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General Equilibrium Impacts in Imperfect Agricultural Markets: Evidence from the Tanzanian Cotton Industry

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This paper evaluates the local-economy general equilibrium effects of agricultural market structures by examining how market power of downstream intermediaries shape the economy-wide impacts of technological improvements in agriculture. Economic impact evaluations in developing countries usually do not include spillovers, and they do not explicitly consider market power. Using industry and original survey data from the Western Cotton Growing Area of Tanzania, I construct an index of oligopsony power of cotton ginners in their cotton purchase, and non-parametrically estimate the index as 0.28. The market power of downstream cotton ginners reduces cotton prices by 33-45 percent. A parametrized general equilibrium model of a cotton-producing local economy using micro-household data shows that a technological improvement in cotton production has significant spillover benefits for households not directly involved in cotton production. Intermediary market power of ginners not only mitigates the direct benefits for poor cotton-producing households but also significantly diminishes the indirect benefits for non-cotton-producing households. The direct income increases of technology improvement for the cotton producers are reduced by 2.2 to 5.6 percentage points, and the indirect income increases for the non-cotton producing households are reduced by 0.5 to 0.8 percentage points. A realistic analysis of policies aimed at raising welfare in rural economies must consider effects of market power. Taking agricultural market structure into account opens up new policy considerations and opportunities, including the benefits of laws limiting or proscribing anticompetitive behavior to prevent formation of mergers and coalitions downstream from farms.

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Abstract

This paper evaluates the local-economy general equilibrium effects of agricultural market structures by examining how market power of downstream intermediaries shape the economy-wide impacts of technological improvements in agriculture. Economic impact evaluations in developing countries usually do not include spillovers, and they do not explicitly consider market power. Using industry and original survey data from the Western Cotton Growing Area of Tanzania, I construct an index of oligopsony power of cotton ginners in their cotton purchase, and non-parametrically estimate the index as 0.28. The market power of downstream cotton ginners reduces cotton prices by 33-45 percent. A parametrized general equilibrium model of a cotton-producing local economy using micro-household data shows that a technological improvement in cotton production has significant spillover benefits for households not directly involved in cotton production. Intermediary market power of ginners not only mitigates the direct benefits for poor cotton-producing households but also significantly diminishes the indirect benefits for non-cotton-producing households. The direct income increases of technology improvement for the cotton producers are reduced by 2.2 to 5.6 percentage points, and the indirect income increases for the non-cotton producing households are reduced by 0.5 to 0.8 percentage points. A realistic analysis of policies aimed at raising welfare in rural economies must consider effects of market power. Taking agricultural market structure into account opens up new policy considerations and opportunities, including the benefits of laws limiting or proscribing anticompetitive behavior to prevent formation of mergers and coalitions downstream from farms.

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1. Introduction

Governments and donors across the globe make substantial investments in agricultural research, policies and support mechanisms to stimulate crop production and improve the welfare of farming households. A key focus of agricultural interventions is to increase the supply response of small farmers through technological improvements while creating direct welfare benefits for the targeted farmers. There is evidence that interventions aimed at increasing agricultural productivity have contributed to poverty reduction in many African and Asian countries (e.g., Datt and Ravallion, 1998; Dorward et al., 2004). However, there are also instances in which they failed to benefit the poor farmers (e.g., Pingali, 2007; Barrett, 2008).

Agricultural research in developed countries gives compelling evidence that imperfect competition and market power, both upstream and downstream from the farm, can be crucial factors in agrarian markets (e.g., Sexton and Lavoie, 2001; McCorriston, 2002; Jensen, 2010; Russo, Goodhue and Sexton, 2011). The presence of imperfect competition potentially reduces the magnitude of policies by creating deadweight loss. Agricultural intermediaries with market power may capture some or most of the benefits of policies and shape the distribution of welfare (Sexton et al., 2007).

Most policy evaluations in developing countries assume markets are perfectly competitive. These analyses do not formally consider the role of agricultural market power in explaining why productivity increases in crop production may not translate into higher welfare of farming households. While there is considerable agricultural research on imperfect competition in the developed countries, only a few studies have explored market failures and market power for agricultural input procurement in developing countries (Rosegrant and Binswanger, 1994; Spielman et al., 2014; Dillon and Barrett, 2017; Barrett et al., 2017). Furthermore, formal analysis of agricultural market power using modern new empirical industrial organization (NEIO) methods (Kaiser and Suzuki, 2006) is lacking in the developing world.[1]

The impacts of agricultural policies and interventions can spread well beyond the directly targeted farmers as economic spillovers to households, other than the target group, due to market linkages that connect households and local businesses. The linkages could be via consumption and production, credit markets, and other social interactions. A nascent literature in economics has developed ways to measure these spillovers in local economies using randomized experiments and

[1] Only two studies so far have quantified agricultural market power using the Lerner index (Lerner, 1934) in developing country contexts. Lopez and You (1993) estimate a Lerner index of oligopsony for Haitian coffee exporters, and Kopp and Brummer (2017) estimate market power using the Lerner index for Indonesian rubber traders.

general equilibrium (GE) frameworks (Angelucci and De Giorgi, 2009; Filipski and Taylor, 2012; Thome et al., 2013; Taylor and Filipski, 2014, Gupta et al., 2017). Nevertheless, the influence of market power on spillovers has not been a focus of agricultural development impact evaluations (Taylor, 2018). If market power influences the direct impacts of policies on farmers, we would also expect it to affect income and production spillovers in rural economies. It potentially mitigates the local economy benefits of agricultural interventions. The reduction in benefits magnify in rural areas of developing countries because of strong market linkages within local economies.

This paper examines the role of market structures of downstream intermediaries and evaluates the GE impacts of agricultural policies in imperfectly competitive agricultural markets. In particular, I evaluate the GE welfare effects of agricultural market power by estimating the direct and the spillover effects of technological improvements in agriculture when the downstream sector is imperfectly competitive and compare them to the synthetic case of perfect competition. Using data from the cotton industry in the Western Cotton Growing Area (WCGA) of Tanzania, I estimate an index of oligopsony power for cotton ginners in their input (raw cotton) market.[2] The oligopsony index of market power for ginners is non-parametrically estimated from a market structure model using NEIO methods. The market power of downstream ginners significantly reduces cotton prices received by farmers.

Integrating the market structure model into a GE framework linking cotton ginners to the local economy of cotton and non-cotton producers, I parameterize the model econometrically, using micro-household-level data from the WCGA. Simulations reveal that technological improvements in cotton production have significant economic spillovers to households not directly involved in cotton production. Intermediary market power of cotton ginners mitigates both the direct benefits for poor cotton-producing households as well as the indirect benefits for non-cotton-producing households. The direct income increases of technology improvement for the cotton producers as well as the indirect income increases for the non-cotton producing households are reduced in the local economy.

Understanding the impacts of market power is essential for policies that aim to benefit poor farmers, because agricultural market power has substantial direct, as well as indirect (spillover), effects in rural economies. Many interventions have widespread spillover effects; dissipation of primary benefits due to market power also reduces spillover benefits. Insights from this paper

[2] Cotton farmers produce raw cotton that is used by cotton ginners to produce cotton lint. Raw cotton is also called seed cotton. To distinguish between seed-cotton, cotton-seed, and cotton-lint, I use the terminologies cotton for seed (or raw) cotton, lint for cotton-lint, and ginners for cotton-ginners throughout the paper.

enhance our understanding of agricultural policies and their impacts in both developing and developed countries for two reasons. First, I highlight the role of intermediary market power in shaping the welfare outcomes of productivity-enhancing agricultural interventions. Second, the integration of a market structure model within the general equilibrium framework reveals that downstream market power in agriculture can have further negative consequences via spillovers in the rural economies than what most evaluations based on a partial equilibrium analysis can overlook.

For realistic assessments of effectiveness, analysis of policies aimed at raising welfare in rural economies must consider the oft-hidden effects of intermediary market power. Taking these effects into account may open new policy angles and opportunities. There are implications for introducing laws that limit or proscribe anticompetitive behavior to prevent mergers and buyer coalitions downstream of the farm. Introducing interventions that ensure elastic demand of farm products complement the welfare-enhancing programs that governments undertake in potent and dynamic – yet easily overlooked – ways.

The paper is organized as follows: Section 2 contextualizes how downstream market power affects the direct and indirect welfare within the local economy. In Section 3, I outline a methodology to set up a theoretical market structure model integrated with a local economy-wide GE framework. Section 4 gives the setting of the cotton industry in Tanzania and describes the local economy of cotton producers. In Section 5, I describe the empirical strategy and present the estimation results. The results of simulations of market power and an intervention of technological improvement in cotton productivity are presented in Section 6, followed by concluding Section 7.

2. Local economy Impacts of Agricultural Market Power

The households in any local economy that do not produce the targeted crop (of a policy) engage in the production of other agricultural commodities, livestock, and businesses such as retail, services or other activities. All production activities use factors as well as intermediate inputs that are usually sourced both inside and outside the local economy. Assessing the impacts of agricultural policies in rural economies is complicated by the interactions among various commodity and factor markets and the interlinkages among households participating in diverse production activities. However, as Barrett (2008) explains, current research on technological change in staple production uses either a micro-household or aggregate (national) computable general-equilibrium modeling strategy. A micro-household focus misses the general-equilibrium effects of technology change, including price effects.

A detailed impact evaluation of spillover effects of market power is missing because data for measuring market competitiveness and local economy linkages are not readily available or gathered. Furthermore, identification of impacts of intermediaries' market power is not possible through randomized experiments. Through local inputs and goods markets, prices transmit distributional impacts from the intermediaries to the non-producers of an agricultural crop. Hence, depending on the extent to which the downstream sector is competitive, both the direct and indirect (spillover) benefits in the local economy are affected.

The lack of competitiveness of intermediaries reduces the local economy welfare for two reasons. First, market power diminishes the total gains from a policy intervention by creating deadweight loss. Second, if the intermediaries capture a significant proportion of the benefits from the intervention, the directly targeted households remain with lower welfare gains. The intermediaries, in theory, can seize substantial amounts of economic surplus if they are located outside the local economy. As a result, most of the benefits of technological gains might leave the local economies where the targeted households live. This is particularly true in developing country contexts where the intermediaries are usually based in urban areas, and, thus, extract welfare gains away from the rural economies.

The detrimental effects of market power for the targeted households are exacerbated in settings where transactions costs are high. Higher transactions cost impels farmers to sell their output in localized markets that are characterized by local market clearing conditions. The downstream intermediaries' limitations to absorb larger production volumes could dampen the welfare gains for the directly targeted households even further. There are two levels of capacity restrictions that intermediaries might have. First, while operating in local markets, they cannot accommodate larger farm supply due to localized restraints. Such restraints could arise from high transactions costs for the intermediaries themselves because of their inability to adjust fixed inputs in the short run, for example, having limited space in their transport vehicles, and, moreover, they could be cash constrained in daily spot markets. Second, after local procurement, the intermediaries may additionally have capacity constraints in their processing facilities, which will have further implications for adjusting the local procurement markets.

In the Tanzanian cotton industry, downstream ginners process cotton to produce lint, cottonseed cake and cotton oil, which are then sold as final products. The ginners procure cotton from different cotton-producing regions where they have varying degrees of market power in purchasing cotton. I explore both the spatial and temporal dimension of cotton purchase by the ginners and indicate how the market structures vary regionally. The average prices received by farmers depend on the number of ginners operating in a cotton-buying season. The ginners can exercise buyer power in two ways: one, by exercising market power unilaterally, as in a Cournot game, depending on the number of ginners in a region, and, two, by forming ginner coalitions. Coalitions of ginners exist in some regions. In the other areas without ginner coalitions, the average prices received by the farmers are significantly higher than regions with coalitions due to competition among ginners.

The benefits of any technological change in cotton production could be transmitted downstream to cotton ginners and outside of the local economy. Whether or not this happens depends mainly on the market structure of the downstream ginners. Adverse price impacts are not a concern if farmers are price takers in global markets. However, since cotton is bulky (and thus expensive) to transport, all cotton farmers, the majority of whom are poor, sell their output at village buying posts set up by local ginners. Furthermore, localized constraints for the ginners and their agents to carry larger supplies of cotton could exacerbate the welfare gains.

I consider a technological improvement from agricultural R&D that holds the potential to increase cotton output. The cotton-producing households gain from higher productivity owing to the technological change. Higher wages, induced by productivity gains, benefit wage labor households while raising costs for cotton producers who hire workers. Changes in income and demand alter the prices of local non-tradable commodities, and this indirectly affects consumers, firms that produce non-tradable commodities and other firms that demand non-tradables as intermediate inputs. The reduction in benefits from a technological change has ramifications for the entire local economy where the cotton producers live and are interconnected to other households and businesses. The lower the benefits for the cotton farmers, smaller are the spillovers for other households. Also, if the intermediaries are not a part of the local economy, like outside investors or absentee owners, the share of the benefits captured by them cannot reach the local economy via income spillovers.

3. Methodology

First, I construct a market structure model of intermediaries that allows for varying degrees of market power in their purchase of the farm supply. The market structure model of ginners shows how the degree of market competitiveness, captured by an index of ginner market power, affects the welfare of cotton farmers. This happens through transmission of impacts via price and quantities of cotton in the market. Second, I present a stylized theoretical setup of a GE model that connects the cotton-farmers with other farm and non-farm households in the local economy of the WCGA. Using the market structure model of downstream ginners, and integrating this model with the GE framework, I test for hypothesized scenarios using simulations and econometric methods to identify and predict outcomes of technology change in cotton production.

3.1. Market Structure Model

Assume that cotton is a homogeneous (not vertically differentiated by quality) crop produced by many competitive farmers. The total cotton output is procured by ginners who process it with other marketing inputs to produce lint, which is then sold in a competitive output market. The processing is done using fixed proportions such that the marketing inputs cannot be substituted for cotton. The cotton production is characterized by N identical cotton producers with a constant return to scale (CRS) production technology. A representative farmer produces cotton with two inputs, one variable and the other fixed.[3] The application of this model in the empirical section uses the results from the multiple-inputs case for farmers belonging to different groups based on their activities; but for simplicity of exposition and to spare additional notations, the two-input case with identical farmers is intuitive to understand the generalization.

I assume a specific CRS Cobb-Douglas production function of a cotton farmer i with one variable input L and one fixed input K, fixed at $\overline{K}$, such that

$$q_{c,i} = A{L_i}^{\alpha}{\overline{K}_i}^{1-\alpha} \qquad with \qquad 0 < \alpha < 1$$

where A is the technology parameter and α is the exponent on the variable input. Without loss of generality, normalizing the total number of farmers N to one, the total short-run farm supply of cotton in the local economy is

$$Q_c = Q_c(p; W, A) = A^{1/_{1-\alpha}} p^{\alpha/_{1-\alpha}} W \tag{1}$$

where w is the variable input price and $W = \overline{K}\left(\frac{\alpha}{w}\right)^{\alpha/_{1-\alpha}}$ is a constant. The total farm supply depends on the variable input price , the technology parameter A, and the fixed input quantity $\overline{K}$. The supply function has standard first derivatives, i.e., it is increasing in output price, the shift parameter and the

[3] Here, I show the case with two inputs and then extend it to show a general case with multiple inputs, which is presented in Appendix A1.

fixed input, but decreasing in the input price. From (1), the short-run farm supply elasticity, $\epsilon = \left({}^{p}/_{Q_c}\right)\left({}^{\partial Q_c}/_{\partial p}\right)$ of cotton is

$$\epsilon = \frac{\alpha}{1-\alpha} \tag{2}$$

The ginners are identical in their technology use fixed proportions of cotton and processing/marketing inputs in the production of lint such that their cost is separable in the inputs. Assume, without loss of generality, that one-unit of cotton is used to produce one-unit of lint and thus $Q_c = Q_g = Q$, where Q_g is total lint produced by all the ginners. In addition, in each cropping season, there are no inventories. Each ginner is constrained by a maximum ginning capacity that they cannot adjust in the short run.[4] The capacity constraint of the ginning industry is at $\bar{Q}_g$ that limits the total amount of cotton the ginners can process in the short run. The ginners can absorb any excess supply of cotton from the farm as long as there is excess ginning capacity. Upon reaching their full capacity, the ginners' demand for cotton is assumed to be perfectly inelastic. To understand a representative ginner's profit maximization problem, first consider the cost-side of the ginner.

The assumption of fixed-proportions production of lint and the capacity constraints in ginning gives the short-run total cost function of a representative cotton ginner j as

$$C_j = \begin{cases} (c(\mathbf{V}) + p)q_{g,j} + F & \text{if} \quad q_{g,j} < \bar{q}_{g,j} \\ \infty & \text{if} \quad q_{g,j} \geq \bar{q}_{g,j} \end{cases} \tag{3}$$

where $\mathbf{V}$ is the vector of prices for variable processing/marketing inputs and $q_{g,j}$ is the quantity produced by a representative ginner, which is capped at $\bar{q}_{g,j}$ for that ginner.[5] $c(\mathbf{V})$ is the marginal cost of processing inputs and F is fixed cost in lint production in the short run.

[4] The assumption of capacity constraints in agricultural intermediaries is common in both developed and developing country contexts (e.g. Carriquiry and Babcock, 2002; Sexton, 2012).

[5] If there are M ginners in the industry, each with $\bar{q}_{g,j}$ as the capacity constraint, then $\bar{Q}_g = M\bar{q}_{g,j}$.

