulations, etc. There is a negative investment

relationship with risk in the presence of irreversibility of ownership/sunk cost (Leahy and Whited, 1995), risk aversion, and incomplete markets (Craine, 1989). However renting out increases the "mobility and fungibility" of capital, thereby decreasing risk (Kessides, 1990) [A (+); B (-); C (+)].

7. Industry experience: Defined as a dummy variable equal to 1 if they had prior experience in a food related industry. There is a positive relationship between industry experience and the propensity of internalizing production instead of contracting it out (e.g. Bigelow and Argyres (2008) find that older firms were more likely to vertically integrate) [A (+), B (+), C (-)].
8. Other control variables include the age of the main owner at start-up, age of the business, and dummy variables equal to 1 if they are a women, if they had a bank account, and indicating the district that they come from.
9. In order to help control and test for some nonlinearities in the model, we include the square of prior assets (sales volume) and the age of the business, the cross product of prior assets with a number of relevant variables, the cross product of education and prior experience, and the cross product of collaboration with whether they received finance and their perception of risk. We also include cross products of the age of the business with each start-up variable (excluding owner age), in order to control for the impact of time on the impact of each start-up variable.

Data

This paper is based on a USAID funded survey of maize flour businesses conducted in September through November, 2016, in Dar es Salaam, Tanzania. The data, covering all of the previously mentioned variables, was collected using tablet questionnaires, with questions asked by trained enumerators eliciting verbal responses.

As depicted in figure 2, we conducted a multi-stage stratified sampling strategy of flour businesses.

