The Effects of Changing Technology: The Impacts of a Changing Cost Structure on Land Tenure Arrangements in the Mississippi Delta, 1996 – 2004

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Abstract

Genetically modified (GM) cotton varieties have changed many aspects of cotton production in the United States. The advent of GM varieties has fueled the ongoing trend of increasing farm size and fewer farmers. Mississippi is no exception to this trend. The rapid adoption of GM cotton varieties in Mississippi has allowed some producers to increase the acreage of their farming operation. This study analyses the impact of GM varieties on relative profitability over certain types of land tenure arrangements. The type of land tenure arrangement and the cost associated with the arrangement are compared to determine relative probabilities of breaking even for different farm sizes in the Mississippi cotton industry.

Keywords: Mississippi cotton production, Genetically Modified cotton varieties, land tenure, structural change.

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Row crop production is a competitive industry. Row crop producers must utilize new technology, make the correct production decisions based on risk assessments, employ inputs efficiently, and use the proper practices to be profitable in this competitive market. If producers do not adapt to changing technology or utilize the correct inputs and strategies they will be driven out of the market due to their lack of efficiency.

Agricultural technology has changed a great deal in the past sixty years, leading to many different innovations that have increased farm productivity. Advanced agricultural research and development techniques have led to production innovations, both products and concepts, and can be considered one of the factors driving this constant change. These innovations have made farming more efficient over time, allowing farmers to replace labor with capital.

One of the most important developments in cotton production in the past decade has been genetically modified seed. Transgenic seeds are bred so that the resulting plants have advantageous traits. One example is Bt cotton in which a gene is injected into the plant's DNA (Perlack et al., 1990). The Bt gene induces the plant to produce an insecticidal protein similar to a naturally occurring soil bacterium *Bacillus thuringiensis* (Bt) (Peferoen, 1997). This helps protect the plant from specific insects and reduces the number of pesticide applications made by producers. Another example is glyphosate tolerant cotton. This type of modified seed has a tolerance to glyphosaic herbicides which enables farmers to control foreign plants within cotton fields with increased efficiency. Both (Bt) varieties and the glyphosate tolerant varieties can be combined or used individually so that the plants possess the desired characteristics. Transgenic seed has made cotton production a much more efficient alternative for farmers.

In general, genetically modified (GM) seeds produce plants that require less attention throughout the growing season, allow producers to have more control over their crops during the growing season, and reduce the amount of money spent on the crop during that time. These new varieties have also proven to yield more than previous varieties. GM seed varieties and other technological innovations have changed some of the risks associated with production. This can be observed through the insect resistance associated with Bt cotton. The bacterium is produced within the plant so that there is continually a certain level of protection against lepidopteron infestation throughout the plant's lifecycle. The continuous protection of Bt cotton has shifted producer risk and given farmers more options during the growing season. For example, a field that could not be planted due to soil compaction could now be placed back into production because the number of pesticide applications has been reduced which means fewer trips through the field and ultimately less soil compaction. Producers who use these varieties can also reduce their input costs by making fewer pesticide applications, burning less fuel, and eliminating the cost of labor associated with making the application.

These characteristics compliment the steady movement toward fewer producers farming larger farms. Assuming this trend is actually occurring, a portion of producers who remain in business from year to year must acquire additional farmland. Consequently, the advent of better, more specialized inputs such as transgenic cotton may be partly responsible for the change in farm structure. Since these inputs affect the profitability of crop production, they also indirectly influence land prices and thus land tenure arrangements. Common tenure arrangements for farmland include cash leases, share leases, and purchase. Each method differs according to the requirements specified by the landlord. Each type of tenure arrangement also requires a different level of capital investment and potentially results in a different distribution of returns to the producer. The question of how evolving technology has influenced producer returns under alternative land tenure arrangements is the focus of this study.

Objectives

Past studies have indicated many potential benefits of planting genetically modified (GM) seed varieties. The focus of many of these studies, however, is somewhat broad. Some analyses have measured nationwide impacts of growing GM varieties on many factors such as yield, profitability, production costs, trips through the field, and overall productivity. The general objective of this study is to determine how GM varieties may have influenced land tenure arrangements. This analysis is similar to past research but is focused on a single commodity and location. The first specific objective of this study is to assess the impact of the rapid adoption of GM seed varieties on the relative profitability of alternative land tenure arrangements in cotton production. The second specific objective is to determine how the profitability of farms of different sizes has been impacted by the shift to GM varieties. Because this study is focused on a smaller area, farm size can be better defined and relative profitability can be easily compared across all observations. Moreover, focusing on one state allows the dismissal of many of the assumptions that must be made in studies conducted at the national level.