Upon reaching the maximum capacity at $\bar{q}_{g,j}$, ginner j is unable to absorb any excess farm supply in the short-run without increasing the number of cotton gins. The costs of purchasing new gins to adjust and absorb more cotton is assumed to be infinitely high within a cotton-buying season. This is a reasonable assumption to characterize the short-run total cost function of a ginner as long as purchasing new gins is very expensive and a decision that a ginner takes over a longer time period.[6] The sharp discontinuity in the cost function implies that the short-run marginal cost of ginner j is indeterminate and undefined at $\bar{q}_{g,j}$. This is because the slope of the total cost function for any infinitesimal changes of output is not the same in either direction of $\bar{q}_{g,j}$, i.e. in a small $\delta > 0$ neighborhood around $\bar{q}_{g,j}$ the *right-hand* and the *left-hand* derivatives of C_j are different (e.g. Bishop, 1948; Stoft, 2002).[7]

The marginal cost of production of a representative ginner MC_j can be obtained by partially differentiating (3) with respect to $q_{g,j}$ until $q_{g,j} = \bar{q}_{g,j} - \delta$ where δ is an infinitesimal positive number. As $\delta \to 0$, i.e. as $q_{g,j} \to \bar{q}_{g,j}$, MC_j is undefined. Mathematically, for values of $q_{g,j} > \bar{q}_{g,j}$, MC_j is also undefined. The short-run marginal cost of ginner j is given in equation (4) as

$$MC_j = \begin{cases} (c(\mathbf{V}) + p) & \text{if} \quad q_{g,j} < \bar{q}_{g,j} \\ \text{UNDEF} & \text{if} \quad q_{g,j} > \bar{q}_{g,j} \end{cases} \tag{4}$$

This implies that a ginner faces a constant marginal cost of lint production, which is the sum of per-unit variable cost of processing inputs and price of one unit of cotton, until the maximum ginning capacity is reached. At the maximum ginning capacity, the marginal cost of production is undefined. Beyond the maximum capacity, the marginal cost is infinitely high which prohibits the ginners from processing any extra farm supply in the short run. Next, I use the cost-side of the ginner's problem to characterize the profit-maximization problem for the representative ginner j and describe the equilibrium in the cotton industry when the ginning capacity does not bind, i.e. for values of $q_{g,j} <$

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[6] Even if the decision to buy more gins is made in a given buying season, the installation and operation of the newly purchased gins in that season is unlikely to happen.

[7] The limit is not defined at $\bar{q}_{g,j}$, which makes the first derivative of the total cost function undefined at that point.

$\bar{q}_{g,j}$. The equilibrium price and quantity depend on the index of ginner market power and other parameters. The comparative statics and the limiting cases of perfect competition and monopsony are analyzed when the ginners have excess capacity.

3.1.1. Equilibrium

The profit maximization problem for ginner j when $q_{g,j} < \bar{q}_{g,j}$ is

$$\max_{q_{g,j}} \pi(\cdot) = \big(P - (c(\mathbf{V}) + p)\big) q_{g,j} \tag{5}$$

where $\pi(\cdot)$ is the profit function, P is the competitive price of lint that ginners take as given in their output market. Assuming $q_g = q_c = q$, the first-order condition (FOC) of (5) gives

$$\frac{\partial \pi(\cdot)}{\partial q} = \big(P - c(\mathbf{V})\big) - p\left[1 + \left(\frac{Q}{p}\frac{\partial p}{\partial Q}\right)\left(\frac{\partial Q}{\partial q}\frac{q}{Q}\right)\right] = 0 \tag{6}$$

Rearranging the terms in the FOC as given in (6), I can solve for cotton price as a function of $P, c(\mathbf{V}), \theta$, and ϵ

$$p = \left(1 + \frac{\theta}{\epsilon}\right)^{-1} \big(P - c(\mathbf{V})\big) \tag{7}$$

where $\epsilon = \left(\frac{p}{Q}\right)\left(\frac{\partial Q}{\partial p}\right)$ is the farm supply elasticity of cotton and θ is a conjectural elasticity parameter in the input market of cotton procurement for the ginners, which also measures the degree of oligopsony power.[8] I interchangeably use the terms (input-side) market power and oligopsony power since the output side oligopoly power is not considered in this analysis. The term conjectural elasticity is intuitive for capturing the notion of input-side market power of ginners. It is a ginner's perception of how her rivals will respond to her procuring and processing one additional unit of cotton, i.e. $\theta = \left({}^{q}/_{Q}\right)\left({}^{\partial \mathrm{Q}}/_{\partial q}\right)$.

The economic intuition behind the possibility of cooperative or quasi-cooperative outcomes is due to the dynamic nature of ginners' strategic interactions with other ginners. Since the ginners participate in cotton procurement almost every period, cooperation or quasi-cooperation among

[8] The above FOC could be generalized to include output market power for cotton ginners and then it would include two additional parameters: demand elasticity of lint and conjectural elasticity of ginners in their output market. That case is not presented in this paper.

them can be sustained as a non-cooperative equilibrium in infinitely repeated interactions (Friedman, 1971). The infinitely repeated nature of interactions among the ginners allows ginners to have market power. The outcomes in infinitely repeated games will be different from the non-cooperative Nash equilibrium outcome, which arise from a one-period static interaction. One-period games establish the existence of a non-cooperative equilibrium of defection among ginners, which gives the competitive equilibrium price. However, given the dynamic nature of interaction, varying degrees of market power, other than zero, are possible.

The range of oligopsony power is between zero and one with $\theta = 0$ representing the case of perfect competition in cotton procurement, and $\theta = 1$ indicating a monopsonist ginner, i.e. a single buyer of cotton or a ginners' cartel. The intermediate values of the parameter represent different degrees of oligopsony behavior like those arising from Cournot competition, with higher values indicating lower competition in cotton procurement.

The concept of the ginning industry's perceived marginal factor cost (PMC) is defined as a linear combination of the inverse supply function $S(Q)$ of cotton and the monopsony marginal factor cost curve (MFC). The PMC curve is can be expressed as

$$PMC(Q) = \theta MFC(Q) + (1-\theta)S(Q)$$

where the perceived marginal factor cost curve is the inverse supply function when the ginners are perfectly competitive, i.e. $\theta = 0$, and the marginal factor cost curve when $\theta = 1$. For further development of this idea, see Saitone, Sexton and Sexton (2008) and Saitone and Sexton (2009).

The equilibrium price and quantity of cotton in this setup is obtained by solving (1) and (7) using (2). The equilibrium price p^* and quantity Q^*, assuming $\theta \in (0,1)$ are

$$p^* = \frac{[P-c(\mathbf{V})]\alpha}{\alpha+\theta(1-\alpha)} \qquad\qquad Q^* = A^{1/_{1-\alpha}} \left[\frac{[P-c(\mathbf{V})]\alpha}{\alpha+\theta(1-\alpha)}\right]^{\alpha/_{1-\alpha}} \mathrm{W}$$

3.1.2. Comparative Statics with Technology Change

To present the comparative statics and limiting cases of oligopsony power, I assume that the ginning capacity does not bind. The limit cases of perfect competition and monopsony in cotton procurement by ginners can be obtained by plugging in the value of θ as 0 and 1, respectively. When the ginners are perfectly competitive, the equilibrium price for cotton is $p^{PC} = [P - c(\mathbf{V})]$. This means that the ginners break even in lint production with no variable profits and the cotton farmers receive the maximum price. The other extreme is the case of a monopsonist ginner or a coalition of ginners. Such a scenario would result in the market price to be a monopsonist price $p^M = \alpha[P - c(\mathbf{V})]$. Since parameter α, the exponent on the variable input is less than 1 due to the assumption of CRS cotton production, I have $p^M \leq p^* \leq p^{PC}$.

[Figure 1 Here]

Figure 1 shows the equilibrium market price and quantity of cotton under different degrees of ginner market power. The subscript 0 against the quantities represent an initial equilibrium which are later changed in Figure 1 to depict how price and quantity change with an improved technology through change in parameter A. $S(Q_0)$ is the inverse supply curve of cotton farmers with MFC_0 as the marginal factor cost and PMC_0 is the perceived marginal cost at the initial supply. The maximum ginning capacity of the industry is at $\bar{Q}_g$ in Figure 1. Any excess farm supply of cotton from an improved technology can be absorbed by the ginners, i.e. the capacity constraints in the ginneries do not bind even after the increased cotton production from farmers.

From Figure 1, given $\theta = 0$, the perfectly competitive price and quantity are p^{PC} and Q_0^{PC}, respectively. For $\theta = 1$, the monopsony case, the equilibrium price and quantity are p^M and Q_0^M, respectively. The equilibrium obtained in between the perfectly competitive and the monopsony cases are for values of $\theta \in (0,1)$. The values of θ between 0 and 1 include the possibility of any degree of oligopsony power in cotton procurement market. In Figure 1, the higher the slope of the perceived marginal cost curve, i.e. the closer it is to MFC_0, the higher the degree of market power; and, the closer it is to the inverse supply function $S(Q_0)$, the market for cotton purchaser is closer to the case of perfect competition.

[Figure 2 Here]

The equilibrium price and quantity, expressed in terms of the parameters of the model, have intuitive comparative static results. I show the comparative statics with respect to oligopsony power θ, the shift parameter A, and the cross partials of θ and A. The marginal effect of oligopsony power in the non-limit cases of θ on market clearing price and quantity of cotton are $\frac{\partial p^*}{\partial \theta} < 0$ and $\frac{\partial Q^*}{\partial \theta} < 0$. This means that higher degree of market power results in lower equilibrium price and quantity of cotton in the industry. The farmers face a less competitive output market to sell cotton, where they receive a lower price and produce less cotton. Graphically, this means that in Figure 2, as

θ increases, the PMC_0 curve is closer to the MFC_0 curve and hence the equilibrium quantity and price are lower than in a case with lower values of θ.

Other things constant, the marginal effect of an improved cotton technology on market clearing price and quantity of cotton are $\frac{\partial p^*}{\partial A} = 0$ and $\frac{\partial Q^*}{\partial A} > 0$. The equilibrium price remains unaffected since the technology in the Cobb-Douglas production function is assumed to be factor-neutral. In other words, unless the technology affects productivity of the variable input in production, price will not change with improved technology when the ginning capacity is not constrained. Another channel through which technology can affect cotton price in this model is if the demand for ginners' lint in the world or final output market changes with cotton technology. That is not the case here since the ginners face a competitive output market for lint and are assumed to be price takers.

Technological improvement with excess ginning capacity, thus, has no impact on equilibrium cotton price. However, ceteris paribus, total equilibrium quantity produced of cotton increases with technological improvement leading to welfare gains for the cotton producers since price remain unchanged. The cross-partial effects of technology and oligopsony index on market clearing price and quantity of cotton are $\frac{\partial^2 p^*}{\partial A \partial \theta} = 0$ and $\frac{\partial^2 Q^*}{\partial A \partial \theta} < 0$, respectively. The cross partial effect on price is trivial since technology does not affect it. However, the cross partial on equilibrium quantity indicates that the effect on increased output due to technological improvement is mitigated due to higher degrees of market power, resulting in mitigated welfare benefits for the cotton producers and others within the local economy.

3.2. Local-economy General Equilibrium Model

Evaluating general equilibrium impacts are not possible with structural micro (i.e. agricultural household) or aggregate country-level computable general-equilibrium (CGE) models. It is also not practical to measure these impacts with a reduced-form experiment since randomization of technology treatment could be challenging to perform at a sufficiently large number of clusters to obtain precise econometric estimates. Understanding the spillovers within a local economy requires a micro household-level GE approach that captures the impacts of crop-producing households on the local markets.

Technological change creates direct and indirect (spillover) impacts. Producers benefit directly from increases in productivity, which raise their incomes and consumption possibilities. The spillovers from technology change operate principally through prices. Depending on the equilibrium price of cotton determined from the models of processing capacity and market structure of downstream sector, any change in cotton production affects a considerable amount of cash that flows in the local economies, where households tend to spend most of their income close to home, and many of the goods and services households demand are supplied within the local economy.

Because of impacts on input markets and consumption demand, an additional shilling from cotton production could generate a real-income multiplier greater than one shilling in the cotton-growing regions. Local demand and supply side constraints, on the other hand, may limit the multiplier effects of technological change on production and incomes. In my case study in Tanzania, cotton farmers are directly affected by any policy or project aimed at cotton production. Thus, they are analogous to the 'eligible' households in an experimental design. I also include non-cotton producing agricultural households and other households that are not primarily agricultural. These households, by definition, are 'ineligible' for the cotton-productivity "treatment."

3.2.1. Households, Activities and Model Calibration

I use agricultural household models to nest each household group's productive activities, income sources, and expenditure patterns. These groups participate in many activities, including cotton production, cultivation of other crops, livestock production, and businesses like retailing and services. I use micro-survey data to econometrically parameterize a series of agricultural household models (see Singh, Squire and Strauss, 1986; Taylor and Adelman, 2003) to construct an economy-wide general equilibrium model. The households are then nested within a GE framework following the local economy wide impact evaluation (LEWIE) methodology presented in Taylor and Filipski (2014).

The local economy includes cotton producers, other agricultural households involved in production of crops (other than cotton) and livestock, businesses, and some households that are landless laborers. The businesses are classified as retail, services, ginning, or other non-agricultural (including local food processers). All activities require factors like hired and family labor, land and capital that are obtained from within the local economy and some intermediate inputs like purchased agricultural inputs or merchandise for shops are sourced outside the local economy. Trade in goods, services and factors also connect households within the cotton producing local economy to outside. Like cotton production, all other activities in the local economy are assumed to be described by activity-specific CRS Cobb-Douglas production functions for the transformation of factors into outputs such that for household i involved in activity m, the production function is

$$q_{m,\,i} = A_m HL_{m,i}{}^{\beta_{m1}} FL_{m,i}{}^{\beta_{m2}} \overline{T}_{m,i}{}^{\beta_{m3}} PI_{m,i}{}^{\beta_{m4}} \overline{K}_{m,i}{}^{\beta_{m5}} \tag{8}$$

$$\text{with} \sum_{k=1}^{5} \beta_{mk} = 1$$

where A_m is the technology parameter, HL_m is the hired labor, FL_m is the family labor, PI_m is purchased inputs, T_m is the land input and K_m is the capital stock used in the production of activity m. The restriction on the exponents result in a CRS production function.

I assume that household capital and land endowments are fixed, and neither capital nor land can be reallocated between activities, including cotton. In the immediate short run for most activities, this is a reasonable assumption. Thus, the rental rates on capital and land are household-specific shadow values. Most households also supply wage labor to local production activities, and they purchase goods and services locally or outside the local economy. I also assume that labor is tradable within the local economy implying that wages are endogenous. Labor supply elasticities cannot be estimated with the available data and are assumed to be nearly perfectly elastic.

All the households in the local economy are linked in the consumption market. The consumption demands are modeled as household-specific linear expenditure systems, implying Stone-Geary utility functions. The estimated expenditure functions on various food and non-food categories are obtained from estimation of a system of equations for different household categories. The households in the local economy consume and demand a locally produced subsistence crop, livestock, retail and services. No households consume cotton and all the produced cotton is sold exclusively to the ginners. The households also spend a proportion of their income on goods that are produced outside the local economy, which enters the GE model as a trade with the rest of the world (ROW).

The price and the quantity of total cotton produced in the local economy is determined by the equilibrium condition shown in equations (1), (2) and (7) in the market structure model when the ginners' processing capacity does not bind. The impacts of market power of ginners enter the local economy through equilibrium cotton price and quantity. The direct and indirect benefits of a technological improvement in cotton production for the cotton farmers and others within the local economy, respectively, thus depend on the ginning capacity and the degree of competitiveness of ginners.

Cotton price carries the impact of market power of ginners throughout the local economy where the cotton producers live. The effects translate from the market structure model described above to the local economy through the GE-LEWIE model. The structural model provides the change in equilibrium price of cotton following a change in market power and technological improvement. Using the price change for cotton, I simulate the impacts on welfare of different household groups in the local economy using the LEWIE model for the cotton local economy of WCGA, including impacts on the activities of production.

The household data provide initial values for all variables in the LEWIE model. An input spreadsheet contains all the initial values of each variable in the model, together with the model parameters and standard errors and is interfaced with GAMS, where the LEWIE model resides.[9] The sets, accounts, variables, parameters, equation definitions, and equations in the model are also summarized in Appendix A3 in Tables A1-A6. The model equations include production and input demand functions; expenditure functions for each household group; and local market-clearing conditions, which determine prices for a non-tradable good or, for a tradable good, net trade with the rest of the country at exogenous prices.

3.2.2. Model Closure

For each good and factor, closure rules determine where markets clear and prices or wages are determined. A challenge in general equilibrium analysis is that we usually do not know exactly where prices are determined. The two theoretical models, the model of processing capacity and the model of market structure, give the equilibrium price and quantity of cotton in the GE framework. However, the prices of other goods and factors need to be determined.

I assume that household capital and land endowments are fixed and neither capital nor land can be reallocated between activities. These are reasonable assumptions, particularly in the short run, given the choice of activity aggregation: crop cultivation is of little use in livestock or service activities, especially when markets are thin.[10] Thus, the rental rates on capital and land are household-specific shadow values.

Labor is tradable within the WCGA, but considering high transaction costs, the region cannot freely 'import' wage workers from other parts of the country; thus, wages are endogenous. Impacts of labor-demand shocks may be muted if there is an elastic supply of labor, as is likely to be the case in the WCGA where un- and under-employment rates are high. Labor supply elasticities cannot be

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[9] The LEWIE model is available as a GAMS text file upon request.