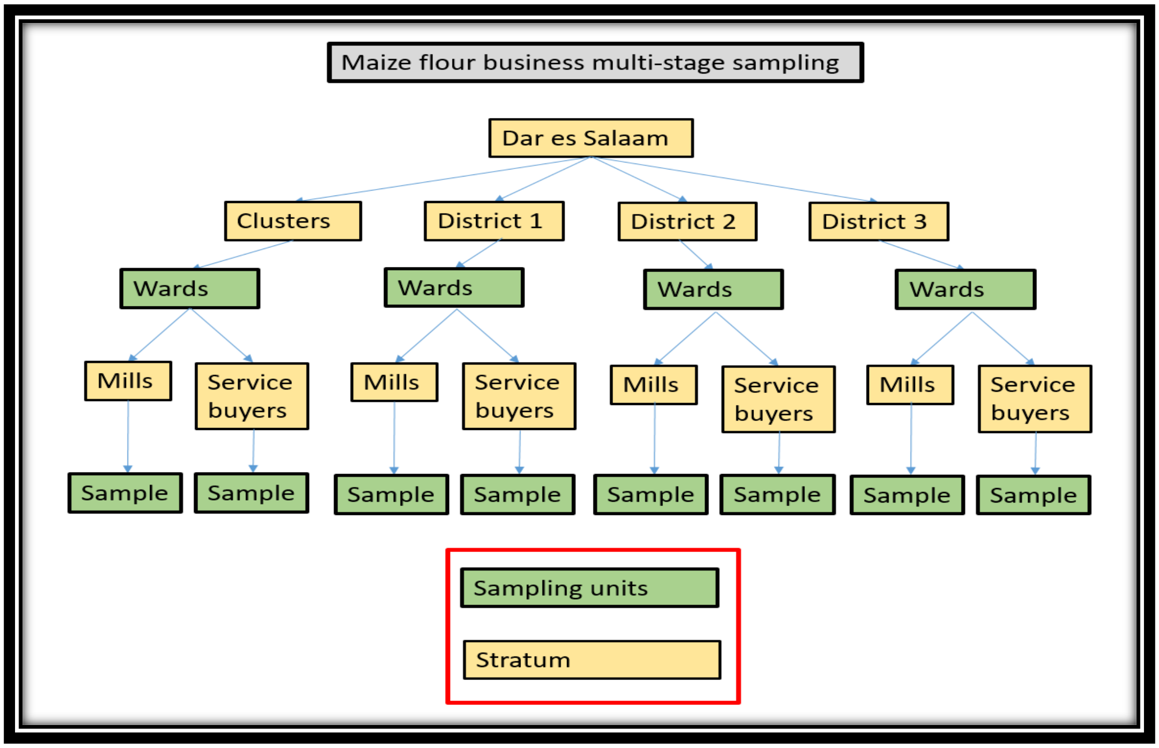

Figure 2. Diagram of multi-stage sampling strategy

In the first stage, we stratified into four stratum. In the first stratum, we selecting known maize milling "clusters" (i.e., areas that contained many maize milling firms in close proximity) within the city by consulting with local key informants to identify all wards that fell within or intersected known or hypothesized maize milling clusters. By using this approach, we selected eight wards within the Temeke district, three wards within the Kinondoni district, and three wards within the Ilala district. For the next three stratum, we then took a random sample of six wards within each of the three districts (totaling eighteen wards) from all of the remaining wards that we did not identify as belonging to clusters.

In the second stage, we conducted a full listing of maize mills in each of the selected wards. In each case, the ward office was visited and, if possible, an initial list of mills was developed with the help of the ward officers. Then the enumerators, with the help of a guide, systematically visited and listed each of the known mills in the ward. We then took a random sample of a maximum of 12 mills in each of the wards, implying that, in many of the wards, a full census was taken because there were fewer than 12 mills listed. In wards where there were more than 12 mills sampled, the remaining mills were made available as potential replacements in the order that they were sampled. There was a final listing of 313 mills, and of these 234 mills, through the process described above, were randomly selected for interview, comprising the first stratum in the second stage.

Next, we sampled service buyers (SBs) (i.e., type C in the framework above - businesses that don't mill themselves and instead only purchase milling services). First, we identified the mills that operate milling machinery (OMMs) from our listing that claimed to provide milling services for other flour businesses. Then, we sampled a maximum of three mills per ward in the wards where at least one OMM met this criterion. This produced a list of 30 mills. Next, we randomly assigned a day of the week (excluding Sunday) to each of these businesses so that five mills were assigned to each day of the week, and also randomly chose replacements for each day of the week. Each of these mills[2] was visited for an entire day by an enumerator, who listed any identified businesses that generally purchased milling services from that mill (not necessarily milling on that day). We found a total of 117 businesses through this method and were able to arrange and conduct interviews with 91 of them. These comprised the second stratum in the second stage.

Many of the mills that were sampled and interviewed were not brand owners (e.g., they only provided milling services) and were excluded from this analysis. The final dataset for this analysis contained 108 mill owners and 91 service buyers.

Empirical model

In order to test the first set of hypotheses, we run two models: (1) a logit model that tests the decision to own a machine {A or B, C}, and (2) a multinomial logit model that tests {A, B, C} separately. There are a couple of econometric challenges that we address. First, there is the issue of the simultaneity of the operational decision with the time-varying explanatory variables. For this reason, we use a variable indicating the current operational status, but we construct the time-varying explanatory variables based on what they recall from around the time that they started their business. It should be noted that relatively few businesses changed their operational status (e.g., transitioning from purchasing services to owning a mill and providing services) since they started. For those that haven't, we assume that the

[2] In total, three mills were replaced and three mills only milled for consumers (contrary to the information that was listed) and were dropped from the sample.

choice to stay with the current business type has been made sometime after start-up, and is therefore influenced by the attributes at start-up.

Second, we suspected that the choice to collaborate at the start of the business is endogenous to the model predicting operational type. In order to test for endogeneity in a non-linear model with a hypothesized discrete endogenous regressor, we used a control function approach (Wooldridge, 2015). The parents' level of education (approximate grade level) was used as an instrumental variable (IV) for collaboration. It appeared to be good choice since it is significantly correlated (controlling for other variables) with the dummy variable for collaboration, and is unlikely to be significantly correlated with the disturbance ε. Next, we regressed the exogenous variables (excluding the cross products with collaboration) on the IV using a probit command, calculated the generalized residual, and then included that residual as a control in a 2^{nd} stage binomial multinomial logit estimation (again excluding cross products with collaboration). Since this estimation involves sample weights, we generated a set of replicate weight variables and then used a survey data bootstrapping procedure that bootstraps the standard errors from both stages simultaneously. The bootstrapped standard error of the residual was not significant, and therefore we failed to reject the null hypothesis that the collaboration variable is exogenous. Therefore we moved ahead without using an IV for collaboration in the model.