Literature Review

The structure of American agriculture has been changing for decades. One of the most common and obvious theories related to structural change is that farms are growing larger in size and fewer in number (Gebremedhin & Christy 1996). This theory has been consistent in U.S. aggregate findings for some many years. Many other studies have attempted to create models that rank the factors most responsible for certain structural changes such as changes in farm size and productivity. Gebremedhin and Christy (1996) postulated through descriptive analysis and a survey of literature that average farm size in the U.S. had doubled, the land in farms had fallen, and the number of farms was declining and as a result larger farms accounted for most of the United States commodity sales. They also found that fewer families were living on farms and that off-farm income was rising. Huffman and Evanson (1997) found results similar to Gebremedhin and Christy using an econometric model as well as production and cost functions to determine structural and productivity changes in U.S. agriculture. Huffman and Evanson (1997) found that public extension, education of farmers, and agricultural commodity programs contributed to productivity on U.S. farms. They also found that the change in farm size was mostly due to changes in input prices and that the change in input prices was a dominant force in increasing crop specialization. Other studies have contradicted the findings of Huffman and Evanson. Studies over smaller regions have contradicted the notion of input prices being the dominant factor in determining farm size. Martin *et al.* (2002) conducted a mail survey of Mississippi Delta cotton farmers and found that farmers were using larger equipment, there were more acres per pieces of equipment, and larger farms were using less labor when compared to the 1997 survey. Other trends indicated by the survey were that farm size and the percentage of rented farmland rather than owned farmland was increasing (Martin *et al.* 2002). In a similar study, Parvin (2004) used the Mississippi State Budget Generator (MSBG) to estimate direct and fixed costs per acre for four different cotton production systems in the Mississippi Delta. Production systems differing in variety, tillage practice, commodity mix, row spacing, and equipment size were compared by the MSBG cost estimates to determine the most efficient combination of techniques. Parvin argued that growers will continue to adopt new technologies, change their production strategies, and utilize larger equipment and that these factors will continue to lead to increased farm size. Ultimately, this argument holds that producers are attempting to realize economies of size by expanding their operations.

The adoption of a new technology that allows the factors of production to be used more efficiently can, depending on the adoption rate and aggregate use of the technology, cause the structure of a market to change. One of the more remarkable recent technological breakthroughs in agriculture has been transgenic seed varieties. The varieties of transgenic crops presently available were introduced separately during the mid 1990's except for hybrid corn which was introduced over half a century ago. Since their introduction, studies have analyzed many effects of transgenic crops on an aggregate level as well as the farm level. Much research has been done to try to estimate the environmental, economic, and social costs and benefits of these crops. Lin *et al.* (2001) researched the difference in yield and pesticide costs associated with adopters and non-adopters of Bt and herbicide tolerant cotton. They found that the pesticide costs were decreased and the yield was increased for adopters of Bt cotton when compared to non-adopters. Edge *et al.* (2001), Klotz-Ingram *et al.* (1999), Brooks & Barfoot (2005), Purcell & Purlack (2004), and Kalaitzandonakes (1999) all found increased yield in Bt cotton when compared to conventional varieties. In herbicide tolerant cotton Lin *et al.* found that there was no difference in pesticide costs between adopters and non-adopters but did find a yield increase for the adopters. Several other studies found that there was a decrease in pesticide costs and pesticide use for GM varieties of cotton when compared to conventional cotton varieties (Marra *et al.* 2002), (Carpenter & Gianessi 2000), (Kalaitzandonakes 1999), and (Edge *et al.* 2001). Previous studies have also considered factors other than yield and pesticide costs. Edge *et al.* (2001) found that Bt cotton improved profitability, worker safety, control of both target and non-target pests, and increased the effectiveness of beneficial insects while also reducing the number of pesticide applications, thus lowering producer risk as well as production costs and fuel usage. Others have analyzed the effects of transgenic cotton on revenue and profitability and found that they were both increased (Marra *et al.* 2002) and (Carpenter &Gianessi 2000). Other benefits include time savings, increased land efficiency, ease of management when compared to conventional varieties, and production flexibility (Kalaitzandonakes 1999) and (Klotz-Ingram *et al.* 1999). There have been many benefits from the implementation of transgenic cotton but there are some negative externalities associated with Bt cotton. One negative externality is outlined in a study which focuses on the “refuge”. For every acre of Bt cotton planted, a certain number of acres of non-Bt cotton must be planted. This non-Bt acreage is called a refuge in the sense that the pests targeted by Bt cotton can take refuge in the non-Bt varieties so that the pests will not become resistant to the Bt gene. Banerjee *et al.* (2005) found that the required planting of refuge cotton decreases returns. Some less-developed countries have a negative view of transgenic crops because of personal beliefs and cultural practices. Others feel that scientists are tampering with natural plant evolution and believe adverse effects related to GM crops are possible in the future. Nevertheless, transgenic crops have been and will continue to be commercialized thus creating changes in the structure of production agriculture.