[10] This also means that agricultural tradables (which I aggregated with all other tradables) do not compete with agricultural non-tradables for land and capital, which I believe is an acceptable simplification. Tradables represent a small fraction of total agricultural output and tend to be different crops (e.g., fruit trees). Alternatives offer little appeal. Perfectly re-allocable land would overinflate supply responses. Imperfectly elastic land reallocation *a la* Jonasson et al. (2014) would have required for us to guess at elasticities of transformation, for little gain.

estimated with available data. I assume a nearly perfectly elastic labour supply (=100).[11] All other goods in the model are assumed to be tradable, with prices determined outside the WCGA. Thus, the model distinguishes among three levels of market closure: the household, the regional market, and outside the region.[12]

4. Data

Almost half a million smallholder and medium farmers are engaged in cotton production in some of the poorest and least fertile areas of Tanzania. The country produces about seven percent of the total cotton in Africa. Tanzania is the fourth largest exporter of cotton-lint in Africa after Benin, Egypt and Togo, and accounts for 8.2 and 0.1 percent of total exports of Africa and the world, respectively. Tanzanian farmers face several challenges in cotton production, which include poor soil quality and lack of inputs. They fail to procure inputs often due to missing input and credit markets, which prevent them from achieving the income gains of their US, Asian, Australian or even West African counterparts. Tanzania's average cotton yields are 550 kg per hectare, which are almost a quarter of the world average including smallholders in West Africa who get twice as much in yields per hectare (Tanzania Gatsby Trust, 2018).

The WCGA, which has about 20 percent of the total population in Tanzania, produces 95 percent of the total cotton produced in the country. Figure 3 shows the nine cotton growing regions (in red border) in WCGA. In this paper, I use three datasets: first, a primary data on cotton- and non-cotton-producing farmers, including livestock and local businesses in WCGA; second, a survey of ginners on production and costs for 2012-2015 collected by Omari (2016); third, annual datasets collected for 2014-2016. The surveys for the primary data were collected by Royal Tropical Institute (KIT) and Cotton Sector Development Programme (CSDP) of Tanzania Gatsby Trust (TGT) in 2014.

[Figure 3 Here]

Primary data on local economy actors from the KIT survey are used to estimate the inputs in the LEWIE model. Twenty districts were randomly selected from the nine regions. Then three villages were randomly selected from each district, and respondents were chosen randomly within each village. The KIT dataset has a total of 60 villages and 1534 households, which is used to link the cotton

[11] This reflects excess labor supply in the WCGA and is like the way labor is treated in social accounting multiplier (SAM) models. Excess labor supply can be expected to lower inflationary pressures by limiting wage increases. It does not remove inflationary pressures, however, because land and capital constraints continue to limit the local supply response.
[12] Model Validation and sensitivity analysis of the general equilibrium model are available in Appendix A2.

producers to other households in the local economy. The second dataset is an unbalanced panel data on 10 cotton ginners for the years 2012-2015.[13] The CSDP annual datasets give information on annual production and procurement of cotton regionally.

4.1. The Tanzanian Cotton Ginning Industry

Almost all of Tanzania's cotton production is concentrated in nine cotton-growing regions in the WCGA. Only 5 percent of cotton grows in the eastern part of Tanzania. The cotton ginneries are scattered across these nine cotton-growing regions. Of the 81 ginners in the WCGA, not all are operational every year. Some ginners do not find it profitable to get licenses for all their ginneries, and sometimes ginners exit the market temporarily (Omari, 2016).

For example, in 2012-13, 43 ginners procured cotton from farmers. This number decreased to 28 in 2014-15, and there were only 22 active ginners with licenses in 2015-16 season. Hence, the structure of downstream ginners varies every year. This also indicates that the Tanzanian cotton ginners are characterized by excess ginning capacity. In fact, the Tanzania Cotton Board (TCB) ginneries data for 2015 indicates that 36 percent of the ginneries are dormant, and of those active, they are running at 79 percent capacity on average (Price Waterhouse Coopers, 2015).

Figure 4 shows the location of 67 ginneries in the WCGA.[14] The majority of ginneries are located in Shinyanga, and then followed by Mwanza, and Mara. There are no ginneries in Geita, Kigoma and Simiyu. Tabora region has two ginneries, and Kagera and Singida has one each. The ginneries are owned by private ginning-company owners (ginners), each of whom independently own a ginnery in one of the six cotton-growing regions. A typical ginner usually has a management team, permanent, and seasonal staffs who manage her ginnery. The owners are usually based in Dar-es-Salam although their ginneries are in the WCGA. As a result, most of the ginner profits escape the local economy of the WCGA.

Ginners need license to operate and purchase cotton from a district in any buying season. The district(s) that a ginner decides to procure depends on the location of her ginneries. The greater the distance of ginneries from primary catchment area, the larger are transportation costs. In addition, the provision of inputs, setting up of numerous village posts (for purchasing cotton) and supervising buying agents increase costs when ginneries are farther away. Another ginner with a spatial

[13] I use the cost data for those ginners that operate in WCGA that were collected. Details of the cost data are in Omari, 2016.
[14] Only the location of 67 ginneries were available from the data collected by Omari (2016). Other ginneries have been dormant for many buying seasons and were not considered to be relevant to include in the sample.

advantage over ginnery location is a potential competitor in her cotton procurement. From a game theoretic point of view, a ginnery location has implications for neighboring ginners, which could lead to the possibility of a tacit collusion. In some cases, they form coalitions (of a group of ginners) that would approach the local government to obtain exclusive purchasing rights for a region.

[Figure 4 Here]

Drawing on TCB's historical data on ginner production, Figure 5 shows the catchment area of ginners regionally, i.e. how many ginners procure from a given region for the years 2009-2015. Simiyu gets the highest number of buyers every year with an average of about 26 ginners. Mwanza and Singida usually get 10-15 ginners on average annually. The numbers of ginners procuring cotton from Geita and Tabora has decreased in the last year, while Mara has attracted more ginners recently. The remaining three regions are less competitive with less than five ginners. Depending on the number of buyers in a region, the average price received by farmers varies. Those with more ginners give higher and competitive prices on an average than regions with fewer buyers.

The market structure of ginners is complex and interesting in the Tanzanian cotton sector for two reasons: one, there are temporal variations in prices within a buying season and spatial dimensions to the choice of catchment areas, and, two, there is possibility of obtaining exclusive purchasing rights through contracts as an individual ginner or a coalition of ginners. The ginners in Tanzania probably do not interact with their rivals like other oligopsonistic settings where active enforcement of antitrust laws exist, e.g. the European Union and the US.

[Figure 5 Here]

The market structure of ginners' dynamics every year is interesting for the following reasons. First, in any particular season, a ginner with monopsony power in one district might fiercely compete with her rivals in other districts. Second, common knowledge of price floor allows the possibility for farmers to carry their cotton and sell to other buyers, although this is highly unlikely since cotton is bulky. Third, the price floor restricts a monopsonist ginner to extract the entire surplus from farmers. Fourth, from a dynamic point of view, rival ginners could potentially form coalitions to obtain purchasing licenses and operate as monopsonies.

The presence of Fair Competition Commission of 2007 established under the Fair Competition Act of 2003 in Tanzania prevents any overt collusion among ginners. While the minimum price restricts the ginners to exercise maximum market power, it allows them the possibility of tacit collusion, which could very well exist in this setting. The welfare implications of a price floor under the assumption of a perfectly competitive processing sector could be different and completely alter conclusions in cases of imperfect competition (Russo, Goodhue and Sexton, 2011). Evidence from credit card markets suggests that price ceilings can act as a focal point for tacit collusion (Knittel and Stango, 2003). While the price floor can in fact benefit farmers in regions with few ginners, in regions with more ginners, the price floor can serve as a focal point for tacit collusion.

There are regional variations in the degree of competitiveness in cotton purchase. Market concentration may arise due to the comparative cost advantage of ginners and the proximity of their ginneries to regions with higher yields. Thus, depending on the number of buyers in a region, the average cotton price received by farmers varies. The districts with more ginners usually have higher and more competitive prices on an average than regions with fewer buyers. A regional analysis of market competitiveness is not possible due to lack of data at the regional level. Therefore, I analyze the market structure of ginners at the industry level in Tanzania. The flexibility of my theoretical model allows for a range of outcomes, including the extreme cases of perfect competition and monopsony, while allowing for the intermediate cases of oligopsony. I estimate a nonparametric index of market power in the cotton-ginning sector after analyzing the cost-side of cotton ginners. Nevertheless, I highlight the spatial and temporal dimensions of cotton purchase and review the existing contracts and coalitions of cotton ginners.

4.1.1. Coalitions and Contractual Agreements

Since liberalization of the cotton sector in 1994/95, the TCB made several efforts to improve the sector. One example is encouraging the practice of contract farming, which started as a pilot program in Mara region in 2008/09 and continued until 2010/11 season.[15] Anecdotal evidence suggests that while cotton quality improved and loan repayment was very high, the expansion of contract farming in 2011/12 to the entire WCGA led to challenges for ginners. They could not provide inputs on time and failed to recover their loans. This led to an eventual failure of contract farming until it regained some momentum in 2014/15. A feature of contract farming in Tanzania is that the TCB wants to protect the ginners who invest in the growing capacity of farmers from rivals by providing them with exclusive purchasing rights in a region.

[Table 1 Here]

[15] Contract farming in the setting of Tanzanian cotton should be understood as an arrangement where the gin would invest in the cotton farmers by providing loans for buying inputs, supply extension services for ensuring best agricultural practices, deliver any chemicals as required by the farmers and finally procure the seed cotton from them, as well as recover the loans. See Poulton (2016) for details.

Two coalitions of ginners were formed in the 2014/15 buying season, UMWAPA and KIWAPA.[16] Table 1 summarizes zone-wise average prices received by farmers in 2014/15, constructed from the 2015 CSDP annual survey. I classified the sample of over 2000 farmers into the different zones in which they belong: UMWAPA, KIWAPA, Seed Multiplication Zone (SMZ) and Other Regions. SMZ are individual ginner areas in Singida and Tabora regions. Other regions include all the other remaining zones in WCGA that are not a part of any coalition or SMZ.

In Table 1, the average prices received by farmers in both SMZ and UMWAPA were TSH 45/kg and TSH 88/kg lower than the prices received by farmers in zones without any coalition or contract farming. However, the average price in KIWAPA and Other Regions are not statistically different. While coalitions and contracts can benefit the farmers by timely provision of inputs, exclusive purchasing rights to ginners allow them to extract producer surplus from upstream cotton producers.

4.1.2. Spatial and Temporal Dimension of Cotton Purchase

There is a temporal variation in cotton prices within a buying season resulting from the market structure of downstream ginners. The variation comes from a possible shift of bargaining power from the ginners to the farmers in regions with more buyers. The farmers with larger quantities of cotton (and not in immediate need of cash) can hold on to their produce to sell it later in the season. The ginners in competitive regions are scrambling for cotton, particularly later in the season, to meet their lint demand in their output market, and are willing to pay higher prices. In regions with monopsonists or small number of ginners, the bargaining power remains with the ginners due to lack of competition throughout the season. The temporal dynamics of price is not formally modeled due to lack of data on prices within the cotton-buying season.[17]

[Figure 6 Here]

The ginners primarily target regions with higher total production. A region with more cotton for purchase attracts ginners since from a representative ginner's perspective it is beneficial to get licenses in areas where the ginner can save on transportation costs. However, the regions with higher

[16] UMWAPA started as a new model of contract farming with nine ginners investing almost TSH 4 billion across seven districts in Geita, Mwanza and Shinyanga. There were some challenges and benefits in the 2014/15 season of UMWAPA coalition, which are highlighted in detail in an evaluation report as a response to the Prime Minister's request. KIWAPA is another such coalition of ginners with a contract farming model, also started in the same season, and included eight ginners in Kwimba district of Mwanza region.

[17] The TCB along with CTDP have started to monitor weekly price data by district for capturing this aspect of price dynamics for future analysis.

cotton output have higher competition from rival ginners. Therefore, a representative ginner strategically chooses catchment areas based on cost advantage with transportation, fewer rivals and some degree of market power. The choice of catchment area is not considered for two reasons: one, lack of detailed data to model market power regionally; and, two, the focus of this paper is the analysis of welfare distribution due to market power and observed cotton prices indicate and capture ex-ante strategic interactions and purchase-location choices of ginners. [18]

Figure 6 shows the regional distribution of ginners and the average prices received by farmers in 2015. The black dots in Figure 6 are the number of ginners operating in a region, while the vertical bars are the average cotton prices. The left y-axis measures the price of cotton, while that on the right is for ginners. Simiyu had the highest number of ginners, and the farmers received the highest average price; regions other than Simiyu that received average prices more than TSH 850 are Mara, Mwanza, Shinyanga and Singida. Other than Singida all regions with average prices greater than TSH 850 had at least five competing ginners. This snapshot of the buying season does not necessarily claim that higher number of ginners caused the average price to be higher but indicates a positive correlation.

4.1.3. Market Shares and the Costs of Cotton Lint Production

The industrial organization literature uses Herfindahl-Hirschman Index (HHI) for measuring market concentration (Rhoades, 1993). HHI is defined as the sum of squares of the market shares of firms within an industry. In this context, if HHI were 1, that would indicate a monopsonist ginner, and a value of HHI approaching 0 would describe perfectly competitive ginners. Higher values of HHI indicate high degrees of market concentration. Measures of HHI in the range of 0.25 or above describe high market concentration, and that in the range between 0.15-0.25 usually denote moderate concentration (Horizontal Merger Guidelines of the U.S. DOJ and the FT commission, 2010).

Using the TCB data on ginners from 2009-2015, I calculate the HHI for Tanzanian cotton ginners to reflect the level of market concentration regionally, which I present in Figure 7.[19] Singida is highly concentrated with only one or two operating ginners. Mara, Kagera and Geita are moderately concentrated with the remaining regions being competitive. In the context of Tanzanian cotton ginners, high concentration in cotton procurement might not necessarily indicate high degrees of

[18] The flexibility of the model to capture different degrees of market power preserves the main objective of the analysis without formally modeling locational choice of the ginners.

[19] Kigoma is excluded from the graph in Figure 9 because it had only one ginner operating with a HHI of 1 for the time frame considered.

market power due to the complexities described earlier. However, the HHI reflects the regional variation in market concentration and necessitates the need for analyzing market power structurally through the analysis of ginner costs.

[Figure 7 Here]

The ginners use cotton with other processing inputs to produce lint that is then sold in the domestic or world markets. They buy cotton from village buying posts (set up in every cotton-producing village), transport it to their ginnery, and then process it with other variable inputs to produce lint. The total costs of ginning include variable costs of purchasing cotton, variable costs of processing inputs and other fixed costs associated with production of lint. The variable cost for cotton is the total quantity of purchased cotton times the average price paid over the season and regions. The variable processing costs include the costs of ginning, buying costs associated with procuring cotton, like payments in maintaining the village buying posts etc., packaging of lint, transportation and other finances. The fixed costs include maintenance of gins and other assets in a ginnery. Tanzanian ginners use two types of gins-roller and saw gins.

[Table 2 Here]

I analyze the ginners at the country-industry level with data from 2012-2015 in WCGA.[20] Table 2 gives the summary statistics on the ginners' cost side with the total quantities of cotton purchases and lint produced. In panel (a), the ginners purchased 16.3 million kilograms of cotton in a season to produce 4.7 million kilograms of lint on an average. Panel (b) of Table 2 gives the total and average costs per kg of lint for each category of variable processing costs. The costs of ginning include maintenance of gins, labor costs (both seasonal and permanent), electricity charges, maintenance of weigh and bridge scales. The costs associated with buying are those of maintaining village buying posts, labor costs associated with procuring cotton, rent on storing units, bagging of cotton to be brought to a ginnery, commission charges and weighing scale fees. The packaging costs include the materials used for packing lint after the processing of cotton into lint. Transportation costs include both conveyance of cotton to the ginnery and the logistics of lint sales and distribution. There are additional variable finance costs, which on an average are TSH 79.4 per kilogram of produced lint.

I add all the variable costs of production except for the costs of seed cotton purchase to estimate a marginal cost of processing inputs in production of lint. This gives an estimate of $c(\mathbf{V})$ in equation

[20] The details on production and cost data of the ginneries are available in Omari (2016).

(3). The data on actual prices paid to cotton farmers by each ginner are not available. Thus, I use average price and the price floor for estimating oligopsony power.

4.2. Local-economy of Cotton Farmers

The dataset obtained from KIT and TGT is used to econometrically estimate the inputs of the LEWIE model for the WCGA. A detailed household survey was conducted of cotton- and non-cotton producing-farmers in September and October of 2014.[21] I classified households as cotton growers if their main source of income and primary cultivated crop was cotton. Other household groups are non-cotton-producing households, businesses and laborers. Non-cotton-producing households engage in crop production other than cotton. Business households are those that primarily engage in retail or services within the local economy but may also produce cotton. The laborers own small plots of land and members within these households work primarily as wage labor or rent plots of land for crop cultivation. These households typically have less than an acre of landholding, but they may lease in land for crop production. The laborer households may also engage in cotton production.

This dataset consists of 839 cotton-producing households, 435 non-cotton-producing households, 111 business owners and 129 laborers (Table 3). Overall, 56% of all households are below the national basic needs poverty line, whom I categorize as poor or below poverty line (BPL) households. Among the different household groups, 57% of the cotton producers, 55% of non-cotton producing households, 41% of the business group, and 68% of the laborers are poor, respectively.[22] Most of the business/other households are above the poverty line (APL), while most of the laborer households are BPL.

[Table 3 Here]

The survey gathered data on all production and income activities carried out by each household, including the cultivation of cotton and other crops, livestock, and any non-farm businesses in which the households engaged. For each activity, detailed information was collected on production and its uses, as well as on all inputs, family provided or purchased, variable or fixed. The survey also gathered information on other income activities, including permanent and temporary wage employment by each household member, public and private transfers, and remittances, as well as

[21] A detailed description of the dataset is available in Zaal, Bymolt and Tyzsler (2014) and is used in the analysis by Gupta *et al.* (2017).