Results

Table 1 shows the following descriptive statistics for firms at the start of their business[3]. First, comparing machine service buyers (type C) with machine owners (type A or B), we find that service buyers produced much less volume of product (44 tons compared to 459 tons), worked outside of their home more (63% to 55%), and collaborated much more (80% compared to 22% of firms). The owners of service buying businesses have just over three years less of education (7.9 years to 11.3), perceived a lower level of market risk by a small but significant amount, were much more predominantly female (80% to 22%), were younger (37 years to 44 years), had less prior experience in a food related industry (22% to 30%), and had a bank account less often (10% to 36%).

Second, comparing machine milling brand owners - whether they provide milling services (type A) or just mill for themselves (type B) - we find that those that provide services worked outside of their home less

[3] With the exception of Female, Years of formal education, and Business age that are time invariant or current

(44% to 63%), and collaborated less (16% to 27%). The owners of service providers are less educated (12 years to 10.8 years), perceived a lower level of market risk, were less predominantly female (23% to 40%), were slightly older (45 to 43), and had a bank account less often (25% to 44%).

Table 1. Mean business characteristics by business type

Current business type	A: Owns machinery and sells services	B: Owns machinery only for own brand	A or B: Operates machinery	C: Purchases milling services	t-test: {A} vs {B}	t-test: {A or B} and {C}
Mean sales (100 tons)	6.14	3.56	4.59	0.44		***
Worked outside of home	44%	63%	55%	63%	***	*
Received financing	33%	34%	33%	41%		
Engaged in Collaboration	16%	27%	22%	80%	***	***
Years of formal education	12	10.8	11.3	7.9	***	***
Perceived market risk	1.87	1.70	1.76	1.63	**	**
Female owner	23%	40%	33%	81%	**	***
Owner age	45	43	44	37	*	***
Prior food experience	30%	30%	30%	22%		*
Bank account	25%	44%	36%	10%	***	***
Business age	3.94	4.18	4.08	4.2		

Significant difference of means at 1% (*), 5% (**), 10% (***); Time varying coefficients indicate status at the start-up of the business

Table 2 breaks down the rates of the different types of collaboration by business type. Across all businesses, there is a clear bimodal distribution, with the joint purchasing of raw material input (mostly maize), sharing of transport, and the sharing of employees being the most collaborative activities (39%, 31%, and 34%, respectively). Most of this difference is due to the high rates of these types of collaboration among machine service buyers. Service buyers also have a slightly higher (though still low) rate of outsourcing orders and jointly marketing their production with other firms, but a slightly lower rate of sharing information. Finally, machine owners rarely outsource or jointly market their products, but those that sell services do so at a slightly higher rate.

Table 2. Rates of each type of collaboration by business type

	A: Owns machinery and sells services	B: Owns machinery only for own brand	A or B: Operates machinery	C: Purchases milling services	t-test: {A or B} and {C}	t-test: {A} vs {B}
Share equipment	6%	6%	6%	4%		
Share transport	11%	6%	8%	51%	***	
Joint purchasing	13%	10%	11%	63%	***	
Share employees	11%	6%	8%	58%	***	
Share information	10%	7%	8%	5%	***	
Outsource orders	5%	1%	2%	11%	***	**
Joint marketing	5%	1%	2%	16%	***	**

Table 3 displays the estimation results, with and without the squared and interaction variables. There were a number of notable findings, of which we will focus on the former:

First, as hypothesized, higher prior asset holdings (proxied by tons of production) increases the likelihood of current machine ownership. Also, as discussed below, there is an indirect effect (i.e., the mediating influences that asset ownership has on the impact of other variables).

