Portable Sawmills – A Small Scale Microenterprise Development

by

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Abstract

A Cobb-Douglas cost function of portable sawmill industry for United States based sawmill owners was estimated using cross-sectional data with two inputs and capital. The elasticity of the output (bf) to total variable cost was estimated to be 0.58. This shows that United States Portable Sawmill industry exhibits increasing returns of scale. The optimal scale of production for these sawmill operations was calculated to be 74607 board feet from the best estimated model. This value lies above the mean production 46182.17 board feet for these sawmill owners.

Results of this research emphasize the fact that forest based microenterprises that utilize equipments like portable sawmills can be operated at increasing returns to scale. The positive economies of scale make it elusive that these operations can be expanded to utilize the positive economies of scale. The production can be increased with decreasing costs until the optimal scale of production is achieved.

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CHAPTER I

INTRODUCTION

According to Zhu and Evans, 1994, one third of the United States is forested which means that the forest products industry is one of the major industries in many parts of the country. For example, many counties in Alabama are dominated by the industry, and are timber dependent in that they depend on the wood industry for their livelihood (Howze et al. 2003). Both the forest land owner and the harvesting crews depend upon this industry for their income generation. The recent technological advances in forest harvesting have made the harvesting of small timber tracts inefficient, while also eliminating small scale harvesting systems (Bailey et al. 2004). This means that the numerous small landowners all over the United States have virtually no options for utilization of their timber.

This is a major problem due to the fact the landholdings are small size (40 acres and below) and many of these properties are located in areas of poverty and poor housing. One way to combat this problem is to target these small tracts and find new ways to efficiently utilize them (DeCoster 1998). One such way can be the use of portable sawmills which are low investment machines, used on these small parcels of forestlands and can further generate jobs and revenue (DeCoster 1998). It can help to create many local forest products, which can be used to build new houses, improve existing housing, build or repair barns and other outbuildings, or provide material for fencing or other domestic and local needs.

Portable sawmills can act as microenterprises for generation of value added products of wood from small tracts of land all over the United States. These products may help sustain the markets impossible to be fulfilled by the mainstream forest industry thus helping to fill the niche created by regular forestry practices. This means the wood product markets which exist for supplying material for the local needs, and fulfilling the needs of the rural community at much lower costs can be generated regionally. The major factor which plays a role in the reduction of sawn wood costs is decreased transportation expenses resulting from short-distance movement of both the raw material and final product distribution. They may go a long way in fulfilling the local lumber needs, thereby improving the well-being and living standards of the rural community.

Salafsky, 1997, notes the importance of forest microenterprises in enhancing community development, and as a result, empowering local people to enhance their own income as well as manage their resources. Ssewamala, Lombe and Curley, 2006, found that "overall there is a considerable level of interest in saving for and investing in small-businesses among poor Americans, including those who are less advantaged in terms of poverty and employment."

The goal in this research is to find cost effective and economical ways of integrating small timberland owners into the forestry market that has not yet responded to their needs and create opportunities for small scale microenterprise sawmills. Therefore, for this research and economic analysis of the portable sawmill industry was conducted. The cross sectional data on the costs which go into operating these portable sawmill was collected through surveys sent to sawmill users nationwide. The study was completed to see whether current portable sawmill users are able to reduce costs, and if so what is the margin for the extension of these operations in a cost effective way. This means that the sawmill users can increase the production level up to a certain level with increasing rate of returns.

This thesis begins with a conceptual cost model being specifically applied in the case of portable sawmills. This is followed by the theory which goes into the basic understanding of cost models. Next the methodological model is explained. And why this project is important is discussed. Then, the data which goes into empirical models which are based on the conceptual models are explained.

The last section includes the results which we obtain from the model. The last section discuss how the results from this study can go into the development of extension programs which can inspire other entrepreneurs under the same economic and regional condition to enter the business and also make profits.