[22] The basic needs poverty line, according to the 2011/12 Household Budget Survey conducted by the Tanzanian government (National Bureau of Statistics: Ministry of Finance 2013), was 437,784 TSH (approximately US$260) per adult equivalent per year.

household expenditures on food and non-food items. For all purchases and sales, the place at which the transaction took place was recorded.

Household economies in WCGA, like in most rural areas, are diversified. Those households that are primarily non-cotton producing, like businesses and laborers, are primarily focused on other agricultural crops and livestock activities, retail and services, but may also produce small amounts of cotton. Because of this diversification, technological improvement in cotton production has a small direct effect on non-cotton agricultural, business, and laborer households. Nevertheless, the main potential impacts are indirect, through these households' interactions with cotton households in local factor and product markets.

[Table 4 Here]

Table 4 reports the differences in household size, landholdings, and cultivated land. Cotton BPL households have the largest average family size (9.2), followed by the non-cotton BPL group (8.2). Cotton BPL households have less land than APL households (11.4 compared to 15.2 acres), and they cultivate less (7.8, compared to 10.4 acres). The laborer group has almost no land (0.2 acres) on average; however, households in this group cultivate an average of 3.7 acres. This reflects an active land-leasing market. We do not find any significant differences in land cultivation between non-cotton-producing BPL and APL households.

5. Empirical Strategy and Econometric Results

Using the household-level micro-data for cotton and non-cotton farmers along with other household groups in the local economy, I estimate activity-specific Cobb-Douglas production functions and household group-wise expenditure functions and then nest them within the LEWIE model. The estimated parameters are combined in a LEWIE-input sheet that is designed to interface with the model in GAMS. From the ginners' side, I estimate the marginal cost of processing inputs. Using the short run farm supply elasticity obtained from the estimated Cobb-Douglas parameters of cotton production, and the marginal cost of processing inputs for the cotton ginners, I obtain the index of oligopsony power for the cotton ginners in subsection 5.4. The oligopsony index for the average price of cotton and cotton price floor are estimated, which are then used within the LEWIE model to simulate the impacts of a 25% cotton productivity increase under ginner oligopsony power.

5.1. Local-economy Production Linkages

Using the KIT micro-household dataset for 2014, I estimate cross-sectional production functions of cotton and other activities as described in equation (8). The estimation of Cobb-Douglas production functions is done using a double-log model as given in following equation:

$$\ln(output_i) = \beta_0 + \beta_1 \ln(land_i) + \beta_2 \ln(housheold\ labor_i) + \beta_3 \ln(hired\ labor_i) + \beta_4 \ln(purchased\ inputs_i) + \beta_5 \ln(assets_i) + u_i \tag{9}$$

where log of output is regressed on log of land, household and hired labor, purchased inputs and assets, and u_i is the i.i.d. error term. A concern in the estimation of agricultural production functions is that of simultaneity bias due to unobserved heterogeneity, which arises primarily due to anticipated shocks attributable to early season weather patterns (Barrett, Sherlund and Adesina, 2008). One approach to address the issue uses instrumenting factor prices for the variable inputs to estimate the endogenous factor usages in the production process. For the estimation of equation (9), I use household-level reported factor prices for all the variable inputs using an instrumental variable estimation technique to obtain unbiased estimates. Since land and agricultural assets are fixed in the short run, no instruments are used for the fixed factors. While there could be a concern regarding the optimal usage of assets in the production process, it is not unreasonable to consider assets as an exogenous variable in the estimation of (9) assuming that almost all farming households in the WCGA are marginal and do not change their usage quantity in the short-run.

Table 5 presents the production function estimates of equation (9) for cotton production and the production of other crops except for cotton. I use a two-stage instrumental variable (IV) approach and report bootstrapped standard errors for the second stage that are clustered at the village level. The instruments used are average outside wage rate for household labor; labor wage rate for hired labor by cotton and other crops; and, per-unit price of purchased inputs. In the first stage for each of the three endogenous variables, that variable is regressed on all the variables in production function including the instruments controlling for village location. The predicted values of the endogenous variables then enter the second stage of production function estimation and I report bootstrapped standard errors of 500 replications that are clustered at the village level. The factor elasticities are constrained to add up to one due to the assumption of constant returns to scale production function.

[Table 5 Here]

In Table 5, I estimate the cotton and non-cotton production for all the households that are engaged in the respective activities.[23] Columns (1) and (2) are estimations for cotton production, and (3) and (4) are for non-cotton crops aggregated together, respectively, under two alternative estimation techniques. In columns (1) and (3), I constrain the factor elasticities to add up to one, while drop capital stock from the regressions of (2) and (4). In the second technique, I obtain the estimate on the capital stock by subtracting the sum of elasticities of all other factors from one. The results are robust to the two estimation techniques. The factor elasticities of land are the highest among all the factors, which are 0.63 for cotton and 0.59 for non-cotton, respectively. Output elasticities with respect to household labor are 0.12 and 0.2 for cotton and non-cotton respectively. Elasticities of agricultural assets in cotton and non-cotton production are 0.02 and 0.11 respectively.

Cotton producers produce cotton-purchasing inputs from households and businesses that are inside and outside the local economy. These farming households source their labor from within their households or hire labor locally. Similarly, a significant portion of other purchased inputs and agricultural assets are sourced from within the local economy. Local labor markets and markets for other inputs transmit the impacts of productivity increase in cotton to other households within the local economy that is not involved in cotton production.

5.2. Household Consumption Linkages

Increased production of cotton following a technology change increases the incomes for cotton-producing households, as well as other households in the local economy via consumption linkages. The households spend most of the increased incomes to purchase local goods and services and also some of it is spent outside the local economy. The consumption linkages determine how impacts are transmitted. I estimate marginal budget shares of food and other goods and services by estimating expenditure functions in (10) for each household group using seemingly unrelated regression (SUR). The expenditure in each category of food item including transfer in and out, and formal and informal savings as a dependent variable of total expenditure are joint estimates, each with its own error term ξ_i. The contemporaneous errors associated with the dependent variables are correlated. Thus, a SUR that uses a feasible generalized least squares method will produce consistent and efficient estimators as compared to ordinary least squares as long as the error terms are correlated.

$$expenditure\ in\ each\ category_i = \alpha_0 + \alpha_1 total\ expenditure_i + \xi_i \qquad (10)$$

[23] Estimations based on household groups for these activities and for livestock and businesses are reported in Appendix Table A7.

Estimations of equation (10) for the household expenditure functions are presented in Table 6. I report the estimates for the six household groups that are defined. The estimations for each household group are done by seeming unrelated regression (SUR) framework with total expenditure as the explanatory variable and the expenditures on different categories as the dependent variables. Cotton producers (cotton households and some business and laborer households) spend over 0.5 TSH on food and other retail purchases (calculated by summing crop, livestock and retail budget shares) for every shilling increase in income.

[Table 6 Here]

A portion of the purchased food comes from local farmers, other from local traders or retail shops. It matters where households purchase their food; buying from local households keeps this income circulating within the local economy (increasing the multiplier effect) while buying from traders and retail shops largely result in leakages to outside markets in which retail stores source their goods. Households spend smaller shares of income directly in markets outside the WCGA. APL households spend more of an increase in income in outside markets than BPL households. Business households spend more in outside markets than laborer households. Local purchases put shillings into the hands of local business owners, livestock producers, and farmers, many of whom do not produce cotton.

5.3. Estimation of Ginners' Cost Function

The total cost of producing ginners' output is the sum of total variable costs of purchasing cotton, costs of marketing or processing inputs, and the total fixed costs. Since, the data are not available for the price of cotton that the ginners paid in the different villages from where they purchased, I estimate a partial variable cost function of ginners without the costs they incur in purchasing cotton. This approach does not restrict me from deriving the index of ginners' market power because of two reasons: First, since I assume that costs are separable in variable inputs, I can add the estimated marginal variable costs of processing inputs with the average cotton prices. Second, this non-parametric estimate of market power can be derived using the estimate of marginal variable cost of processing, cotton price, and the output price of ginners.

Let $C_{j,t}$ be the total variable cost of processing inputs for ginner j. Equation (11) estimates the marginal variable cost of processing inputs using the reduced-form specification. The estimate γ_1 is the marginal variable cost of processing inputs, which I defined as $c(\mathbf{V})$. Following the specification, I get

$$C_{j,t} = \gamma_0 + \gamma_1 q_{g_{j,t}} + \mathbf{V}_{j,t}\Gamma_1 + T_t\Gamma_2 + D_{j,t}\Gamma_3 + \psi_{j,t} \tag{11}$$

where $q_{g_{j,t}}$ is the total quantity of lint and $\mathbf{V}_{j,t}$ is a vector of input prices for ginner j in year t. T_t is the year fixed-effects, $D_{j,t}$ is a vector of catchment area dummies for ginner j in year t, and $\psi_{j,t}$ is the residual term in estimation of (11). Data are also not available for the vector of input prices, and, as a result, omitted variables in estimation of ginners' variable costs potentially lead to endogeneity of $q_{g_{j,t}}$, which might result in a biased estimate of γ_1.

I use an instrumental variable approach to address the potential endogeneity of lint in the reduced-form estimation of equation (11). The instrument I use is $Z_{j,t}$, which the total cotton produced in year t in the regions from where a ginner procures cotton. A typical ginner does not procure from every region every year, and I control for the choice of catchment areas by adding $D_{j,t}$, the vector of catchment area dummies in estimation of (11). The production of lint by ginner j in year t, $q_{g_{j,t}}$ is correlated with $Z_{j,t}$, the total output of cotton in the regions from where ginner j buys cotton. The total cost $C_{j,t}$ of processing inputs depends on $Z_{j,t}$ only through the quantity of lint produced by a ginner, which implies that the instrument is valid.

I assume that $cov\left(Z_{j,t}, \psi_{j,t}\right) = 0$, i.e., the exclusion restriction of the instrument holds. The condition of exclusion restriction for the instrument can be assumed for two reasons: First, variable costs of processing inputs do not affect the total cotton production in regions from where a ginner buys her supply. Second, the causation is also not in the other direction, except through the quantity of produced lint. However, there could potentially be one criticism to using my proposed instrument. If the wage rate for laborers used by ginners and in cotton production by farmers are highly correlated, then $Z_{j,t}$ could also be correlated with $\psi_{j,t}$. Nevertheless, that is unlikely to be the case if ginning requires permanent staff and laborers with specific skillsets required for ginning. The number of seasonal laborers employed in a ginnery is also less compared to the labor supply in the WCGA, and, as such, wage rates are not likely to causally influence the daily hired-labor wage rate in cotton production. In addition, I rule out this possibility because many ginneries are located farther away from the catchment areas and the high unemployment rates in rural Tanzania make wages sticky in the short run.

Table 7 gives the estimation results of equation (11). I use different estimation approaches including pooled OLS (reported in column 1), fixed-effects (FE) (reported in column 2), and IV estimation using 2SLS and GMM estimators (in columns 3 and 4, respectively).[24] The estimate on lint is the marginal variable cost of processing inputs γ_1. The OLS controls for time and regional dummies whereas the FE control for ginner fixed effects, additionally.

In Table 7, the estimate on γ_1 from OLS and FE estimations are TSH 590.1 and TSH 573.3, respectively, and TSH 863.6 and TSH 876.5 for IV estimation using 2SLS and GMM estimators, respectively. This means that for producing an additional unit of output, the ginners incur an additional cost in the range of TSH 573.3-TSH 876.5. All the estimates are statistically significant. However, due to possible potential endogeneity of lint quantity in estimation of (11), pooled OLS or FE estimates are possibly biased. The OLS and FE are, in fact, biased downwards in this case because of omission of input prices.

[Table 7 Here]

The IV approach using $Z_{j,t}$, the total cotton output in different catchment regions, produces an F-statistic of the first stage of 25.37 (see panel (b) of Table 7). The F-statistic suggests that 2SLS is reliable when lint output is the only endogenous variable (Stock and Yogo, 2005). Due to the inclusion of regional dummies as additional instruments, I test for over-identifying restrictions in the cases of 2SLS and GMM estimators using Sargan and Hansen's J tests, respectively. The p-values of Sargan and Basmann tests for 2SLS and Hansen's J-test for the GMM estimator suggest that the instruments are valid, and the model is specified correctly. I use the 2SLS estimate in calculating the non-parametric index of market power because the OLS or FE estimates are not consistent.

5.4. Estimation of Ginner Market Power

Using the flexible market structure model presented in the Section 3, I non-parametrically estimate an index of market power for ginners. The index of market power is an oligopsony index of ginners in their purchase of farm supply of cotton. The oligopsony index can range between 0 and 1, where 0 indicates a scenario when the ginners are perfectly competitive in cotton procurement, and 1 indicates a monopsonist ginner. Higher values of this index of oligopsony power are associated with higher degrees of market power. From equation (7), the estimated static index of oligopsony power is given by $\hat{\theta} = \frac{\hat{\epsilon}}{p}\left(P - \left(\widehat{c(\mathbf{V})} + p\right)\right)$.

[24] Alternatively, I also included a quadratic term of lint as a dependent variable to consider the possibility of the costs of processing inputs being quadratic in lint. The coefficient on the lint-squared is insignificant with different estimation techniques. The results are not presented.

For obtaining the non-parametric estimate of the oligopsony index, I need the short-run supply elasticity of cotton from the local economy of the WCGA, $\widehat{\epsilon}$, marginal variable costs of processing inputs used by ginners, $\widehat{c(\mathbf{V})}$, equilibrium price of cotton, and the average output price of ginners. I can obtain the estimate of $\hat{\theta}$ at different values of market clearing price of cotton, P. I use two measures of cotton prices, p, for obtaining two estimates of the oligopsony index, $\hat{\theta}$: one at price floor, and, the other at the average farmer-reported price in the WCGA. The price floor p_{floor} is TSH 800, and at the average farmer-reported price p_{avg} is 1000 per kg, respectively, in 2017. The other three estimates, $\widehat{\epsilon}$, $\widehat{c(\mathbf{V})}$, and P are obtained in the following ways.

The short-run supply elasticity of cotton from the farm for the case with multiple variable inputs is $\epsilon = \frac{\sum_{r\in \mathrm{R}} \alpha_r}{1-\sum_{r\in \mathrm{R}} \alpha_r}$.[25] I estimate $\widehat{\epsilon}$ using the estimates of factor elasticities obtained from the pooled cotton production function estimation (see column (1) of Table 5). The sum of variable factor elasticities is $\sum_{r\in \mathrm{R}} \hat{\alpha}_r = 0.35$, which gives an estimate of $\hat{\epsilon} = \sum_{r\in \mathrm{R}} \hat{\alpha}_r \big/ 1 - \sum_{r\in \mathrm{R}} \hat{\alpha}_r = 0.57$. The bootstrapped standard error (s.e.) of $\hat{\epsilon}$ is 0.19. I use the 2SLS estimate of $\widehat{c(\mathbf{V})}$ at TSH 863.6 (see column (3) of Table 7). The estimate on ginners' output price used is TSH 2,360, which is a weighted average price of lint and other ginning byproducts.

Using the above equilibrium condition, and, the estimates on the marginal cost of processing inputs, SR supply elasticity of cotton, world market price for lint, and market clearing equilibrium price for cotton at its average of TSH 1000, I obtain $\hat{\theta} = 0.28$ with a bootstrapped s.e. ($\hat{\theta}$) = 0.096. This oligopsony index estimate of 0.28 suggests a scenario as if the firms are playing a three-four firm Cournot game. However, in reality, I cannot observe their strategic interactions and if they are actually competing on quantities or not. The setting, with the spatial and temporal dynamics of ginner procurement, make it difficult to generalize and observe the exact nature of the underlying game that ginners are playing. If, for instance, there were exactly three homogeneous firms competing like Cournot firms on quantities, we would have an estimated oligopsony index of 0.33, and, in the case of four homogeneous firms, it would be 0.25.

There are regions like UMWAPA and KIWAPA where ginners operate in coalitions. In regions with less competition, ginners typically pay the minimum price (price floor) throughout the buying season. If the price floor of TSH 800 binds, then I obtain $\hat{\theta}_{floor} = 0.49$ with a bootstrapped s.e. ($\hat{\theta}_{floor}$)

25 Appendix A1 shows the derivation of short-run supply elasticity for cotton with multiple variable inputs for my theoretical model. Also, see Lau and Yotopoulos (1972) for a discussion on obtaining agricultural supply elasticities in case of general Cobb-Douglas production functions.

= 0.17. This means that in coalition regions, where the price floor binds throughout the cotton-buying season, the oligopsony index is (significantly) higher than other regions where farmers get the average price of TSH 1000.

Panels (a) and (b) of Figure 8 give the distribution of the non-parametric oligopsony index estimated at the average price and the price floor. The distributions are constructed with the bootstrapped standard errors around the means of 0.28 for the average price and 0.49 for the price floor, respectively. The corresponding 95 percent bootstrapped confidence intervals around the means are [0.27, 0.29] for $\hat{\theta} = 0.28$ and [0.47, 0.49] for $\hat{\theta}_{floor} = 0.49$.

If the TCB and the government do not declare and enforce the minimum price on the purchase of cotton from WCGA, then market clearing cotton price in regions with ginners-coalitions would, in fact, be less than TSH 800. Thus, the price floor ensures that the ginners cannot exercise their maximum buyer power in cotton purchase, and the index of oligopsony power has an upper bound of 0.49. The upper bound of the oligopsony index indicates a situation as if there are two homogenous firms playing a Cournot quantity-game. To summarize, ginner coalitions could operate as a monopsonist and exercise monopsonistic buyer power, which is, however, restricted by the TCB's price floor. The coalitions, instead, function as if there are two Cournot firms competing in quantities due to the price floor. At the average price, firms operate as if they are in a setting of a three-four homogeneous firm Cournot oligopsonists who are competing for cotton procurement.