Second, as hypothesized, locating the main work premises outside of the home increases the likelihood of machine ownership. Moreover, there is an interaction effect with prior assets; decreased asset ownership increases the importance of working outside the home on the likelihood of machine ownership. These results align with the typology of Bricas and Broutin (2008), suggesting that a characteristic of micro-enterprises is that they have specialized premises at home.

Third, as hypothesized, receiving semi-formal or formal financing increases the likelihood of machine ownership. However there is also a substitution effect with prior assets; owning fewer assets increases the importance of receiving finance on the likelihood of ownership. The return on investment to micro-firms can be very high (for example, in a study of Sri Lankan microenterprises, the return to capital was 55% to 63% annually (De Mel et al., 2008)), suggesting that it may be sensible to expand access to finance for smaller firms. However, given the presence of a rental market, these enterprises may still choose to avoid taking on the risk.

Fourth, firms that engaged in collaboration with other firms are more likely to purchase milling services, although not surprisingly, this effect becomes less important for firms with greater prior assets. There are a number of possible interpretations of this. First, this result doesn't necessarily contradict the social networking literature because these firms are still adopting technology (which unlike in the farm scenario, is a pre-requisite for participation in the market) through the milling service market. Second, based on TCE theory, it also suggests that collaboration, via repeated interaction and familiarity with other firms, decreases the relative transaction costs of purchasing services, thereby making it more likely that they will choose that organizational form. Third, it may speak to the stages of industrial clustering hypothesis of Sonobe and Otsuka (2011). Those firms that are highly embedded within a collaborative framework are less likely to be characterized as being in the third stage of *quality improvement* (and having the property rights to the primary production technology that gives them this flexibility), and are more likely to be characterized as being in the quantity expansion stage with many smaller scale imitators of low technology product.

Fifth, as hypothesized, higher educational attainment increases the likelihood of machine ownership. This reinforces the notion that education is a form of human capital that prepares one to better manage the risk of ownership. Also as hypothesized, prior industry experience increases the likelihood of machine ownership, and interaction of education and prior experience is negative, which suggests that, to some degree, they are substitutes.

Sixth, higher perceived risk at the start makes one less likely to own machinery. This only partially confirms our hypothesis that while it would deter choice B (selling own brand only), it would not deter choice A (selling own brand and services). There are a couple of qualifications to this result. First, collaboration, even though it independently decreases the likelihood of machine ownership, appears to also decrease the importance of perceived risk in preventing machine ownership. This may be to do a risk reducing function of collaborative networks that has been described, for example, in qualitative research in India showing that "mutual assistance networks" of poor farmers are used to buffer against risk (Kozel and Parker, 2000). Second, increased prior assets also appear to decrease the importance of perceived risk in preventing machine ownership, aligning with main conceptual (Pratt, 1964) and empirical (e.g. Binswanger, 1981) findings in the literature that individuals display decreasing absolute risk aversion.

Seventh, it is interesting to note that the variable indicating the age of the firm is positive and significant, but that its squared term is negative. This suggests three things. First, it corresponds with

Bigelow and Argyres (2008) that firms with more industry experience are more likely to be vertically integrated. Second, it suggests that there is more turnover among service buying firms, corresponding to the description by Li and Rama (2015) of a rapid churning of micro firms. Third, this positive impact of age is decreasing over time, meaning that the relative impact of age is strongest for more recent firms.

Finally, we note that the interaction of the age of the firm with the start-up variables mostly has the opposite sign of the individual variables. This makes sense; it indicates that the longer that the firms are in the industry, the less impact certain start-up conditions have on the current business type. One exception to this is the collaboration variable. The interaction effect on total ownership (type A or B) and owning a machine just for their own brand (type A) is not significant. However, the effect on owning a machine and selling own brand and services (type B) is negative and significant, the same effect as the collaboration variable. This suggests that initial collaboration has a long term increasing impact on the likelihood of providing services, which is necessarily collaborative.