Literature Review

There is not much literature in analyzing the costs for portable sawmill use. The primary reason is that it is hard to obtain financial data for small businesses in general. Also, these machines are used by a lot of people as a hobby, so owners do not keep records. This makes the economic analysis of these machines harder and complicated. They were quite a popular piece of equipment in the beginning of the 20th century (Boisfontaine 1930). But they lost their charm as the operators started increasing the scale of operations for cutting back the costs. This is a common behavior observed in a lot of production businesses which tend to morph according to the market conditions. The prices of timber were increasing in the mid century and it was an attractive business to take risks and investments. As the contemporary wood harvesting and processing technologies increased in scale, new niches for smaller scaled technologies were created. Owners of small tracts of timberland needed access to a market for their timber, and portable sawmills have fit that need (Lupo 2010).

This section of the thesis underlines the importance of portable sawmills, what lead to their revival, and what are their advantages and possibilities of success in the current scenario. There is a lot of emphasis on their usage among the current forestry business and it will be discussed over the following few pages. There has been considerable research done in other parts of the world such as Africa, Britain, and Australia. Portable sawmills are more attractive for the developing parts of the world since the scale of operations is small and initial capital investment on the equipment is low, accompanied by low labor and material costs. The low labor costs and material costs make them an attractive piece of forest equipment for the developing part of the world. Portable sawmills can fill the niche which the traditional milling industry is unable to fulfill. The extension report published by Jonathan and Joy, 2003, explains how they are regaining their importance in the current situation.

Seventy different manufactures of these mills exist in the equipment industry, providing a variety of options depending upon the requirement and offer a wide variety of models with different specifications (Kays and Drohan 2003). The simplest of these machines depend on manual labor for their entire operation except powering of the blades, while the hydraulic and electric ones require the least manual labor. Demand for the services of such machines is a relatively new development for the handling of management issues of the forests. The maturing stands in the North-central, Midwest, North-eastern, and South-eastern United States are heavily forested with stands of mixed hardwood and softwood species (Kays and Drohan 2003). This implies that the wood resource for small mills is virtually limitless. On one side, the acreage of the forest lands and the volume is increasing, while on the other side the land parcels and ownership tenure is decreasing. This makes the use of large sawmills unrealistic for use by these land owners. Operators can gain access to free or inexpensive logs, saw dimension lumber, and saw on sites with low sawtimber volumes, hence saving trucking expenses to and from a mill.

The portable sawmill business has additional revenue potential if the mill owners can perform simple machine services themselves, and are willing to move between sites and maneuver to the different lumber locations (Kays and Drohan 2003). Many operators do not have a need to market or advertise their business locally for selling their material, but the ones who want to enter the competitive market can develop a marketing campaign to fit in the market.

The argument that increasing the size of operations can help to cut back the costs is valid for larger sawmills since they can offset the high cost of capital. This means higher speed and more efficient machines can help to cut back the costs of buying and processing logs (Gorman and Dramm 2002). Nevertheless, when log prices (material input for small scale portable sawmills) are low, some portable mill owners may find it possible and desirable to function at a profit.

In her research work, Lupo, 2010 who conducted survey on these portable sawmill operators in United States, has documented that 73 % of the respondents harvest timber from their own land. So this offsets the material costs for these operations, opening a window for their successful and cost effective operation. After analyzing the numbers, it was also reported that there is a significant relationship between the income and the material procurement from their own private lands. This means that higher the income from sawmills, more likely the material was acquired from their own lands, thus cutting back the costs. In economic terminology, higher profits occur when material costs are low.

Mill Capacity Change Leads to Fall of Businesses

The history of forestry presents portable sawmills as an important piece of equipment for wood procurement (Boisfontaine 1930). It was stated that more than one-half of the lumber production of the south came from portable sawmill setup operating at a scale smaller than 200,000 board feet. Most of the timber harvested in these operations was second growth which came from large cut-over lands of past operators. It was stated in this paper that "These thousands of small mills can no longer be ignored as production factors." A 1929 survey as mentioned in the same paper shows that of the total pine produced, 53 percent was cut by these small portable saw mills. This totaled to six billion board feet a year. In Georgia, they accounted for 91 per cent of the pine produced; in Virginia 80 per cent, in North Carolina 74 per cent; Alabama 68 per cent; and South Carolina 66 per cent. The beauty of such a small mill is the mobility and easy setup at a new location. The move was warranted in those days if the tract promised six month supply of logs.