6. Results of Ginner Market Power and Technological Improvement in Cotton Production

Due to several challenges in growing cotton in the WCGA, which includes poor soil quality, difficulty in procuring inputs often due to missing input markets, absence of credit markets in many regions, cotton competes with several other crops for acreage to avoid replacement and mostly displacement (i.e. changes in proportion grown of the same crop) (Zaal, Bymolt and Tyzsler, 2014). However, there is scope for raising the productivity of smallholder cotton farmers by using a high yielding variety (HYV) UKM08 seeds instead of the commonly used UK92 seeds. The use of UKM08 delinted cottonseeds over UK92 fuzzy seeds have the potential to raise productivity from 35 to 44 percent (Gupta *et al.*, 2017: pp. 21). Most farmers use low variety UK92 fuzzy seeds that are not completely delinted, which reduces the yields. In the past, the TCB has considered introducing new hybrid cottonseeds including Bt cotton but ended up not introducing these seeds. I carry out a 25% increase in cotton productivity using UKM08 variety seeds under the different market structure scenarios of cotton ginners and compare welfare and production results for the different household groups.

In section 6.1, I first present the welfare results (measured by income) on the different household groups by changing the assumption of perfectly competitive cotton ginners to oligopsonistic ginners. In section 6.2, I evaluate the income and production local-economy impacts of a 25% increase in cotton productivity due to the use of HYV delinted UKM08 variety seeds by all cotton-producing households. The analysis is done for two cases: perfect competition of downstream ginners, and the Tanzanian case with $\hat{\theta} = 0.28$ in a typical cotton-producing region in WCGA.

6.1. Local-economy Impacts of Market Power

The income effects within the local economy for cotton and non-cotton producing households, including local businesses and laborers are obtained by simulating the degree of ginner market competitiveness from the assumption of perfect competition to oligopsony cases using the LEWIE model. This is done by an equilibrium price-change experiment of tradable cotton from the case of perfect competition within the LEWIE model using 500 Monte Carlo simulations.[26]

In case of perfectly competitive ginners, the cotton producers receive higher prices from what they receive currently, both at the average market-clearing price and in the case where the price floor binds. I simulate the impacts of $\hat{\theta} = 0.28$ and $\hat{\theta} = 0.49$ and present the results on household real (inflation-adjusted) incomes for different groups. The total real income in the economy is the population-weight-adjusted income deflated by an endogenous price variable created within the LEWIE model for the non-tradables within the local economy. Table 8 presents the results. The first column for each case (of oligopsony power) gives the estimate on the percentage change in real income from the assumption of perfectly competitive ginners while the second column indicates a 90% confidence interval (CI) around the estimate. If the CIs contain zero, then the impacts are not considered statistically significant.

[Table 8 Here]

The total real income in the economy is the population-weight-adjusted income deflated by an endogenous price variable created within the GE model for the non-tradable goods within the local economy. The total real income generated in the local economy is reduced by 3.11 percent when ginners have market power of 0.28, and by 3.95 percent when the ginners pay the price floor of TSH 800, respectively. The bootstrapped CIs around both these income reductions due to different

[26] The estimated standard errors for each parameter in the model are used together with Monte Carlo methods to perform significance tests and construct confidence intervals around program impact simulation results. See Appendix A2 for details on the construction of confidence intervals.

degrees of market power do not contain zero. Thus, at 5 percent level of significance obtained from the bootstrap technique, the impacts of market power on the total inflation-adjusted incomes are unambiguously negative.

The changes in real incomes are heterogeneous by the different household groups. The cotton-producing households are adversely affected with ginners' market power. The impacts are worsened when the farmers receive the price floor of TSH 800 compared to the average price of TSH 1000. The BPL and APL cotton producers lose about 8.5 and 7.2 percent of their incomes when the ginners pay the average price of TSH 1000 per kg, and 10.8 and 9.4 percent in the case where the price floor binds, respectively. The negative impacts of market power are within the 95 percent bootstrapped confidence bounds.

The business households lose due lower incomes from cotton production and reduced profits from their retails and services, which happens due to reduced demand in the local economy. Their losses are the most among all cotton-producing households. This happens because when ginners have market power, a significant proportion of the producer surplus of cotton farmers is extracted out of the local economy of the WCGA to other parts of Tanzania by the imperfectly competitive ginners. This leakage of income from the local economy reduces the demand for local merchandise and services that are provided by the business households. The incomes of the business households reduce by 11.5 to 14.8 percent.

The leakage of incomes from the local economy is inevitable in most rural areas as in the WCGA of Tanzania. There are two extreme theoretical possibilities of leakages: one, where all the intermediaries' profits remain within the local economy, and, two, where all their profits escape the local economies. This economic leakage might spill over to other parts of the country if the ginner profits are spent by the owners of domestic intermediaries nationally, or may escape to other (particularly, developed) countries if multinational corporations are operational in a local economy.

In this setting, most owners of ginning companies live in Dar-es-Salam, and I assume 50 percent of the ginners' profits leak from the local economy of the WCGA to other parts of Tanzania. The assumption of 50 percent leakage of ginners' profits is a conservative estimate deduced from anecdotal conversations I had with the managers of the ginning companies in the WCGA and the authorities of the TCB. So, the negative impacts of market power are possibly lower bound on the estimates presented in Table 8.

The laborer households who produce some cotton also witness an income reduction of 2.5 to 3.1 percent depending on whether they receive the average or the minimum cotton price. Owing to the reduction in incomes of the different cotton-producing households due to ginners' market power, the non-cotton producers suffer a loss in their incomes indirectly. In particular, among the non-cotton producers, I find that the BPL households lose 1.3 to 1.6 percent of their incomes and the APL households lose 0.8 to 1 percent of their incomes. The point estimate income reductions for the non-cotton producers also do not contain zero, and with 95 percent confidence, I can infer that they lose incomes indirectly due to market power of cotton ginners.

All the cotton-producing households, including the businesses and laborers who produce some cotton, are adversely affected due to market power of ginners. Moreover, market power reduces the total cotton production, which shrinks the economic pie in the local economy of the WCGA due to deadweight loss from imperfect competition. The lower incomes for the cotton producers negatively impact the welfare of the non-cotton producing households who supply food and non-food items including services and other merchandise in the local economy. As a result, the total income of the WCGA reduces due to market power.

6.2. Local-economy Impacts of Technology Change in Cotton Production with Ginner Market Power

Given the potential of higher cotton yields from using HYV UKM08 cottonseeds, I simulate the impacts of a 25% increase in cotton productivity. In Section 3, this is done by changing the Cobb-Douglas shift parameter A in equation (1). This experiment assumes that all the cotton producers in the local economy use the high-yielding variety UKM08 seeds and obtain a 25 percent increase in their cotton productivity. The 'control' economy, in this case, will be an economy where every farmer is using the traditional variety UK92 seeds. The productivity increase experiments are carried out under the assumptions of perfectly competitive and oligopsonistic cotton ginners, and then I compare the results from them.

When the ginners are assumed to be perfectly competitive, cotton price remains unchanged upon technological improvement in cotton production. The 500 iterations of the Monte Carlo simulations of the base model of LEWIE in GAMS provide the estimated impacts and the bootstrapped CIs of the real incomes of different household groups and the local economy production, which are further disaggregated by activities and household groups.

I carry out the simulations of the technology-change experiment at the estimated market power of ginners at $\hat{\theta} = 0.28$, i.e. the case when the cotton farmers receive the average price. Using the point estimate of market power at 0.28, I simulate the base model of LEWIE to obtain the general equilibrium impacts of 25 percent technology change in cotton production. Again, holding the estimate of market power at $\hat{\theta} = 0.28$, rightwards shift of the cotton supply curve due to the technological improvement does not reduce cotton price any further. Similar to the technology-change experiment under the assumption of perfectly competitive ginners, I simulate 500 iterations of the base model of LEWIE at the oligopsony index's point estimate of $\hat{\theta} = 0.28$ to obtain the bootstrapped percentile CIs around the outcomes of interest.

6.2.1. Income Effects

Table 9 gives the income impacts of a 25 percent cotton productivity increase for the four household groups that produce cotton, which are BPL and APL cotton producers, businesses and laborers, and the two non-cotton producing household groups, the BPL and APL non-cotton producers. The experiments are done for two scenarios, the perfectly competitive and the oligopsonistic cotton ginners paying an average cotton price of TSH 1000. The impacts are worsened for the case when the cotton farmers receive the price floor.[27] The first column in Table 15 under each market-structure (perfect competition and oligopsony, respectively) scenario provides the point estimate and the second column gives the 95 percent bootstrapped confidence bounds around the estimate.

[Table 9 Here]

The total real income in the local economy increases by 5.87 percent [CI: 5.05, 7.02] under perfect competition, which is reduced to 2.35 percent [CI: 2.00, 2.70] under the assumption of oligopsonistic ginners, respectively. This indicates more than a 50 percent reduction in total welfare gain to the local economy from the technological change, measured by population-weighted aggregate real income, due to oligopsony power of ginners. The impacts are heterogeneous by different household groups.

The real income increases are reduced to 6.71 percent from 11.29 percent for the BPL and from 7.42 to 4.50 percent in the case of APL cotton producers, respectively. Note that although given a 25 percent increase in cotton productivity, I find that only 11.29 percent and 7.42 percent increase in real incomes for the BPL and APL cotton producers, respectively, when the ginners are assumed to

[27] I do not present the simulation results with $\hat{\theta} = 0.49$.

be perfectly competitive. This is because cotton production contributes to about 45 and 32 percent of total household incomes for the BPL and APL cotton producers, respectively. Their income gains reduction from higher cotton productivity is due to lower cotton price and less increase in cotton production when ginners have market power.

The income increases of the business and laborer households are also reduced from 12.79 to 7.16 percent, and from 4.72 to 2.53 percent, respectively. Real incomes of local businesses for two reasons: first, their engagement in cotton production; and, second, a reduced demand for output from retail and other service activities because of the overall contraction of income gains in the local economy.

Almost all studies focusing on the welfare impacts of technological improvements in agriculture with intermediary have market power have only considered the direct impacts. In this context, that would mean finding the welfare impacts of market power with higher cotton productivity for the different cotton producing households. However, having the integrated general equilibrium model of market structure allows us to find the indirect impacts of market power on the non-cotton producing households when there is higher cotton productivity.

The indirect income increases of higher cotton productivity are dampened for the non-cotton producers. Their income increases are reduced from 1.51 percent [CI: 1.00, 2.26] to 0.75 percent [CI: 0.69, 0.82] for the BPL, and from 0.97 percent [CI: 0.67, 1.42] to 0.48 percent [CI: 0.44, 0.52] for the APL, non-cotton producing households, respectively. The reduced indirect impact on the non-cotton producers is due to lower income gains for the cotton producers themselves. Lower income increases of the cotton producing households reduce their demand for food and non-food consumption goods that are mostly produced locally, which the non-cotton producing households primarily produce.

One way to interpret if the reduction in income increases due to market power are significant or not is comparing the bootstrapped CIs of the perfectly competitive and the oligopsonistic cases and checking if they overlap or not. If the bootstrapped CIs do not overlap, then with 95 percent confidence from the random draws of the parametric distribution and the Monte Carlo simulations, we can infer that market power negatively impacts income gains from higher cotton productivity. In Table 15, the bootstrapped CIs for all the household groups do not overlap for the perfectly competitive and oligopsonistic cases.

6.2.2. Production Impacts

Using the same experiment of a 25 percent increase in cotton productivity, I simulate the GE impacts on total and cotton production in the local economy, and on production values by activities and household groups. Table 10 presents the results. Note that the production values indicate the revenues from production activities are not net of production costs. The simulations are carried out for the two scenarios, i.e., with perfectly competitive and oligopsonistic ginners. I present the results with the point estimates for the two cases in the first column, and the 95 percent bootstrapped CIs in the corresponding second column. The bootstrapped CIs are obtained using the same Monte Carlo draws of 500 iterations as described earlier.

Total production and cotton production in the local economy increase by 4.50 and 39.89 percent, respectively, under the assumption of perfect competition. Note that a 25 percent increase in cotton productivity in a partial equilibrium analysis would give a 25 percent increase in cotton production given the assumption of a CRS cotton production function when ginners are perfect competitive. The general equilibrium analysis, however, allows cotton producing households to reallocate some of their resources, i.e. the variable inputs, into cotton production, which gives the 39.89 percent increase.

Increased income from cotton production stimulates demand for other production activities in the local economy including other crops, livestock, retail, and services. The technology change in cotton production increases the production of other activities by 3.67 to 5.63 percent when cotton ginners are perfectly competitive. Changes in production values are disaggregated by the different household groups, which include the changes in their total production values weighted by the different activities in which they are engaged. The changes in total production value are 20.41 and 13.65 percent for the BPL and APL cotton producers. The businesses and laborer households' total production values also increase by 7.94 to 11.96 percent. The non-cotton producers' value of total production increase by 4.02 to 5.26 percent.

[Table 10 Here]

Market power of cotton ginners reduce the increase in cotton production following higher cotton productivity. This mitigated impact on cotton production transmits to other activities in the local economy. The increase in crop (other than cotton) production value is reduced from 5.40 to 2.89 percent due to market power. Likewise, I find that there is a reduction in production spillovers from cotton productivity to other activities like livestock, retail, and services. Production value gains of livestock, retail, and services reduce from 5.63 to 3.04 percent, 3.67 to 1.90 percent, and 4.82 to 2.57 percent, respectively.

The increases in total production values across the different household groups are also mitigated due to ginners' market power. The gains in total production values for BPL, APL, and laborers range between 11.96 to 20.41 percent in the case of perfectly competitive ginners, which are reduced to 6.67 to 13.31 percent, respectively, with market power. The reduction in total production value for the non-cotton producers are in the range of 2.16 to 3.44 percentage points. The last panel in Table 10 shows the reduction in cotton production values by the different cotton producing household groups. The reduction in cotton production values due to ginners' market power is in the range of 12.81 to 19.54 percentage points.

7. Discussions and Conclusions

Imperfect competition creates negative spillovers that reverberate through local economies, reshaping impacts of policies and other exogenous shocks. This is the first paper to incorporate oligopsony power into a general-equilibrium model of a local economy. Simulations reveal that the oligopsony power of downstream cotton ginners significantly alters the spillover effects of a technology change in cotton production, with important welfare ramifications for both cotton producers and other households. This mechanism works through the reduced prices cotton farmers receive from ginners when the latter have market power in buying cotton.

Past studies provide evidence of direct impacts of intermediary market power on households that produce a particular commodity. This paper extends the analysis by documenting indirect impacts on households that do not produce the commodity. Its potential uses extend to evaluating the direct and spillover effects of other shocks, for example, agricultural policy interventions, migration, and climate change. It is applicable to the analysis of food crops, which small-farm households consume and sell to potentially influential downstream intermediaries or other markets in rural and urban areas of developing and developed countries where local economy market linkages matter.

Government regulations such as minimum support price could mitigate some of the negative impacts of downstream market power. Such interventions prevent intermediaries to extract the entire surplus from upstream farmers while restoring welfare in the local economies. For the Tanzanian cotton case, the minimum price that the TCB sets before the cotton purchase season restricts ginners' ability to operate as monopsonists in regions where they form coalitions. The flexibility of the market structure model in this paper allows for simulating a range of local economy welfare impacts for different degrees of intermediary market power. This framework extends beyond the case presented for Tanzania and permits for simulating scenarios in cases where industry level data are not available for estimating oligopsony power.

Viewing impacts through a GE lens reveals new insights into how development interventions might achieve welfare gains for small farmers as well as others in the local economy of which they are part, but also into how market power of downstream actors might limit these gains. Consider, for example, market interventions to alleviate supply constraints. For example, missing input, credit, and insurance markets prevent small farmers from reaching their full potential as producers. If governments obligate downstream actors to provide input subsidies or credit, the welfare reducing impacts of market power could be mitigated somewhat by stimulating the small-farm supply response. This particularly holds for developing country contexts where farmers might reduce acreage or completely switch to others crops without the support of government interventions due to lack of resources for initial investments in crops that are sold to intermediaries.

Although the provision of inputs and extension services mitigate some of the negative effects of market power, downward pressure on crop prices due to downstream oligopsony power would continue to reduce benefits to farmers. The GE model shows that it also would limit positive welfare spillovers in local economies. For realistic assessments of program effectiveness, analysis of interventions aimed at raising welfare in rural economies must consider the oft-hidden effects of market power and downstream capacity constraints. Taking these effects into account may open new policy angles and opportunities.

Introducing interventions that ensure elastic demand of farm products when intermediaries are capacity constrained could complement the welfare-enhancing programs that governments and donors undertake. Findings also reveal that there are implications for introducing laws that limit or proscribe anticompetitive behavior to prevent mergers and buyer coalitions downstream of the farm. The implications are more profound in developing countries that lack anticompetitive laws or fail to enforce such laws and where local economy linkages matter with welfare ramifications for other households beyond the directly targeted beneficiaries. Exploring the potential impacts of these and other interventions, including their interactions with market power in a GE framework, is an important topic for future research.