Table 3. Results of logit and multinomial logit models

Model Type	**Logit**	**Multinomial logit**	
Business Type	**Type A or B: Machine owner**	**Type A: Sells brand and services**	**Type B: Sells own brand only**
Tons (100) own brand	2.635**	0.024**	0.027**
	(1.08)	(0.01)	(0.01)
Worked out of home	6.148***	4.408***	6.277***
	(1.29)	(1.33)	(1.36)
Formal loan	7.879***	7.597***	8.154***
	(1.48)	(1.58)	(1.44)
Collaborator	-10.242***	-9.629***	-10.370***
	(1.15)	(1.19)	(1.24)
Years of education	1.067***	1.298***	1.012***
	(0.16)	(0.18)	(0.16)
Market risk	-4.386***	-5.251***	-4.173***
	(0.53)	(0.68)	(0.55)
Female main owner	-3.454***	-6.949***	-2.868***
	(0.48)	(0.57)	(0.46)
Age at start	0.048*	0.020	0.055*
	(0.03)	(0.03)	(0.03)
Food experience	5.770***	6.700***	5.229***
	(1.55)	(1.82)	(1.62)
Bank account	4.385***	3.044***	4.408***
	(0.45)	(0.54)	(0.45)

Age of business	0.360***	0.346**	0.435***
	(0.12)	(0.16)	(0.14)
Ilala district	2.223**	2.194**	2.401**
	(0.82)	(0.84)	(0.89)
Kinondoni district	1.750***	2.633***	1.857***
	(0.52)	(0.56)	(0.57)
Age of firm^2	-0.007	-0.005	-0.013***
	(0.00)	(0.01)	(0.00)
Age of firm*Tons (100)	-0.013	-0.083**	-0.021
	(0.04)	(0.04)	(0.04)
Age of firm*Outside	-0.773***	-0.925***	-0.717***
	(0.12)	(0.15)	(0.13)
Age of firm*Loan	-0.426***	-0.349***	-0.450***
	(0.10)	(0.11)	(0.10)
Age of firm*Collaborator	-0.083	-0.269***	-0.086
	(0.07)	(0.09)	(0.09)
Age of firm*Risk	0.386***	0.461***	0.378***
	(0.05)	(0.06)	(0.05)
Tons (100)^2	-0.016**	-0.033***	-0.006
	(0.01)	(0.01)	(0.01)
Tons (100)*Outside	-2.032***	-1.676**	-2.181***
	(0.56)	(0.61)	(0.61)
Tons (100)*Loan	-1.154**	-0.748	-1.084**
	(0.52)	(0.49)	(0.48)
Tons (100)*Collaborator	2.441***	3.050***	2.659***
	(0.37)	(0.43)	(0.38)
Tons (100)*Education	-0.066	-0.085	-0.024
	(0.07)	(0.06)	(0.06)
Tons (100)*Risk	0.754***	1.057***	0.555***
	(0.13)	(0.20)	(0.17)
Tons (100)*Female	-0.979*	-0.545	-1.392**
	(0.50)	(0.57)	(0.56)
Education*Experience	-0.442**	-0.458**	-0.387*
	(0.18)	(0.21)	(0.20)
Collaborator*Loan	-4.634***	-6.825***	-4.656***
	(0.86)	(0.88)	(0.94)
Collaborator*Risk	2.492***	1.382**	2.489***
	(0.42)	(0.54)	(0.43)
Constant	-11.221***	-10.760***	-12.103***
	(2.81)	-3.08	-3.02

*** p<0.10, ** p<0.05, *** p<0.01; note that the base outcome is type C (purchasing services)**

Discussion

This is the first study (as far as I know) that evaluates the role of machine service markets and the make or buy decision in a developing country post-farm food system context. However, the results graft well (with one exception) onto other strands of literature. The results align with the farm-level food system literature on the role of service markets in lowering the threshold to indivisible technology. We find that smaller firms (as defined by total assets and proxied by volume of production) are generally more likely to purchase services. Furthermore, the mechanism of impact is also shown to be indirect. Increasing firm size reduces (via substitution) the positive impact that operating outside of the home and utilizing semi-formal or formal financing have on the likelihood of ownership, and reduces the negative impact of collaboration and perceived risk on ownership.