The fall of 1929 marked a steeper decline of products from small mill production than the large mills (Boisfontaine 1930). In October of that year, Southern Pine

Association collected statistics of 237 small mills covering the states of Alabama, Florida, Georgia, Mississippi, Arkansas, Louisiana, and Texas. Of these 237 mills, 188 were closed down. The following year, production was estimated to fall below 47 percent that of 1930 and 66 percent of that of 1929. However, the dependence on small mills was not completely lost. They were considered to be in an ideal position as their production could be expanded or curtailed according to the available maket lumber demand. The operators opted to own little or no timber so if inactive they did not have to pay any taxes. Since these small mills are operated by mill workers themselves and their families, they don’t have any labor repsonsibilties such as insurance and liabilities. The only favorable thing required for their successful operation were favorable market conditions. Boisfontaine’s statement in the 1930 publication still holds true : “It is also doubtless true that with the cutting out of the bigger mills, the portable sawmill will represent the most economical and efficient means of sawing the trees that remain on scattered tracts, and harvesting our timber crops of the future”.

Preliminary survey of the lumber production in the six states namely North Carolina, South Carolina, Virginia, West Virginia, Kentucky, and Tennessee during 1942 was estimated to be 5.8 billion board feet (Toler 1943). Various sawmills were used for the processing of lumber at that time. Approximately one third of the sawmills in the US were located in these territories alone. There were 15,294 sawmills of which 12,557 mills were operating and 2,737 mills were idle. These mills varied in their size from small circular mills capable of cutting one to two thousand feet of lumber per day to large band mills with output over 100 thousand board feet per day. In the operating mills category, 99 percent of the mills, including both custom and commercial operations, were small mills that produced less than 5 million board feet of lumber during the year. These circular mills accounted for 82 percent of total production during 1942. These mills were owned by persons who operated the mills occasionally in connection to farming or other work. It was reported that they charged a flat fee per thousand board feet for sawing, and the stumpage owners were responsible for the logging and handling of lumber. The lumber produced by the smaller mills was used for farm construction and other local use, while that sawed by larger custom mills was usually sold to concentration yards which can be used for commercial purposes. The small commercial mills were operated by owners whose main livelihood was lumbering. Some of these operators worked under contract while others worked independently buying their own stumpage and selling direct to the yards, mines or other purchasers of lumber.

Mill Consolidations and Market Fluctuations

A report published on the primary wood-product industries of Pennsylvania in 1969 highlights the changes in the sawmill industry. When the sawlog production went down to less than 0.5 percent, it dropped the mill number from 999 to 684 (1969 Primary Wood Product Industries of Pennsylvania Report). There was a total drop of 32 percent in the number of operating sawmills (both portable and large-scale) in Pennsylvania. Timber industries were important in the state; they provided 57,000 jobs in 1967 and paid the employees approximately $350 million in wages. The evaluated value of the products manufactured by these industries was more than $1.5 billion at that time. It was also mentioned in the report that there was an abundance of growth and it exceeded the forest cut.

This report also mentioned that the number of sawmills decreased as unit production increased. There were approximately 1,500 sawmills operating in this region in 1899, many of which were low volume portable sawmills. As production declined over the years, the number dropped to a significant low of 211 in 1932. Then, a rise in lumber demand in the early 1940's increased the demand of these mills which rose to 1,381 from 369 in 1942, and finally reached a record high of 2,745 in 1947. So, the numbers fluctuated drastically within a seven year span. In the two decades when production was static, the number of portable sawmills decreased. In 1954, 96 larger sawmills (more than million bf /year) [1] were producing 25 percent of the total production while the rest was being produced by 2,283 small portable sawmills. In 1969, 150 of 689 sawmills were producing more than one million board feet annually and a similar trend was seen throughout the north-eastern states. The low volume mills were ceasing operations and high volume mills were increasing production. This trend occurred to cut back the costs for large scale lumber production.

The trend was different in less-forested regions of southeastern and western regions of Pennsylvania where few low-volume sawmills discontinued operations (1969 Primary Wood Product Industries of Pennsylvania Report). Taking into account the overall picture, the prediction was that the highest mortality took place in the lowest production classes. But in the other two regions of the state which were heavily forested, an increase in the number of high volume sawmills occurred which was accompanied by a decrease in low-volume sawmills. This observation leads to two possible inferences. The first may be that there was a low level of competition between the low and high volume sawmills. The second possible explanation can be that low-volume sawmills in these regions had captive local markets for their limited production.