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Figures

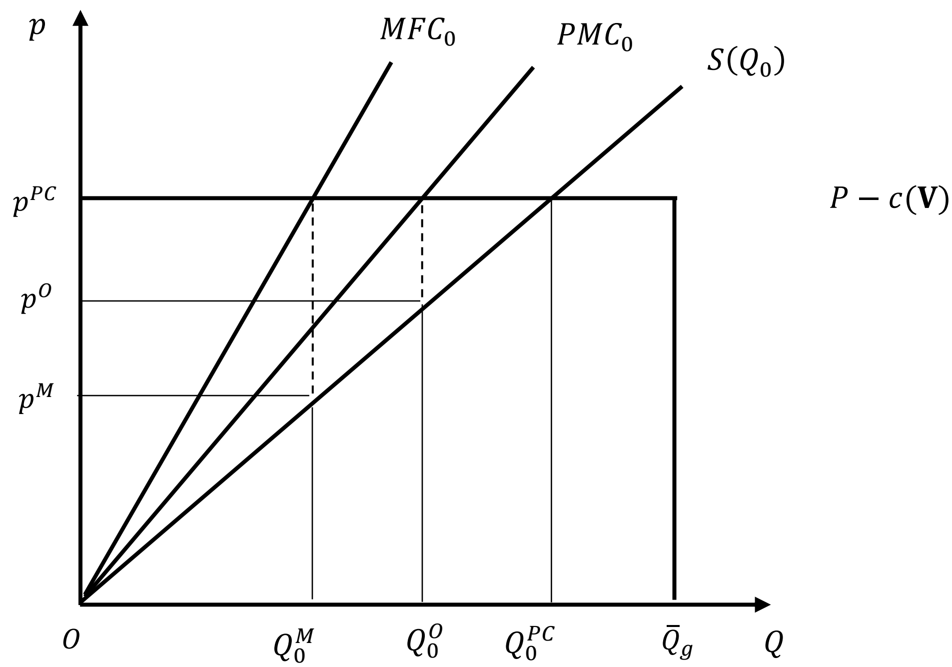


Figure 1: Cotton market equilibrium under different market structures

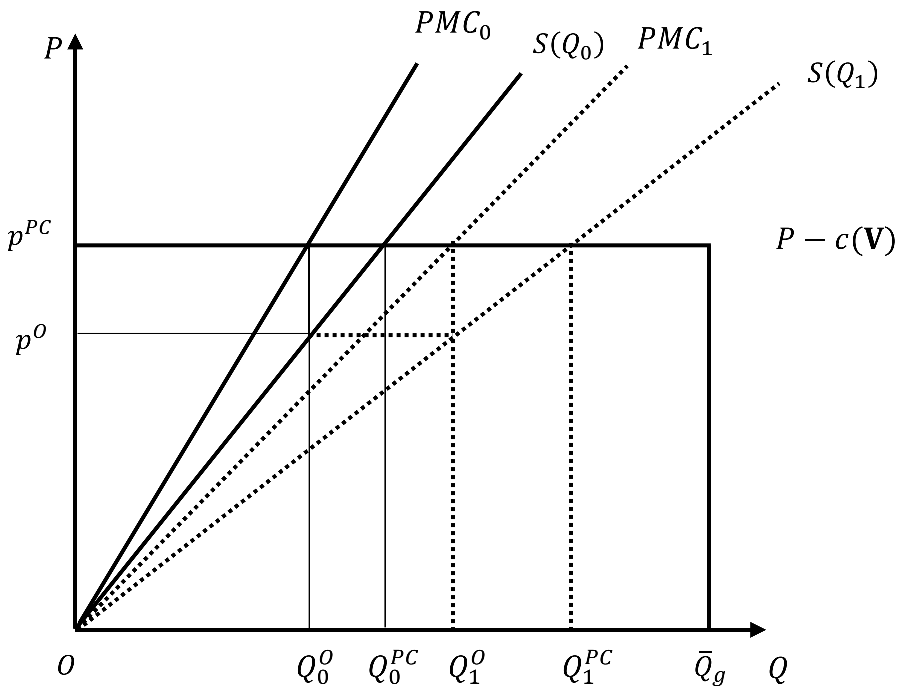


Figure 2: Cotton market equilibrium with technological change

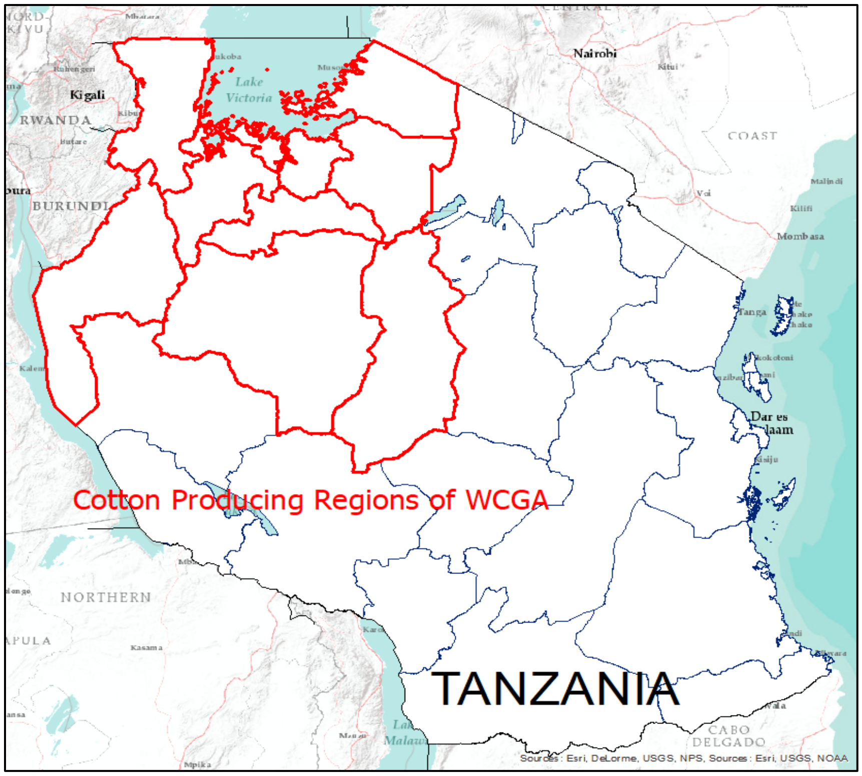
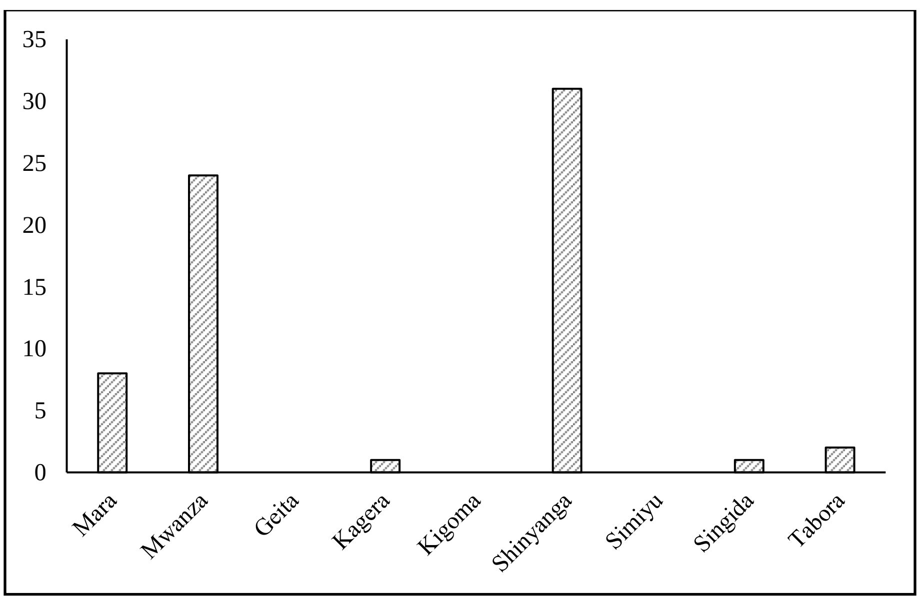
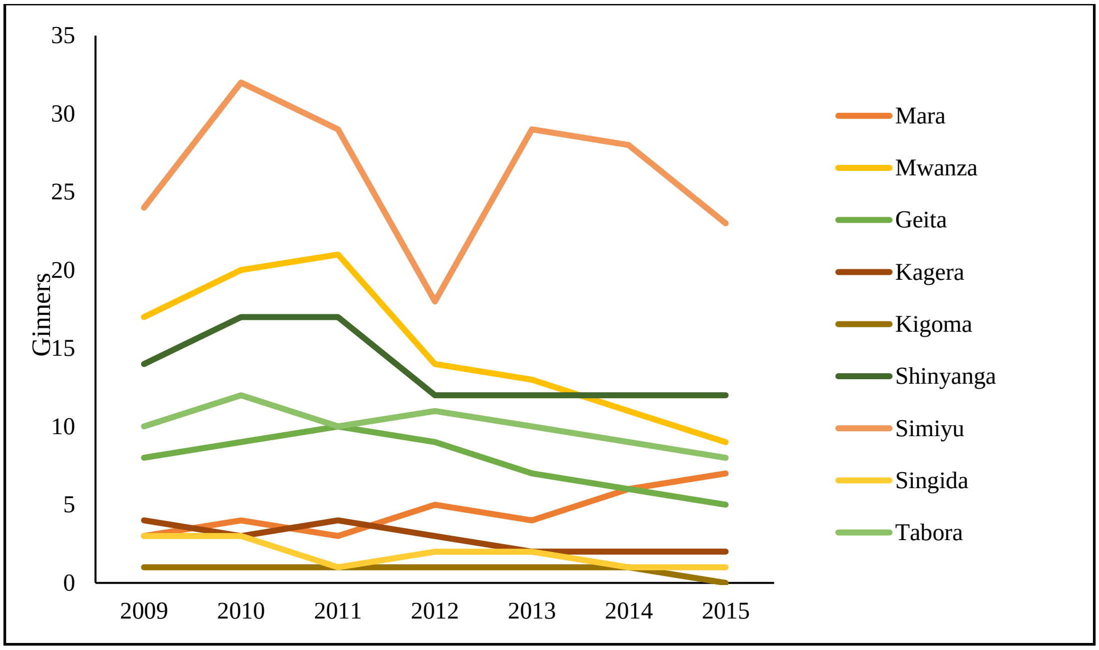


Figure 3: Cotton Producing Regions in WCGA of Tanzania



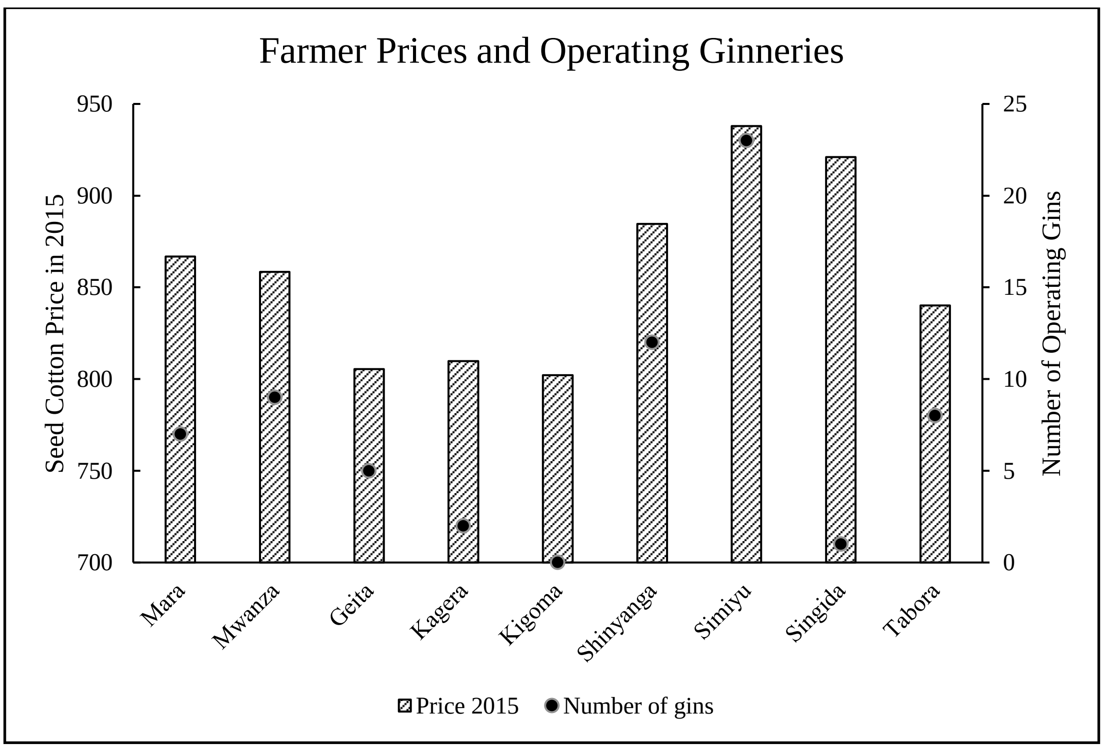
Source: Omari (2016) and author's calculations

Figure 4: Regional location of ginners



Source: CSDP datasets and author's calculations

Figure 5: Regional yearly distribution of ginnery catchment area



Source: Omari (2016) and author's calculations

Figure 6: Cotton prices and number of operating ginneries in 2015

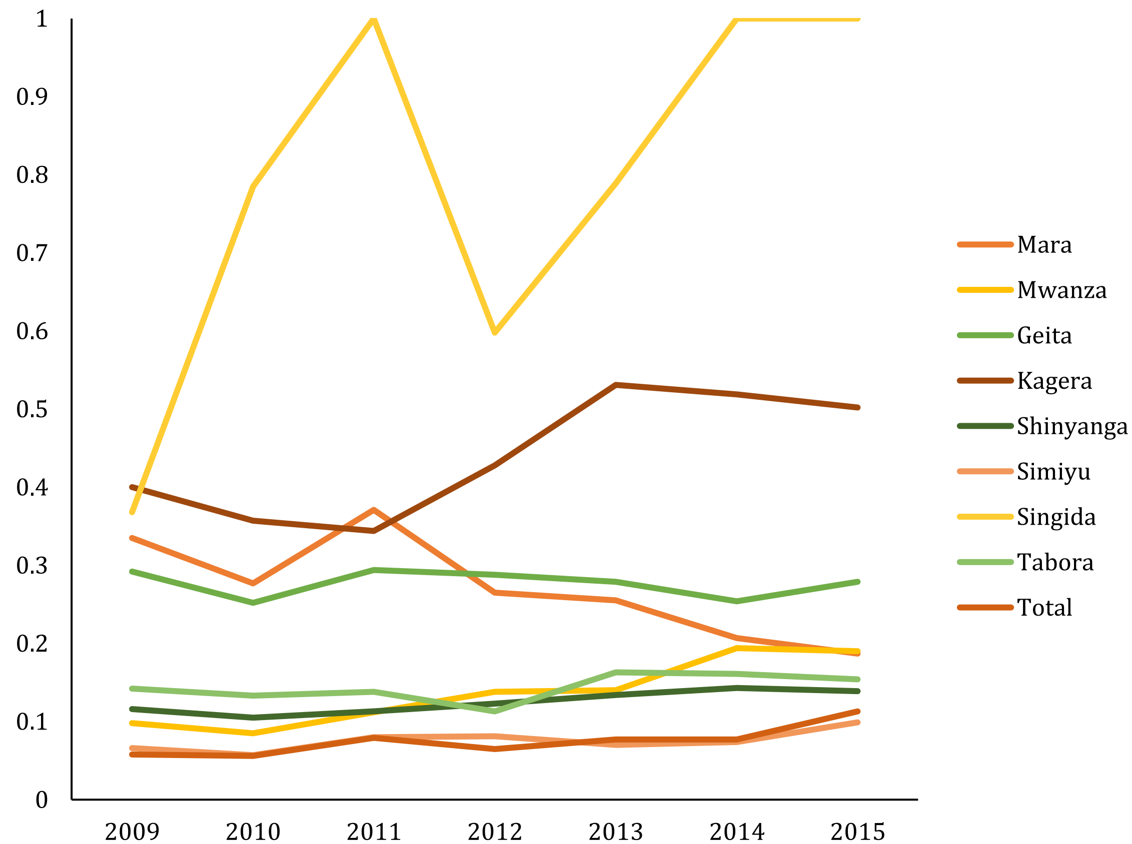
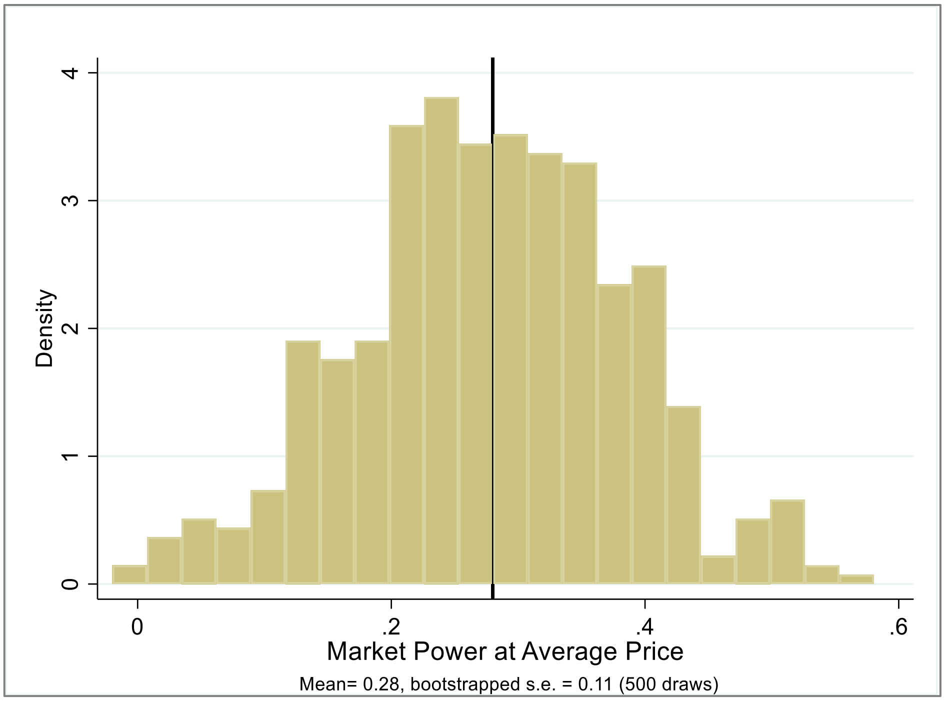
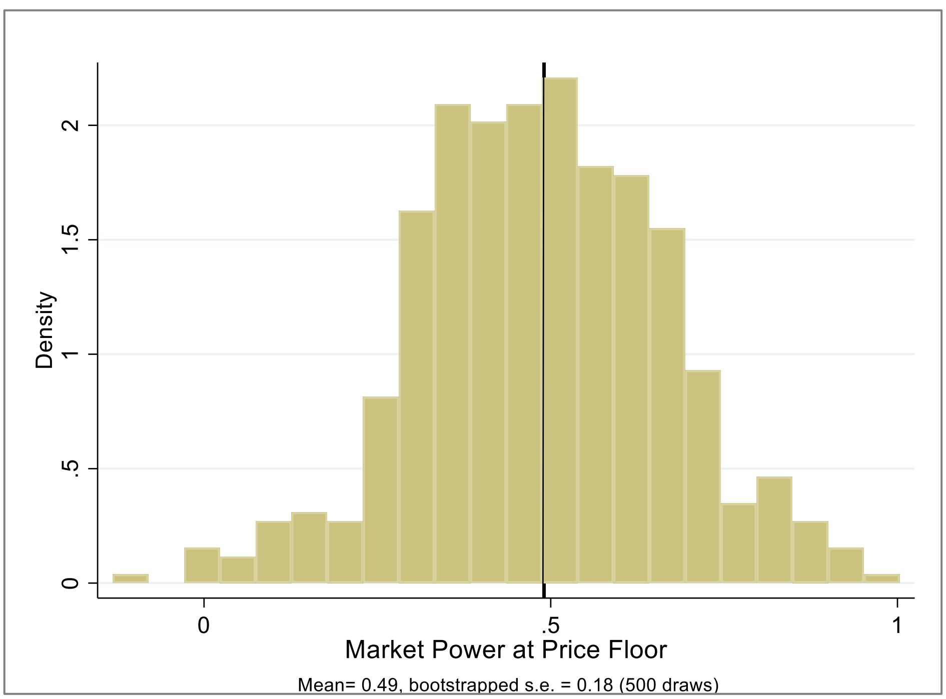