Along the lines of the *quantity expansion phase,* as described by Sonobe and Otsuka (2011), collaborating firms (which also happen to be significantly smaller) are more likely to purchase milling services. There are similarities with this and McCormick (1999), who found that in six industrial clusters in Africa, there was a rapid proliferation and clustering of micro-sized firms in a "groundwork" phase benefiting from improved market access and possibly some limited labor market pooling and technological spillover. However, collaboration also has an indirect but positive impact on the likelihood of ownership by lowering the drag that perceived risk has on the likelihood of ownership.

Contrary to the prediction of TCE theory that market uncertainty in the presence of asset specificity leads to vertical integration[4], uncertainty (measured as perceived market risk) has a negative, not a positive impact on the choice to integrate (conduct own-milling). However, most of the studies in the TCE literature are conducted in a developed country context containing larger firms with much more specialized production processes (and hence high asset specificity), where capital constraints to vertical integration (the "make" decision) and risk aversion are perhaps not as salient to the firm's decision process as the risk of getting trapped in a "hold-up" situation with another highly specialized firm. Indeed, as we have shown, increasing prior assets moves the results in the direction of the classical TCE results (likely due to decreasing absolute risk aversion).

Tanzania, like much of Sub-Saharan Africa, appears to be in the early stages of food system modernization. Much of the food processing industry is characterized as having a proliferation of SMEs

[4] Note that David and Han (2004), in a systematic review of the empirical literature, found the evidence for this prediction unconvincing, with almost as many studies showing the opposite effect.

and a few larger firms that are differentiating themselves through product differentiation and marketing their products to a growing middle class of consumers. The results from this study appear to align with the findings of Kessides and others that find that the presence of rental markets (or in this case service markets) lowers the asset threshold to entry into the market, resulting in lower market concentration and lower industry size dispersion. However, if the historical patterns of other regions are any indication, it is likely that within the next couple of decades, driven by foreign direct investment and consumer demand for food quality and safety, the processing industry will consolidate and larger firms will overtake many of the micro-markets in the informal retail sector that many informal micro-firms are currently serving.

While we believe that industry consolidation is likely inevitable, we argue that there are at least two reasons to support SMEs, and, thereby, maintain a dynamic and diverse firm structure. First, as Li and Rama (2015) point out, there is much churning among small firms (most of them are “mice”), but “gazelles” can also emerge that are ready to exploit new market opportunities and prevent complacency among the larger firms. Second, Tanzania, and Sub-Saharan Africa in general, will require rapid employment growth in order to provide upward mobility for a surging youth population. While it was not the focus of this paper (and so therefore was not included above), our data shows that smaller firms tend to employ significantly more people, controlling for output (higher labor over output ratio) (table 4).

Table 4. Mean labor output ratio and profitability by size quintile

Size Quintile measured by total receipts (million TSH)	Mean Labor / Output ratio (FTE employees /million TSH)
1	0.407
2	0.063
3	0.026
4	0.014
5	0.006

As we have argued, the presence of a machine service market lowers the barriers to entry into the market, and the policy environment should continue to encourage this. Furthermore, there are a range of additional options to help build the capacity of the SME sector in a modernizing (and consolidating) food system. These include improving access to credit, training, technology and marketing, facilitating food safety certification and ease of business formalization, and improving infrastructure and in particular, access to affordable energy.

Acknowledgment

We would like to thank the United States Agency for International Development (USAID) for funding this research, and the Global Center for Food System Innovation (GCFSI) at Michigan State for providing graduate student assistantship. We would also like to thank all of the field research staff and enumerators that assisted with the data collection, and the business owners for participating in the survey.

Citations

Acemoglu, Daron, Pol Antràs, and Elhanan Helpman. 2007. "Contracts and Technology Adoption." *The American Economic Review*, 916–43.

Akoorie, Michèle EM, and Qiang Ding. 2009. "Global Competitiveness in the Datang Hosiery Cluster, Zhejiang." *Chinese Management Studies* 3 (2): 102–16.

Bandiera, Oriana, and Imran Rasul. 2006. "Social Networks and Technology Adoption in Northern Mozambique." *The Economic Journal* 116 (514): 869–902.