New technologies are implemented differently depending on the situation. Technological changes also differ by region due to unique regional characteristics, the crop mix within a particular region, and the alternate production methods used within each region. Researchers can employ numerous models and methods to measure technical change depending on the data set, variables within data sets, and the characteristics of the variables. In their study on U.S. agriculture, Zofio & Knox-Lovell (2001) used a hyperbolic efficiency measurement relative to the graph of production technology and the Malmquist Index to measure technological change. Other methods for measuring technological change include nonparametric tests which can also measure efficiency and productivity. Bar-Shire & Finkelshtain (1999) and Morrison *et al.* (2001) both used nonparametric tests in measuring technical change in U.S. agriculture. Morrison *et al.* (2001) found that, at the national level, productivity growth was due to technological innovation rather than input efficiency and that farm size and typology also influenced total factor productivity. They also found that variables such as off-farm income, farm size, and the livestock-to-crop ratio affected total factor productivity differently in different regions. Alfred *et al.* (2005) used several techniques to develop a method to estimate technologies at the farm level. Their techniques included budgeting, linear and quadratic programming, dynamic programming, and econometric approaches. They found that this approach could use whole-farm models, incorporated dynamic and stochastic attributes of certain technologies, and it could be used as an input to determine welfare impacts of technology adoption. Overall, technological change has influenced the structural change in U.S. agriculture and previous research has shown that the degree of influence varies by region.

Previous research has determined that farm size and technological change influence productivity and that farm size is increasing while the number of farms is decreasing. How tenure arrangements are organized over the remaining farmland is an interesting question. Studies have analyzed land tenure arrangements through simulation models, principal agent games, co-integrated techniques, and based on farmland prices. Awokuse & Duke (2004) used Directed Acyclic Graphs (DAG)s co-integrated (VAR) techniques, and other empirical models to estimate influential factors in determining land prices. Their findings indicated that capital gains, capital gains tax, land price expectations, real estate debt, and the opportunity cost of capital directly influence land prices whereas net returns to farming and the interest rate indirectly affect land prices. Davis (2004) conducted a simulation model to analyze the returns to landlords and tenants in different leasing situations. In this study cash, share, and flexible leases were compared and contrasted in a simulation model which incorporated stochastic yields, prices, and government payments to generate returns for landlords and tenants (Davis 2004). Results in this study showed that tenants received the largest returns to unpaid labor, management, and fixed machinery costs under cash lease agreements and landlords received the largest average rent from a 50-50 crop share lease. Other results indicated that risk attitudes do not have much effect on the tenant's or the landlord's preferred leasing agreement but that flexible leases do reduce revenue risk at a tradeoff of lower average returns.

Previous research has investigated the impact of technological change (including the adoption of transgenic seed varieties) on farm-level productivity and profitability. Research has also investigated the risk/return profiles of alternative land tenure arrangements. This study brings these two threads together exploring how GM variety adoption in the cotton industry has affected the distribution of relative returns to alternative land tenure arrangements.

Data Development and Methods

The data used in this experiment was collected by surveys sent out to a random sample of cotton farms in the Mississippi Delta. The survey data used in this study starts in 1996 and continues to the end of the 2004 crop year. The recipients responded to questions about various production costs, quantities of inputs, types and brands of inputs used, and the types and amounts of labor and capital used during one year for a randomly selected field on their farm. At the end of the growing season, a follow-up call was made to determine the yield, in pounds per acre, for participant's operation. The acreage for the randomly selected field was known as well as the total acreage for each individual's operation. Other significant data collected included share of costs (if applicable for share leases); amount (in acres) of rented, owned and leased farmland; county and soil type; and method of irrigation (if any). The survey also includes a section for tracking operations within the selected field. Within this section, farmers must specify the date of the operation, a description of the operation, the type of machinery used, materials applied (if any), and the terms of custom work (if the work was done by a custom operator). The information in this section is used to estimate the costs associated with performing certain operations.

Survey information from individual farms was collected and entered into the Mississippi State University Budget Generator (MSBG) to determine costs associated with specific operations that were performed within a randomly selected field on each recipient's farm for one year. The MSBG includes price estimates for all cotton production inputs (e.g., fuel, fertilizer, pesticides/herbicides, labor, and equipment). The cost per acre for each survey participant was estimated by dividing the costs required to complete each operation within the selected field by the number of acres within the selected field. The costs per acre were then multiplied by a field expansion number. The resulting product from cost per acre and the field expansion number generates an accurate estimate of cost per acre over the entire farm. Therefore, the farm-level survey information (which provides a complete summary of production operations) along with input price information from the MSBG can be used to develop realistic cost estimates for commercial cotton production in Mississippi.