Figure 7: HHI by region and year



(a) Estimate of oligopsony index at average price of TSH 1000



(b) Estimate of oligopsony index at price floor of TSH 800

Figure 8: Non-parametric estimate of market power and its distribution

Tables

Table 1. Prices (TSH/kg) Received by Cotton Farmers in 2015

ZONE	N	Mean	Standard Deviation	Min	Max
UMWAPA	658	808.8	30.3	650	1000
KIWAPA	80	897.5	77.9	700	1000
SMZ	114	851.8	88.6	600	1050
Other Regions	1203	896.6	94.1	650	1100

Source: CSDP 2015 annual survey and author's calculations

Table 2: Summary Statistics on Lint Output and Ginning Costs

Panel (a): Quantities of cotton and lint

Variable	Total (in million kgs)
Cotton purchased	16.3 (9.7)
Lint produced	4.7 (3.3)

Panel (b): Costs in production of lint

Variable	Total Costs (in million TSH)	Per kg of lint Costs (in TSH)
Ginning	1600 (1060)	157.9 (149.6)
Buying (excluding cost of cotton)	1030 (1020)	97.7 (81.5)
Packaging	241 (265)	15.3 (10.9)
Transport	885 (858)	68.5 (47.7)
Finance	862 (679)	79.4 (77.6)
N	34	34

Notes: Standard errors are in parenthesis. Panel (a) and (b) give averages for each of the 10 ginners over 2012-2015. A few ginners did not operate in some season resulting in the sample size to be 34.

Table 3: Classification of households based on the Tanzania National Poverty Line

Household Group	Cotton Producers	Non-cotton Producers	Business	Laborers	Total
BPL (poor)	478 (57%)	241 (55%)	46 (41%)	88 (68%)	852 (56%)
APL (non-poor)	381 (43%)	194 (45%)	65(59%)	41 (32%)	682 (44%)
Total	839	435	111	129	1534

Notes: Figures in parenthesis are percentages of total

Table 4: Summary Statistics (Sample Averages) by Household Group

Household Group Characteristics	Cotton Producers		Non-cotton Producers		Business / Others	Laborers
	BPL	*APL*	*BPL*	*APL*		
Household size	9.2 (0.23)	7.9 (0.22)	8.2 (0.26)	7.4 (0.26)	7.4 (0.34)	5.7 (0.25)
Total landholding (acres)	11.4 (0.85)	15.2 (1.29)	10.8 (0.89)	11 (0.75)	10.4 (1.37)	0.2 (0.04)
Land cultivated in last season (acres)	7.8 (0.26)	10.4 (0.4)	7.4 (0.38)	7.3 (0.34)	7.1 (0.83)	3.7 (0.26)
Total	474	385	240	195	111	129

Notes: Values in parenthesis are standard deviations of means for each variable.

Table 5. Cotton and Non-cotton Production Function Estimates

Dependent Variable: Log of Total Output	Cotton		Non-Cotton	
	(1)	(2)	(3)	(4)
Log of land	0.626***	0.577***	0.558***	0.369***
	(0.0940)	(0.0680)	(0.110)	(0.0987)
Log of Household Labor	0.115**	0.133***	0.197**	0.394***
	(0.0477)	(0.0297)	(0.0929)	(0.0684)
Log of Hired Labor	0.0521**	0.065***	-0.0919	0.0496
	(0.0220)	(0.0235)	(0.0843)	(0.0441)
Log of Purchased Inputs	0.186***	0.0180	0.230**	0.0836***
	(0.0525)	(0.0128)	(0.112)	(0.0305)
Log of Assets	0.0215**		0.108***	
	(0.00910)		(0.0233)	
Constant	9.384***	9.181***	9.059***	8.896***
	(0.695)	(0.543)	(0.428)	(0.343)
N	939	939	913	913
R^2	-	0.461	-	0.115
Village dummies	Yes	No	Yes	No

Notes: Bootstrapped standard errors in parentheses for second stage of IV regressions are clustered at village level. Columns (1) and (3) present the CRS production function estimates by constraining the factor elasticities to sum to one. For columns (2) and (4), I estimate dropping capital stock from the second stage and obtain the estimate by subtracting the sum of estimates of all other factors from 1.
* p<0.10, ** p<0.05, *** p<0.010

Table 6. Expenditure Function Estimations giving Budget Shares by Group for 1 TSH Increase in Income

Dependent Variable	Cotton BPL	Cotton APL	Non-Cotton APL	Non-Cotton BPL	Business/Others	Laborers
Food/Crop						
	0.157***	0.245***	0.267***	0.270***	0.167***	0.117***
	(0.0144)	(0.0168)	(0.0210)	(0.0237)	(0.0304)	(0.0259)
Livestock						
	0.0687***	0.0839***	0.0628***	0.0717***	0.0421***	0.0199***
	(0.00694)	(0.00980)	(0.00727)	(0.0112)	(0.0104)	(0.00646)
Retail						
	0.342***	0.264***	0.246***	0.259***	0.337***	0.372***
	(0.0169)	(0.0191)	(0.0197)	(0.0259)	(0.0346)	(0.0356)
Services						
	0.145***	0.128***	0.116***	0.147***	0.124***	0.138***
	(0.00855)	(0.0129)	(0.0104)	(0.0213)	(0.0215)	(0.0235)
Production						
	0.0313***	0.0147***	0.0197***	0.0116***	0.0318***	0.0267***
	(0.00402)	(0.00386)	(0.00380)	(0.00269)	(0.00754)	(0.00540)
Transfer Out						
	0.00847***	0.00876***	0.00860***	0.00313*	0.00611***	0.00324***
	(0.00179)	(0.00176)	(0.00170)	(0.00175)	(0.00144)	(0.00116)
Transfer In						
	0.00137***	0.00185**	0.000453	0.00263*	0.00421**	0.00257***
	(0.000409)	(0.000773)	(0.000561)	(0.00151)	(0.00163)	(0.000995)
Formal Savings						
	0.00129	0.000980	0.000668	-0.00100	0.00612	-0.00456
	(0.00150)	(0.00221)	(0.00128)	(0.00239)	(0.00468)	(0.00658)
Informal Savings						
	0.0494***	0.0114**	0.00153	0.00382	0.0348*	0.0865***
	(0.00794)	(0.00488)	(0.00118)	(0.00669)	(0.0183)	(0.0219)
N	463	359	234	175	101	123
R^2	0.204	0.373	0.410	0.427	0.230	0.142

Notes: Standard errors in parentheses. Seemingly Unrelated Regressions for each group with total expenditure as the independent variable while the dependent variable is in the first column of Table 6. The parameter estimates are on total expenditure with estimates on constant not reported in the table. The estimates are budget shares for one TSH increase in expenditure for each household group.
* p<0.10, ** p<0.05, *** p<0.010

Table 7: Estimation of Variable Cost Function of Processing Inputs

	No Instruments Used		Instrumental Variables Regressions	
Dependent Variable:	(1)	(2)	(3)	(4)
Total Variable costs of processing inputs	Pooled OLS	Fixed Effects	2SLS	GMM
Lint in kg	590.1***	573.3***	863.6***	876.5***
	(161.7)	(108.2)	(63.74)	(53.87)
Constant	1.18646e+09	-698242526.1	-260795806.5	-257529558.2
	(1.07221e+09)	(905723994.8)	(526708017.6)	(361876177.6)
N	34	34	34	34
R^2	0.920	0.878	0.833	0.831
Time Fixed Effects	Yes	Yes	Yes	Yes
Regional Dummies	Yes	Yes	Yes	Yes
Ginner Fixed Effects	-	Yes	-	-
Instruments	-	-	Yes	Yes
First-stage F-stat (Lint)			25.37	25.37
Sargan p-value			0.12	
Hansen's J p-value				0.07
Shea's Partial R-squared			0.8144	0.8144

Panel (a): Tests of Endogeneity
H_0: variables are exogenous

Robust score chi2 (1)	2.99 (0.08)
Robust regression F(1,28)	2.43 (0.13)

Panel (b): First-stage regression summary

Variable	R-sq.	Adjusted R-sq.	Robust F(10, 20)	Prob > F
Lint in kg	0.84	0.74	25.37	0.00

Panel (c)

Variable	Shea's Partial R-sq.	Adjusted Shea's Partial R-sq.
Lint in kg	0.81	0.71

Panel (d): Weak Instruments Test
H_0: Instruments are weak

	5%	10%	20%	30%
2SLS relative bias	20.74	11.49	6.61	4.86

Notes: Standard errors in parentheses. Panel (a) shows Woolridge's score test rejects the null that *lint* is exogenous at the 10% level of significance. In panel (b), I find that F-stat is 25.37, which indicates that the 2SLS estimator is reliable with only one endogenous regressor *lint*. Panel (c) shows the Shea's partial R-squared and adjusted R-squared measures that adjusts for degrees of freedom of the number of instruments. I reject the null that the instruments are weak allowing for a 5% bias from the 2SLS estimator (see panel (d)).
* p<0.10, ** p<0.05, *** p<0.010

Table 8: Inflation-adjusted (Real) Income Impacts of Market Power

Oligopsony Index:	$\hat{\theta} = 0.28$ (Average Price)		$\hat{\theta} = 0.49$ (Price Floor)	
Change in income	Estimate	95% bootstrapped CIs	Estimate	95% bootstrapped CIs
A. Total	-3.11	*(-3.21, -3.02)*	-3.95	*(-4.05, -3.87)*
B. By Household				
BPL Cotton	-8.49	*(-8.75, -8.24)*	-10.77	*(-11.05, -10.55)*
APL Cotton	-7.18	*(-7.43, -6.95)*	-9.39	*(-9.67, -9.17)*
BPL Non-Cotton	-1.31	*(-1.35, -1.27)*	-1.59	*(-1.61, -1.58)*
APL Non-Cotton	-0.83	*(-0.85, -0.81)*	-1.03	*(-1.05, -1.01)*
Business	-11.52	*(-11.89, -11.17)*	-14.77	*(-15.17, -14.45)*
Laborer	-2.54	*(-2.61, -2.47)*	-3.07	*(-3.13, -3.03)*

Notes: The first column for each case shows the point estimates in percentages on changes in real incomes. The second column for each case shows the 95 bootstrapped confidence intervals (CIs) around simulated real incomes by calibrating the base LEWIE model using the distribution of market power index.

Table 9: Real Income Impacts of 25% Technological Change in Cotton Production

Oligopsony Index:	$\hat{\theta} = 0$ (Perfect Competition)		$\hat{\theta} = 0.28$	
Change in income	Estimate	95% bootstrapped CIs	Estimate	95% bootstrapped CIs
A. Total	5.87	*(5.05, 7.02)*	2.35	*(2.00, 2.70)*
B. By Household				
BPL Cotton	11.29	*(9.64, 13.60)*	6.71	*(6.50, 6.91)*
APL Cotton	7.42	*(6.82, 8.21)*	4.50	*(4.43, 4.58)*
BPL Non-Cotton	1.51	*(1.00, 2.26)*	0.75	*(0.69, 0.82)*
APL Non-Cotton	0.97	*(0.67, 1.42)*	0.48	*(0.44, 0.52)*
Business	12.79	*(11.63, 14.52)*	7.16	*(7.05, 7.26)*
Laborer	4.72	*(3.69, 6.13)*	2.53	*(2.40, 2.65)*

Notes: The first column for each case shows the point estimates in percentages on changes in real incomes and the second column shows 95 confidence intervals (CIs) around simulated real incomes for 500 Monte Carlo simulations of 25% technological change experiment.

Table 10: Inflation-adjusted Production Impacts of 25% Technological Change

Oligopsony Index:	$\theta = 0$ (Perfect Competition)		$\hat{\theta} = 0.28$	
Change in production	Estimate	95% bootstrapped CIs	Estimate	95% bootstrapped CIs
A. Total	4.50	*(4.50, 4.50)*	3.56	*(3.56, 3.56)*
B. Total Cotton	39.87	*(32.57, 49.00)*	32.20	*(24.73, 39.67)*
Change in production value				
A. Total	9.49	*(7.29, 12.21)*	5.21	*(4.61, 5.91)*
B. By Activity				
Cotton	39.87	*(32.57, 49.00)*	21.58	*(16.57, 26.58)*
Crop	5.40	*(3.92, 7.29)*	2.89	*(1.61, 4.17)*
Livestock	5.63	*(4.44, 7.15)*	3.04	*(1.76, 4.32)*
Retail	3.67	*(2.27, 5.36)*	1.90	*(1.54, 2.36)*
Services	4.82	*(3.39, 6.69)*	2.57	*(0.42, 4.72)*
C. By Household				
BPL Cotton Farmers	20.41	*(17.06, 24.37)*	13.61	*(12.14, 15.28)*
APL Cotton Farmers	13.65	*(10.94, 16.75)*	8.42	*(7.40, 9.48)*
BPL Non-Cotton Farmers	5.26	*(3.96, 6.99)*	1.82	*(1.65, 2.05)*
APL Non-Cotton Farmers	4.02	*(2.71, 5.54)*	1.86	*(1.64, 2.12)*
Business	7.94	*(5.12, 12.15)*	4.22	*(3.58, 5.12)*
Laborer	11.96	*(9.37, 15.27)*	6.67	*(5.89, 7.70)*
D. Cotton by Household				
BPL Cotton Farmers	38.97	*(33.22, 45.52)*	26.01	*(21.01, 31.00)*
APL Cotton Farmers	38.29	*(31.51, 45.81)*	25.48	*(19.51, 31.46)*
Business	52.94	*(35.15, 82.66)*	33.40	*(21.19, 45.60)*
Laborer	39.01	*(33.49, 45.80)*	26.03	*(21.25, 30.80)*

Notes: The first column for each case shows the point estimates in percentages on changes in real incomes and the second column shows 95 confidence intervals (CIs) around simulated real incomes for 500 Monte Carlo simulations of 25% technological change experiment.