Bigelow, Lyda S, and Nicholas Argyres. 2008. "Transaction Costs, Industry Experience and Make-or-Buy Decisions in the Population of Early US Auto Firms." *Journal of Economic Behavior & Organization* 66 (3): 791–807.

Binswanger, Hans P. 1981. "Attitudes toward Risk: Theoretical Implications of an Experiment in Rural India." *The Economic Journal* 91 (364): 867–90.

Bricas, Nicolas, and Cécile Broutin. 2008. "Food Processing and Retail Micro-Activities and Poverty Reduction in Sub-Saharan Africa."

Coase, Ronald H. 1937. "The Nature of the Firm." *Economica* 4 (16): 386–405.

Coles, Jerilyn W, and William S Hesterly. 1998. "Transaction Costs, Quality, and Economies of Scale: Examining Contracting Choices in the Hospital Industry." *Journal of Corporate Finance* 4 (4): 321–45.

Conley, Timothy G, and Christopher R Udry. 2010. "Learning about a New Technology: Pineapple in Ghana." *The American Economic Review* 100 (1): 35–69.

Correa, Paulo G, Ana M Fernandes, and Chris J Uregian. 2010. "Technology Adoption and the Investment Climate: Firm-Level Evidence for Eastern Europe and Central Asia." *The World Bank Economic Review*, lhp021.

David, Paul A. 1966. "The Mechanization of Reaping in the Ante-Bellum Midwest." *Industrialization in Two Systems* 30.

David, Robert J, and Shin-Kap Han. 2004. "A Systematic Assessment of the Empirical Support for Transaction Cost Economics." *Strategic Management Journal* 25 (1): 39–58.

De Mel, Suresh, David McKenzie, and Christopher Woodruff. 2008. "Returns to Capital in Microenterprises: Evidence from a Field Experiment." *The Quarterly Journal of Economics* 123 (4): 1329–72.

Demsetz, Harold. 1988. "The Theory of the Firm Revisited." *Journal of Law, Economics, & Organization* 4 (1): 141–61.

Dercon, Stefan, and Luc Christiaensen. 2011. "Consumption Risk, Technology Adoption and Poverty Traps: Evidence from Ethiopia." *Journal of Development Economics* 96 (2): 159–73.

Doss, Cheryl R, and Michael L Morris. 2000. "How Does Gender Affect the Adoption of Agricultural Innovations?" *Agricultural Economics* 25 (1): 27–39.

Feder, Gershon, Richard E Just, and David Zilberman. 1985. "Adoption of Agricultural Innovations in Developing Countries: A Survey." *Economic Development and Cultural Change*, 255–98.

Giuliani, Elisa, and Martin Bell. 2005. "The Micro-Determinants of Meso-Level Learning and Innovation: Evidence from a Chilean Wine Cluster." *Research Policy* 34 (1): 47–68.

Griliches, Zvi. 1957. "Hybrid Corn: An Exploration in the Economics of Technological Change." *Econometrica, Journal of the Econometric Society*, 501–22.

Grossman, Sanford J, and Oliver D Hart. 1986. "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration." *The Journal of Political Economy*, 691–719.

Hart, Oliver, and John Moore. 1990. "Property Rights and the Nature of the Firm." *Journal of Political Economy* 98 (6): 1119–58.

Kessides, Ioannis N. 1990. “Market Concentration, Contestability, and Sunk Costs.” *The Review of Economics and Statistics*, 614–22.

Kessides, Ioannis N, and Li Tang. 2010. “Sunk Costs, Market Contestability, and the Size Distribution of Firms.” *Review of Industrial Organization* 37 (3): 215–36.

Kozel, Valerie, and Barbara Parker. 2000. “Integrated Approaches to Poverty Assessment in India.” *Integrating Quantitative and Qualitative Research in Development Projects*, 59–68.

Leahy, John V, and Toni M Whited. 1995. “The Effect of Uncertainty on Investment: Some Stylized Facts.” National Bureau of Economic Research.

Lerner, Josh, and Robert P Merges. 1998. “The Control of Technology Alliances: An Empirical Analysis of the Biotechnology Industry.” *The Journal of Industrial Economics* 46 (2): 125–56.