Annual survey data was used to develop a simulation of key components of production costs. These components include seed costs, technology fees, insecticide costs, herbicide costs, fertilizer costs, other direct costs, fixed costs, and specified costs. Other direct costs include all of the direct costs less the cost of seed, technology, herbicide, insecticide, and fertilizer costs specified by a producer in each survey. Specified cost is simply the total of all costs incurred during a crop year. In addition to these figures, yields were also simulated. For each year investigated, a total of 1,000 cost and yield outcomes were simulated. The observations were then sorted by the number of acres allocated for cotton production. The observations were categorized into small, medium, and large farms. Small farms operated less than 500 acres, medium sized farms operated between 500 and 1500 acres, and large farms operated more than 1500 acres. To provide a comparison of costs and yields reflecting change due to technology adoption, the years 1997, 2000, and 2004 were simulated. These three years were selected because they provide an accurate reflection of costs and yields over the entire eight year time period and because of the relatively large number of observations within each of these years.

Correlated production cost components and yields were simulated using a technique described by Phoon, Quek, and Huang (2003). This procedure begins with an eigen decomposition of the random correlation matrix to obtain eigenvalues and eigenvectors. These are used to produce a set of correlated standard normal deviates ($\hat{Z}$) as follows:

(1) $\hat{Z} = \sqrt{\varepsilon} Z \hat{\varepsilon}$,

where ε is a set of eigenvalues, $\hat{\varepsilon}$ is a set of eigenvectors, and Z is a set of independent standard normal deviates. Correlated uniform variables on the (0,1) interval are obtained on the standard normal cumulative distribution function (CDF). These correlated uniform (0,1) variables are used as probabilities in an inverse transformation on each of the marginal distributions for the variables being simulated.[1] In this study, cost components were assumed to be log-normally distributed, and yields were assumed to have a Beta distribution.

[1] For a more detailed description of this procedure see Phoon, Quek, and Huang (2003).

Results

Initially, some of the trends that are occurring in Mississippi cotton production must be understood. Many of the changes that coincide with the adoption of GM varieties at the national level are being observed in Mississippi. As stated previously, some of the common characteristics associated with GM cotton varieties include increased yield, reduced production costs, and greater producer flexibility. Mainly, reduced production costs result from the reduction in labor usage, pesticide and herbicide applications, and fewer trips over the field. Table 1 shows some of the preliminary findings for Mississippi.

Table 1. Per-Acre Average Costs/Expenses, 1996 - 2004

Year	Seed Cost	Technical Fee	Herbicide Cost	Insecticide Cost	Fertilizer Cost	Other Direct Costs	Fixed Costs	Specified Costs	Yield (in lbs.)
1996	10.53	32.00	38.34	33.75	35.60	313.87	66.03	379.90	810.53
1997	11.02	38.79	33.85	30.64	38.68	322.77	75.14	397.91	831.86
1998	11.96	42.51	39.35	38.07	34.49	352.36	82.13	434.49	751.43
1999	12.01	42.72	34.07	25.16	31.80	317.85	68.87	386.72	709.00
2000	12.14	49.39	33.24	22.20	33.24	315.50	68.92	384.43	650.15
2001	12.52	54.36	29.97	24.28	44.36	347.19	63.44	410.63	750.19
2002	14.83	39.48	34.04	28.56	41.41	356.34	63.62	419.96	898.91
2003	15.69	45.28	33.24	26.52	43.86	360.36	71.02	431.38	947.96
2004	16.58	49.84	34.08	24.66	41.38	379.56	75.79	455.35	1,062.68

This data verifies previous arguments that the adoption of GM cotton varieties will decrease certain production costs. Average herbicide costs have decreased $4.26 per acre and average insecticide costs have also decreased $9.09 per acre from 1996 to 2004. Average yield also increased roughly 256 pounds per acre overall but fluctuated from year to year. The inconsistency of the state's average yields can be attributed to regional factors such as weather conditions during the growing season and at harvest.

Conversely, the average values for other direct costs and fixed costs, seed and fertilizer costs, and the technical fee increased over this time period. The average cost of seed per acre increased $6.05 and the average technical fee increased more than $17.00 per acre. Average other direct costs and fixed costs increased $65.69 and $9.76 per acre, respectively. Other direct costs in Table 1 are the differences in total direct expenses less seed, technical fee, herbicide, insecticide, and fertilizer costs. The increase in the other direct and fixed cost per acre averages can be attributed to increasing machinery costs and fuel prices as well as the added costs of hauling and ginning greater volumes of cotton. An additional assumption is that greater flexibility as well as other benefits resulting from GM cotton varieties allows producers to farm additional land which increases direct and fixed expenses. This assumption is one of the motives for this analysis.