Appendix

Appendix A1: Extension to Multiple Inputs with Excess Ginning Capacity

The results from the theoretical model with excess ginning capacity can be generalized to multiple inputs in the production of cotton with the same assumptions. The interpretation of the results for equilibrium market clearing price and quantity, the limiting case of oligopsony power and the comparative statics remain unchanged when the capacity constraints do not bind. I set up the problem and provide the equilibrium market clearing quantity and price but do not repeat the other results for the sake of brevity. Let there are multiple, variable and fixed, inputs that could be used in the production of cotton. Let R be the set of all possible variable inputs and S be the set of all possible fixed inputs such that the production function for a representative cotton farmer is

$$q_{c,\,i} = A \prod_{r \in \mathrm{R}} {L_{i,r}}^{\alpha_r} \prod_{s \in \mathrm{S}} {\bar{K}_{i,s}}^{\alpha_s} \quad \text{with } 0 < \alpha_s, \alpha_r < 1 \ \ \forall\, s \in \mathrm{S} \text{ and } \forall\, r \in \mathrm{R}$$

For the production function to be CRS we need $\sum_{r=1}^{R} \alpha_r + \sum_{s=1}^{S} \alpha_s = 1$. The SR supply elasticity in case of multiple variable inputs is $\epsilon = \frac{\sum_{r \in \mathrm{R}} \alpha_r}{1 - \sum_{r \in \mathrm{R}} \alpha_r}$. With the above generalized CRS production function and the underlying assumptions, the equilibrium price and quantity for $\theta \in (0,1)$ are:

$$p^* = \frac{[P - c(\mathbf{V})] \sum_{r \in \mathrm{R}} \alpha_r}{\sum_{r \in \mathrm{R}} \alpha_r + \theta(1 - \sum_{r \in \mathrm{R}} \alpha_r)} \qquad Q^* = A^{1/1 - \sum_{r \in \mathrm{R}} \alpha_r} \left[\frac{[P - c(\mathbf{V})] \sum_{r \in \mathrm{R}} \alpha_r}{\sum_{r \in \mathrm{R}} \alpha_r + \theta(1 - \sum_{r \in \mathrm{R}} \alpha_r)}\right]^{\sum_{r \in \mathrm{R}} \alpha_r / 1 - \sum_{r \in \mathrm{R}} \alpha_r} \bar{\mathrm{W}}$$

where $\bar{\mathrm{W}} = \prod_{s \in \mathrm{S}} {\bar{K}_{i,s}}^{\frac{\alpha_s}{(1 - \sum_{r \in \mathrm{R}} \alpha_r)}} \prod_{r \in \mathrm{R}} \left[\frac{\alpha_r}{w_r}\right]^{\frac{\alpha_s}{(1 - \sum_{r \in \mathrm{R}} \alpha_r)}}$ is a constant with w_r being the input price of variable input L_r. The comparative statics and the limiting cases can be derived from the equilibrium price and quantity with similar economic interpretations on the results when there is excess ginning capacity.

Appendix A2: Model Validation and Sensitivity Analysis

I perform significance tests in the integrated general equilibrium model of market structure to provide a means to establish confidence in the estimated parameters and functions used in the simulations. If the structural relationships in the simulation model are properly specified and precisely estimated, this should lend credence to the simulation results. The estimated standard errors of each parameter in the model can be used together with Monte Carlo methods to perform significance tests and construct confidence intervals around the simulation results. This can be done using the steps Taylor and Filipski (2014) describe for the construction of confidence intervals in the LEWIE model.

I use the parameter estimates and starting values for each variable obtained from the micro household-level data to calibrate a baseline general equilibrium of the market structure model. This is done before technology-change "experiment" in cotton production is carried out. The baseline model is then used to simulate the general equilibrium impacts of ginner market power, and technology change in cotton production under the cases of perfectly competitive ginners and ginners with market power in cotton procurement. Next, I randomly draw a parameter value of interest from each parameter distribution, assuming that it is centered on the estimated parameter, with the standard deviation equal to the standard error of the estimate. This results in an entirely new set of model parameters. Using these parameters, I calibrate a new baseline GE model, and use this model to simulate the same program, as described above, again. Repeating this iterative step 500 times, the simulation results on each outcome of interest are obtained.

I construct percentile confidence intervals $(\hat{Y}^*_{1-\alpha/2}, \hat{Y}^*_{\alpha/2})$ of the variable $\hat{Y}^*$, where $\hat{Y}^*_p$ is the p^{th} quantile of the simulated values $(\hat{Y}^*_1, \hat{Y}^*_2, \cdots, \hat{Y}^*_J)$. For example, for a 95 percent confidence interval, the cut-offs are the highest and lowest 2.5 percent of simulated values for the outcome of interest. This is similar to the percentile confidence intervals in bootstrapping. This Monte Carlo procedure gives the variances of all the parameter estimates simultaneously to perform a comprehensive sensitivity analysis grounded in econometrics. If the model's parameters were estimated imprecisely, this will be reflected in wider confidence bands around our simulation results. However, precise parameter estimates will tend to give tighter confidence intervals. The precision of some parameter estimates might matter more than others within a general equilibrium framework. Structural interactions within the model may magnify or dampen the effects of imprecise parameter estimates on simulation confidence bands.

Appendix A3: The Integrated General Equilibrium Model of Market Structure Equations in GAMS

Table A1. Set, Subset and Mapping Names Used in Model Statement

SETS		Subsets	
g	goods	gtv	Goods tradable in the village
F	factors	gtz	Goods tradable in ZOI
h or hh	households	gtw	Goods tradable with ROW
Var	variable names	gp	Goods that are produced
		gag	Agricultural goods
		gnag	Nonagricultural goods
		gcot	Cotton
		fk	Fixed factors
		ft	Locally tradable factors
		ftv	Factors tradable in village
		ftz	Factors tradable in whole ZOI
Mappings		ftw	Factors traded in outside markets
maphv(h,v)	Mapping of households to their village	fpurch	Purchased variable inputs

Table A2. Commodities, Factors, and Households

Commodities	
Cotton	Cotton produced by all cotton producing household groups
Crop	Local crops: produced and consumed within the village
Livestock	Local livestock, produced and consumed within the village
Retail	Local retailers in the village
Services	Local services in the village
Production	Other local production in the village
Gin	Lint produced from Cotton
Outside good	Any commodity purchased outside the local economy
Factors	
Labor	Labor (family and hired receiving wage in cash or kind)
Land	Land
Capital	Capital
Input	Purchased inputs
Households	
Cotton BPL	Cotton producing BPL households
Cotton APL	Cotton producing APL households
Non-cotton BPL	BPL households that do not produce cotton
Non-cotton APL	APL households that do not produce cotton
Businesses/Others	Households that are primarily in businesses and other occupations
Laborers	Primarily landless laborers with less than 1 acre on landholding

Table A3. Variable Names Used in Model Statement

VARIABLES			
Values		**Consumption and income**	
PV(g,v)	price of a good at the village level	QC(g,h)	quantity of g consumed by h
PZ(g)	price of a good at the ZOI level	Y(h)	nominal household income
PH(g,h)	price as seen by household h (=PV or PZ)	RY(h)	real household income
PVA(g,h)	price of value added net of intermediate inputs	CPI(h)	consumer price index
R(g,f,h)	rent for fixed factors	TRIN(h)	Transfers received by a household
WV(f,v)	wage at the village level	TROUT(h)	transfers given by a household of others
WZ(f)	wage at the ZOI level	SAV(h)	household savings
Theta	oligopsony index of ginners	EXPROC(h)	household expenditures out of the ZOI
Production		**Trade**	
QP(g,h)	quantity produced of a good by a household	HMS(g,h)	household marketed surplus of good g
FD(g,f,h)	factor demand of f in production of g	VMS(g,v)	village marketed surplus of good g
ID(g,gg,h)	intermediate demand for production of g	ZMS(g)	ZOI marketed surplus of a good
QVA(g,h)	quantity of value added created	HFMS(f,h)	factor marketed surplus from the household
HFD(f,h)	factor demand in the household	VFMS(f,v)	factor marketed surplus out of the village
UNEMP(f,h)	unemployment in the household	ZFMS(f)	factor marketed surplus out of the region
HFSUP(f,h)	labor supply from the household (elastic endowment)		
VFD(f,v)	initial factor demand in village		
ZFD(f)	initial factor demand in the economy		

Table A4. Parameter Names Used in Model Statement (GAMS)

PARAMETERS Production		Consumption	
acobb(g,h)	production shift parameter in CD	alpha(g,h)	consumption share parameters in the LES
shcobb(g,f,h)	factor share parameters in CD	cmin(g,h)	minimal consumption in the LES
vash(g,h)	value-added share of output	exinc(h)	exogenous income of household
idsh(gg,g,h)	intermediate input share	vmsfix(g,v)	fixed marketed surplus at the village level
tidsh(g,h)	total intermediate input share	zmsfix(g)	fixed marketed surplus at the ZOI level
fixfac(g,f,h)	fixed factor endowments	Transfers	
unempsh(f,h)	household's share of total unemployment	troutsh(h)	share of transfers in household expenditures
vfmsfix(f,v)	factors fixed at the local level (family, hired labor)	exprocsh(h)	share of expenditures outside ZOI level
zfmsfix(f)	factors fixed at the ZOI level (hired labor)	savsh(h)	share of income saved
endow(f,h)	Household factor endowments	trinsh(h)	share of total transfers received by a given household
hfsupzero(f,h)	Initial labor supply	For Experiments	
hfsupel(f,h)	Factor supply elasticity	transfer(h)	transfer to household
pibudget(g,h)	Liquidity constraint on inputs	subsidy(g,f,h)	subsidy rate to apply on factor price for good g
pibsh(g,h)	Share of pibudget to good g		

Table A5. Equation Definitions

Equation Name	Description
*** prices**	
EQ_PVA(g,h)	price value added equation
EQ_PH(g,h)	market price as seen from household h
*** production**	
EQ_FDCOBB(g,f,h)	factor demands cobb Douglas
EQ_FDPURCH(g,f,h)	factor demands for purchased inputs - constrained or not
EQ_QVACOBB(g,h)	quantity VA produced cobb douglas
EQ_QP(g,h)	quantity produced from QVA and ID
EQ_ID(gg,g,h)	quantity of ID needed for QP
*** consumption**	
EQ_QC(g,h)	quantity consumed
*** income**	
EQ_Y(h)	full income constraint for the household
EQ_CPI(h)	consumer price index equation
EQ_RY(h)	real household income equation
*** transfers**	
EQ_TRIN(h)	inter-household transfers in (received)
EQ_TROUT(h)	inter-household transfers out (given)
*** exogenous expenditures**	
EQ_SAV(h)	savings (exogenous rate)
EQ_EXPROC(h)	expenditures outside of the zoi (exogenous rate)
*** goods market clearing**	
EQ_HMKT(g,h)	quantity clearing in each household
EQ_VMKT(g,v)	market clearing in the village
EQ_ZMKT(g)	market clearing in the zoi
EQ_VMKTfix(g,v)	price definition in the village
EQ_ZMKTfix(g)	price definition in the zoi

*** factor market clearing**

EQ_HFD(f,h)	total household demand for a given factor
EQ_FCSTR(g,f,h)	fixed factors constraint
EQ_HFSUP(f,h)	household elastic supply
EQ_HFMKT(f,h)	tradable factor clearing in the household
EQ_VFMKT(f,v)	tradable factors clearing in the village
EQ_ZFMKT(f)	tradable factor clearing in the zoi
EQ_VFMKTfix(f,v)	wage determination for tradable factors clearing in the village
EQ_ZFMKTfix(f)	wage determination for tradable factors clearing in the zoi

Table A6. Equations in the Model

Name	Equation
1) HOUSEHOLD EQUATIONS	
Price Block	
EQ_PH(g,h)..	$PH_{g,h} = [PZ_g]_{g\in gtz \cup gtw} + \left[\sum_{v\mid maphv(h,v)} PV_{g,v}\right]_{g\in gtv}$
EQ_PVA(g,h)..	$PVA_{g,h} = PH_{g,h} - \sum_{ga} idsh_{ga,g,h} \times PH_{ga,h}$
Production Block	
EQ_QVACOBB(g,h)..	$QVA_{g,h} = a_{g,h} \times \prod_{f} (FD_{g,f,h})^{\beta_{g,f,h}}$
EQ_FDCOBB(g,f,h)	$[R_{g,f,h}]_{f\in fk} + [WZ_f]_{f\in ftz} + \left[\sum_{v\mid maphv(h,v)} WV_{f,v}\right]_{f\in ftv} = \frac{PVA_{g,h} \times QP_{g,h} \times \beta_{g,f,h}}{FD_{g,f,h}}$
EQ_QP(g,h)	$QP_{g,h} = QVA_{g,h}/vash_{g,h}$
EQ_ID(gg,g,h)..	$ID_{ga,g,h} = QP_{g,h} \times idsh_{ga,g,h}$
Consumption and income block	
EQ_QC(g,h)..	$QC_{g,h} = \frac{\alpha_{g,h}}{PH_{g,h}} \times \left(Y_h - TROUT_h - SAV_h - EXPROC_h - \sum_{ga} PH_{ga,h} \times cmin_{ga,h}\right) + cmin_{g,h}$
EQ_Y(h)..	$Y_h = \sum_{g,fk} (R_{g,fk,h} \times FD_{g,fk,h}) + \sum_{g,ftz} WZ_{ftz} \times HFSUP_{ftz,h} + \sum_{ftv} \sum_{v\mid maphv(h,v)} WV_{ftv,v} \times HFSUP_{ftv,h} + \sum_{ftw} WZ_{ftw} \times HFSUP_{ftw,h}$
EQ_TROUT(h)..	$TROUT_h = troutsh_h \times Y_h$

EQ_EXPROC(h)..	$EXPROC_h = exprocsh_h \times Y_h$
EQ_SAV(h)..	$SAV_h = savsh_h \times Y_h$
EQ_CPI(h)..	$CPI_h = \sum_g PH_{g,h} \times \alpha_{g,h}$
EQ_RY(h)..	$RY_h = \frac{Y_h}{CPI_h}$
<u>2) MARKET CLOSURE:</u>	
Market clearing block for commodities	
EQ_HMKT(g,h)..	$HMS_{g,h} = QP_{g,h} - QC_{g,h} - \sum_{ga} ID_{g,ga,h}$
EQ_VMKT(g,v)..	$VMS_{g,v} = \sum_{h\|maphv(h,v)} HMS_{g,h} + packsold_g$
EQ_ZMKT(g)..	$ZMS_{g,v} = \sum_v VMS_{g,v}$
EQ_VMKTfix(gtv,v)..	$VMS_{gtv,v} = vmsfix_{gtv,v}$
EQ_ZMKTfix(gtz)..	$ZMS_{gtz} = zmsfix_{gtz}$
Market clearing block for factors	
EQ_HFD(f,h)..	$HFD_{f,h} = \sum_g FD_{g,f,h}$
EQ_FCSTR(g,fk,h)..	$FD_{g,fk,h} = fixfac_{g,fk,h}$
EQ_HFMKT(ft,h)..	$HFMS_{ft,h} = HFSUP_{ft,h} - \sum_g FD_{g,ft,h}$
EQ_HFSUP(ft,h)..	$\frac{HFSUP_{ft,h}}{hfsup^0_{ft,h} + hfsnewref_{ft,h}} = \left[\sum_{d\|maphd(h,d)} \left(WD_{ft,d}\right)^{\zeta_{ft,h}}\right]_{f\in ftd} + \left[\left(WZ_{ft,d}\right)^{\zeta_{ft,h}}\right]_{f\in ftz\cup ftw}$
EQ_VFMKT(ft,v)..	$DFMS_{g,d} = \sum_{h\|maphd(h,d)} HFMS_{g,h}$

EQ_ZFMKT(ft)..	$$ZFMS_{ft} = \sum_{v} VFMS_{ft,v}$$
EQ_VFMKTFIX(ftv,v)..	$$VFMS_{ftd,d} = vfmsfix_{ftv,v}$$
EQ_ZFMKTFIX(ftz)..	$$ZFMS_{ftz} = zfmsfix_{ftz}$$
For simulations with a budget constraint	
EQ_FDCOBB(g,f,h) (only for purchased factors)	$$FD_{g,f,h} \times WZ_{f} = pibudget_{g,h}$$

Table A7. Production Function Estimates by Activities and Household Groups

	Cotton CRS Cobb-Douglas production function estimation				Production Activities of Non-cotton farmers with CRS Cobb-Douglas Estimation				CRS production function estimation of Businesses	
	Cotton Producers		Businesses /Others	Laborers	Crop production		Livestock Production		Retail	Services
	BPL	APL			BPL	APL	BPL	APL		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent Variables:	Log of Total Value of Cotton Output (in TSH)				Log of Total Value of Output of All Other Crops (in TSH)		Log of Total Value of Output of All Livestock Units (in TSH)		Log of Total Sales from Retail or Services (in TSH)	
Log of land	0.676***	0.686***	0.532***	0.486**	0.641***	0.661***	-	-	-	-
	(0.0816)	(0.0954)	(0.184)	(0.186)	(0.104)	(0.0954)				
Log of Household Labor	0.140***	0.0738**	0.109*	0.111	0.194**	0.157**	0.0515	0.0405	0.0457**	0.122**
	(0.0490)	(0.0313)	(0.0619)	(0.0722)	(0.0920)	(0.0791)	(0.0338)	(0.0369)	(0.0191)	(0.0465)
Log of Hired Labor	0.0798***	0.0474**	0.182*	0.0643	0.130***	0.158***	0.0751**	0.0865**	0.0760**	0.146**
	(0.0271)	(0.0197)	(0.0944)	(0.0816)	(0.0367)	(0.0454)	(0.0323)	(0.0331)	(0.0316)	(0.0675)
Log of Purchased Inputs	0.0964***	0.175*	0.0892	0.205*	0.0480***	0.0204	0.0317**	0.00736	0.878***	0.732***
	(0.0367)	(0.105)	(0.172)	(0.108)	(0.0120)	(0.0141)	(0.0127)	(0.0209)	(0.0259)	(0.103)
Log of Capital Stock	0.00756	0.0180	0.0880*	0.134***	-0.0127	0.00335	0.799***	0.828***	-	-
	(0.0108)	(0.0128)	(0.0441)	(0.0416)	(0.0277)	(0.0300)	(0.0512)	(0.0531)		
Constant	10.33***	10.13***	9.846***	8.669***	10.41***	11.54***	2.325***	2.166***	1.950***	4.017***
	(0.407)	(0.946)	(1.639)	(1.312)	(0.378)	(0.313)	(0.693)	(0.722)	(0.404)	(1.190)
N	453	372	42	64	238	194	131	147	190	70
R^2	-	-	-	-	-	-	0.850	0.762	-	-
F	274.8	2088.9	92.93	190.5	149.6	310.3	117.2	102.7	13.51	336.6

Standard errors in parentheses are clustered at the village level. R-squared values are not reported for the constrained regressions. The CRS production function estimates are obtained by constraining the factor elasticities to sum to one.
* p<0.10, ** p<0.05, *** p<0.010