Li, Yue, and Martín Rama. 2015. “Firm Dynamics, Productivity Growth, and Job Creation in Developing Countries: The Role of Micro-and Small Enterprises.” *The World Bank Research Observer* 30 (1): 3.

Long, Cheryl, and Xiaobo Zhang. 2012. “Patterns of China’s Industrialization: Concentration, Specialization, and Clustering.” *China Economic Review* 23 (3): 593–612.

Lu, Liang, Thomas Reardon, and David Zilberman. 2016. “Supply Chain Design and Adoption of Indivisible Technology.” *American Journal of Agricultural Economics* 98 (5): 1419–31.

Masten, Scott E, James W Meehan, and Edward A Snyder. 1991. “The Costs of Organization.” *Journal of Law, Economics, and Organization* 7 (1): 1–25.

Nichter, Simeon, and Lara Goldmark. 2009. “Small Firm Growth in Developing Countries.” *World Development* 37 (9): 1453–64.

Olmos, Marta Fernández. 2010. “The Performance Implications of ‘grow or Buy’ Decisions in the Wine Industry.” *Food Policy* 35 (3): 256–64.

Olmstead, Alan L, and Paul W Rhode. 2001. “Reshaping the Landscape: The Impact and Diffusion of the Tractor in American Agriculture, 1910–1960.” *The Journal of Economic History* 61 (03): 663–98.

Parente, Stephen L. 1994. “Technology Adoption, Learning-by-Doing, and Economic Growth.” *Journal of Economic Theory* 63 (2): 346–69.

Pratt, John W. 1964. “Risk Aversion in the Small and in the Large.” *Econometrica: Journal of the Econometric Society*, 122–36.

Qanti, Sara Ratna, Thomas Reardon, and Arief Iswariyadi. 2017. “Triangle of Linkages Among Modernizing Markets, Sprayer-Traders, And Mango Farming Intensification In Indonesia.” *Bulletin of Indonesian Economic Studies*, no. just-accepted: 1–32.

Reardon, Thomas. 2015. “The Hidden Middle: The Quiet Revolution in the Midstream of Agrifood Value Chains in Developing Countries.” *Oxford Review of Economic Policy* 31 (1): 45–63.

Reardon, Thomas, Kevin Z Chen, Bart Minten, Lourdes Adriano, The Anh Dao, Jianying Wang, and Sunipa Das Gupta. 2014. “The Quiet Revolution in Asia’s Rice Value Chains.” *Annals of the New York Academy of Sciences* 1331 (1): 106–18.

Sonobe, Tetsushi, and Keijiro Otsuka. 2011. *Cluster-Based Industrial Development: A Comparative Study of Asia and Africa*. Palgrave Macmillan.

Trienekens①, Jacques H. 2011. “Agricultural Value Chains in Developing Countries a Framework for Analysis.” *International Food and Agribusiness Management Review* 14 (2).

Tschirley, D, J Snyder, M Dolislager, T Reardon, S Haggblade, J Goeb, L Traub, F Ejobi, and F Meyer. 2015. “Africa’s Unfolding Diet Transformation: Implications for Agrifood System Employment.” *Journal of Agribusiness in Developing and Emerging Economies* 5 (1).

Tschirley, David, Thomas Reardon, Michael Dolislager, and Jason Snyder. 2015. “Forthcoming, Journal of International Development, May, 2015.” *Journal of International Development*.

Wilkinson, John, and Rudi Rocha. 2009. “Agro-Industry Trends, Patterns and Development Impacts.” *Agro-Industries for Development*, 46–92.

Williamson, Oliver E. 2005. "Transaction Cost Economics." In *Handbook of New Institutional Economics*, 41–65. Springer.

Wooldridge, Jeffrey M. 2015. "Control Function Methods in Applied Econometrics." *Journal of Human Resources* 50 (2): 420–45.

Yang, Jin, Zuhui Huang, Xiaobo Zhang, and Thomas Reardon. 2013. "The Rapid Rise of Cross-Regional Agricultural Mechanization Services in China." *American Journal of Agricultural Economics* 95 (5): 1245–51.