To investigate the impact of changing production costs on producers with different land tenure arrangements, land costs associated with different tenure arrangements were added to each of the 1,000 simulated production cost outcomes. Revenues were calculated as the product of yield multiplied by the cotton loan rate of $0.52/pound. The loan rate was used for each year under consideration (1997, 2000, and 2004).[2]

Figures 1 and 2 show the returns to 100% owned versus 100% leased land for Mississippi cotton farms operating more than 1,500 acres. Figure 1 compares the relative returns for large farms with 100% ownership and farms operating 100% leased land in 1997. The data indicates that, in 1997, large farms with complete ownership were 27%

[2] A common price was used in all simulated years (1997, 2000, & 2004) in order to reveal the impact of changing costs on the relative level of returns across different land tenure arrangements. Clearly, this approach ignores the issue of how increasing productivity has influenced prices in the aggregate. This would be very important in an investigation of changes in the absolute level of profitability in the industry. Here, however, the only concern is the profitability of one type of operation relative to another (where type is defined by land tenure arrangement) and how that relationship has changed due to changes in the cost structure.

more likely to generate returns than large farms with all leased land. Figure 2 shows the relationship between relative returns for 100% owned land and 100% leased land and indicates that large farms were 23% more likely to be profitable if all of their land was owned rather leased. Figures 3 and 4 compare relative returns to 100% owned versus 100% leased land for Mississippi cotton farms operating less than 500 acres in 1997 and 2004, respectively. Figure 3 compares small farms in 1997 involved in either 100% ownership of their land or leasing 100% of their land. Figure 4 compares small farms engaged in the same types of land tenure arrangements but focuses on the year 2004. The results for small farms in both 1997 and 2004 were similar to the results found on large farms. Small farms with complete land ownership were 22% more likely to break even than the small farms that leased all of their land. The greatest difference in the probability of breaking even is shown in Figure 4 where farms with complete land ownership had a 29% higher probability of breaking even when compared to small farms that leased all of their land. Overall, the probability of breaking even was higher under the assumption of 100% ownership for both large and small farms in 1997 and 2004. Small farms with complete ownership of their land had a higher probability of breaking even in 2004 when compared to 1997. Conversely, large farms with complete ownership of their land had a higher probability of breaking even in 1997 rather than 2004.

Figures 5 and 6 compare the probability of large and small farms breaking even under a 100% land lease arrangement in 1997 and 2004, respectively. Figure 5 shows that large farms that leased all of their land in 1997 had a 11% higher probability of breaking even than small farms under the same leasing arrangement. In comparison, large farms in 2004 were only 8% more likely to break even when involved in a cash lease for 100% of their land. These two results are not surprising because larger operations realize lower average costs when compared to smaller farms and can gain economies of size more easily than smaller farms.

Figure 1. Returns to 100% Owned vs. 100% Leased Land for Large Farms, 1997

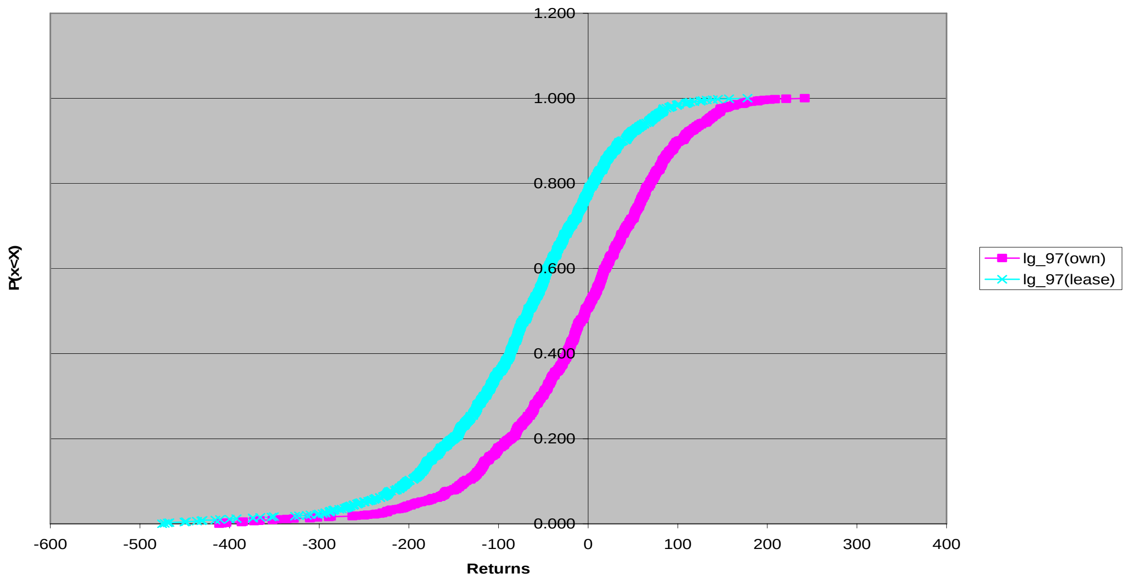


Figure 2. Returns to 100% Owned vs. 100% Leased Land for Large Farms, 2004

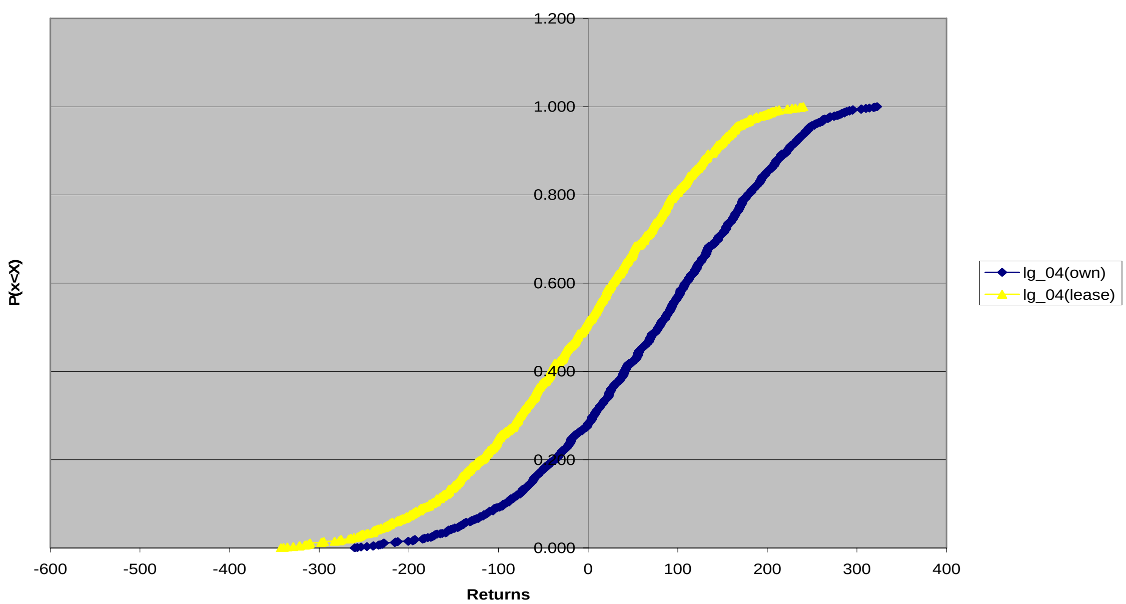


Figure 3. Returns to 100% Owned vs. 100% Leased Land for Small Farms, 1997

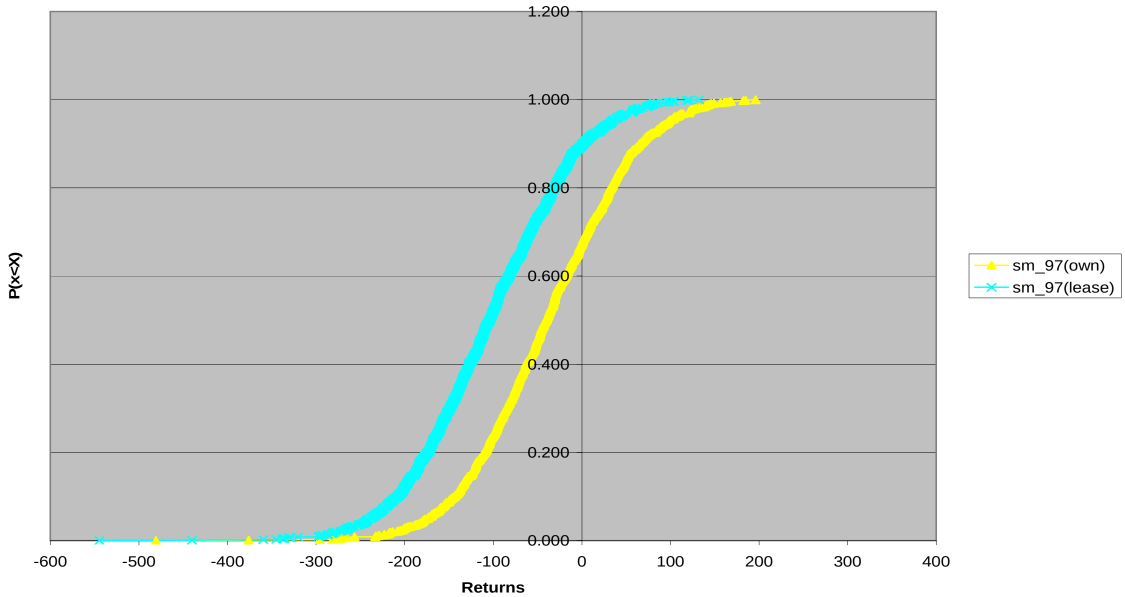


Figure 4. Returns to 100% Owned Land vs. 100% Leased Land for Small Farms, 2004

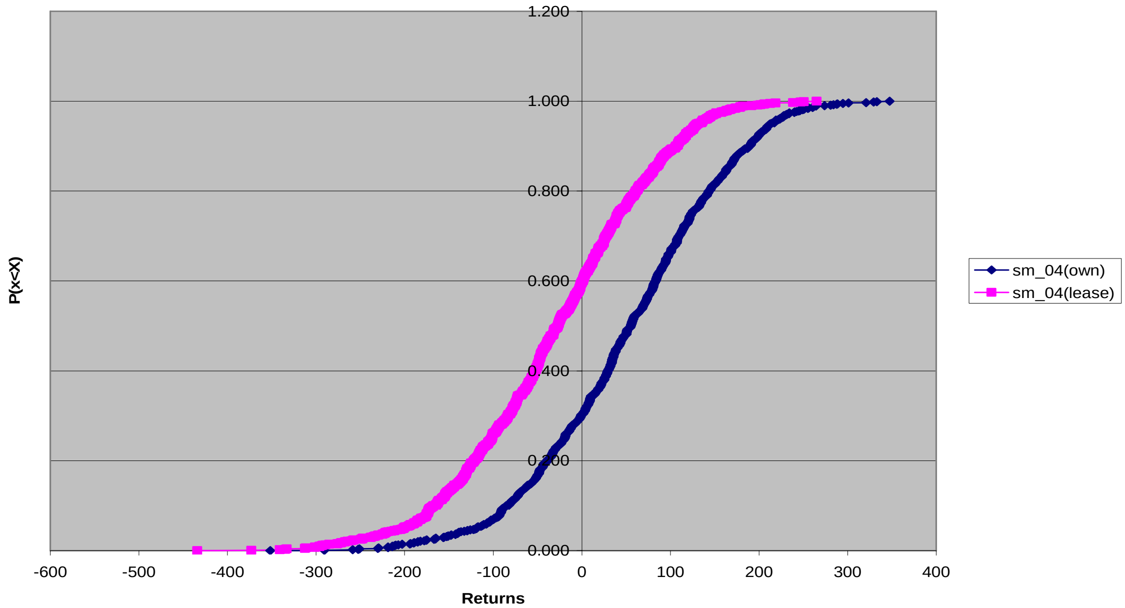


Figure 5. Returns to 100% Leased Land: Small Farms vs. Large Farms, 1997

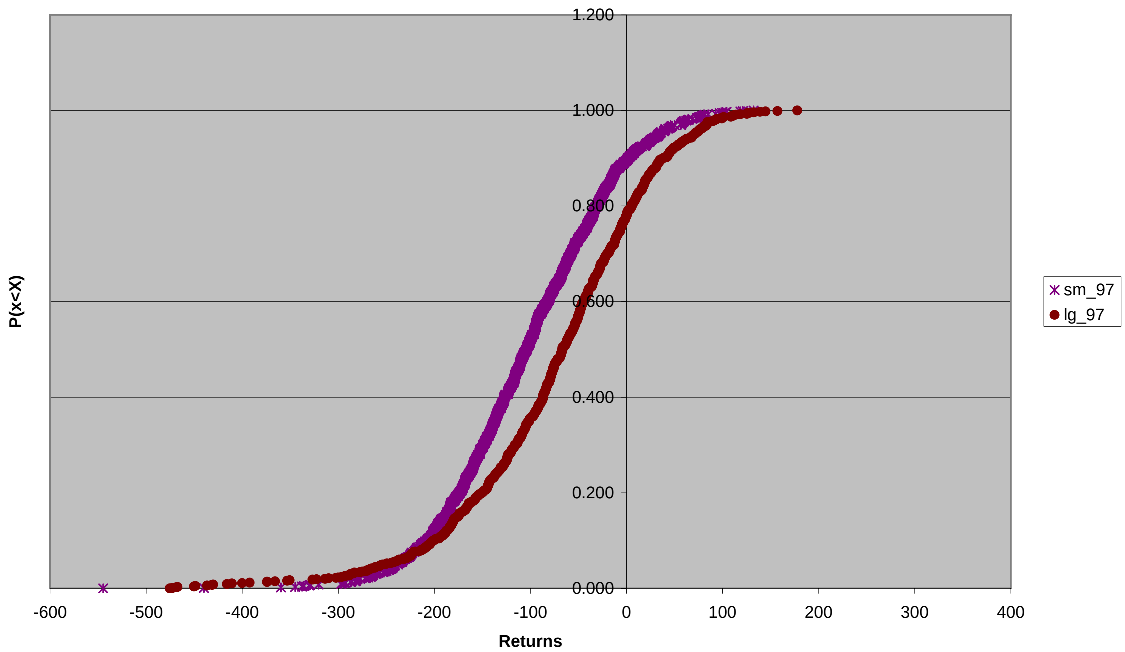
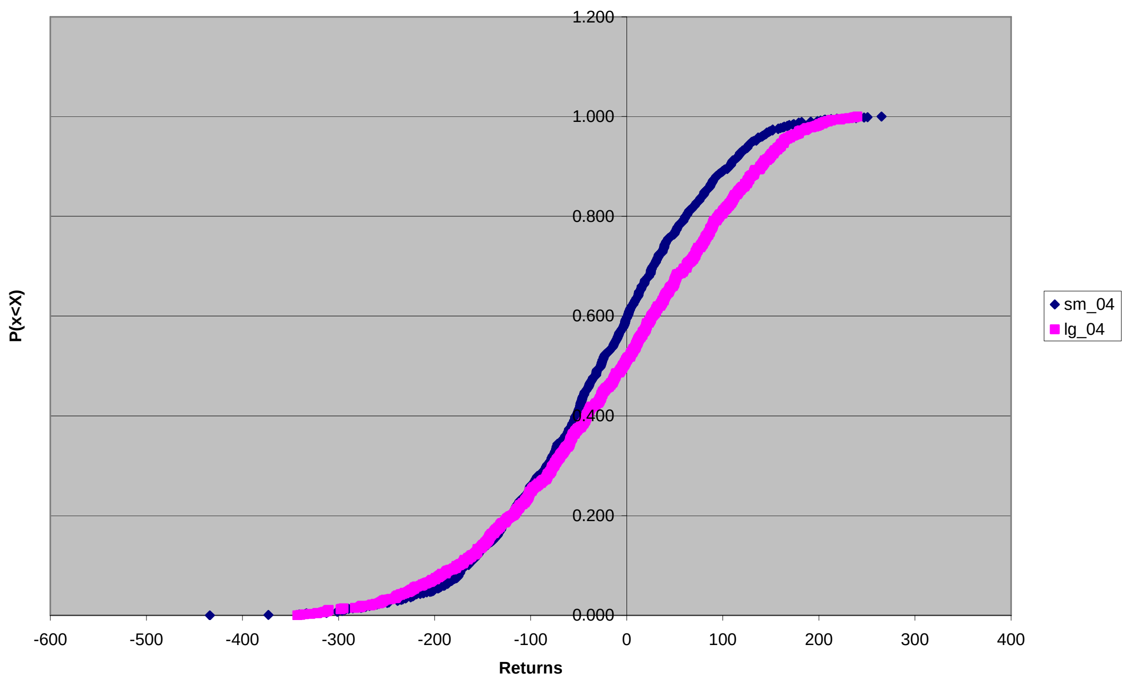


Figure 6. Returns to 100% Leased Land: Small Farms vs. Large Farms, 2004



Summary and Discussion

The results of this study clearly show that it is more probable for large farms with complete ownership of their land to be profitable in Mississippi. Without regard to farm size, ownership of the land on which a producer operates is preferred in most cases and has proved to increase the probability to break even in nearly all situations. Small farmers who are attempting to enter the market in Mississippi are at an obvious disadvantage because of the high amount of capital required to enter. Small farmers also face a lower probability of breaking even and can face other difficulties associated with attempting to expand the size of their operations. Medium and large farms have a slight advantage over small farms because, in many cases, they already possess some of the equipment needed in order to expand their operations. Also, large farms usually have complete ownership of some portion of their land which can increase their probability of breaking even. GM cotton varieties have proven to increase yield and lower some of the costs associated with cotton production. Directly after introduction, the benefits of GM cotton varieties could be easily observed. Presently, many of the benefits have been shadowed by increases in technology fees and other costs of production.

The introduction of GM varieties helped fuel the increase in average farm size at a time when producers had higher probabilities of earning profits. There seems to be increased probability for both small and large farms to break even. This remains true, even though some of the benefits initially recognized from GM varieties have been dampened. This can be attributed to increases in other production costs and the treadmill effect. Overall, technological innovations at the farm-level may be more expensive to the producer but these innovations make it more likely to break even or profit.

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