There is a lack of literature on these small scale portable mills between the years 1950-1996. This can be attributed to an upsurge in the scale of operations as wood was considered an attractive investment during this time period in the United States.

The trends in the southern enterprises changed to build larger operations to reduce unit costs in the decade of 1976-1986 (Granskog 1989). The efficient plant size determined by survivor analysis increased from 1,000 to 1,500 tons per day for pulp mills, 100-250 million sq. feet per year for softwood pulpwood plants, and 20-50 million board feet[1] per year for the pine plants (Granskog 1989). Industrial development in the past has been influenced by severe recession and new competition from imports. Products like wafer board and oriented strand board have forced firms to reduce costs and become more efficient. The scale of operations can be an important factor affecting competitiveness. The scale of operations means that operations within a system setup may be expanded or reduced in size depending upon the cost effectiveness of the business. The scale of operations in wood processing have changed over the years in the United States and in some of the other developed countries of the world.

The forces that attributed the changes in the forest industry in the past decade were attributed to severe recession and competition from imports and products like waferboard and oriented strandboard (Granskog 1989). The 1976-1986 decade marked substantial reconstructing of the forest industry.

[1] 1 bf wood = 144 cubic inches of wood (1 inch thick and 12 inch square feet)

There were strong measures taken to exploit the economies of scale of timber industry. These included increasing the capacity of pulpwood plant to 30%, softwood plywood capacity to 62%, and average sawmill output has risen to 76% (Granskog 1989).

The report by Spelter, 2002, discussed the history of these small mill closures, opening and net capacity changes in the softwood lumber sector. Between the period of 1996 and 2003, 149 sawmills were closed, which accounted for 17.6 million m^3 (17.6*4.81= 84.65 million board feet) of lumber processing volume loss, and represented a total of 12% of the lumber industry. The report only takes into account the large mill closures. There were new additions of the mills which added additional 4.3 million m^3 of lost production potential, and upgrades to the existing mills have added 31 million m^3 to the capacity. The closures occurred every year but the most heavily impacted period was between 2001-2002, during which half of the capacity was lost (8.4 million m^3).

The above mentioned industry transformations also occurred due to the Softwood Lumber Agreement between Canada and United States which demanded that imports beyond a predefined quota (30 million m^3) will be taxed (Spelter, 2002). This is a perfect example how policy change can affect the market conditions. During this period, the timber supply from the U. S. federal lands was shut causing log shortages for the mills. The dynamic nature of economic markets lead to demand and supply fluctuations. This lead to string of activities in the market, which caused some mills to retire and some to sell out. Companies buy or merge with their competitors in long term situations. In short term response to these situations, managers take curtailments, add or remove shifts, and schdedule overtime and downtime. The long term consequence are decisions to build new mills, invest in capital boosting capital improvements in the existing mills, or permanently shut the facilities.

The scale of United Kingdom forestry has changed over the past 70 years (Banks and Cooper 1997). The industry changed from small scale sawmilling serving local market needs to a large scale industry supplying local market needs. The development in the United Kingdom industry is compared that to North American and the Nordic countries. The industry noticed a considerable vertical integration with value being added to the product by either cutting to the preferred dimension, edge sealing and coating, and overlaying with decorative laminates. A vertical integration of market is often proposed in the scenarios to reduce the costs. This led to reduction in the small scale sawmills operations.

The conversion efficiency of the mills in terms of most of lumber processing variables increased with an increase in the size of sawmills but decreased after production exceeded 100 million board feet in the United States (Philip et al. 1991). Large sawmills with higher productive capacity consume more sawtimber than the smaller sawmills, thus having a greater influence on the timber supply. Henceforth, in areas where the supply is limited due to higher transporation costs, smaller sawmills can be put to use for local processing because of their easy mobility factor. The mill size has a significant influence on unit log use and large sawmills use less log volume per unit of the lumber produced.

Requirement of Scale Appropriate Management

The thesis work done by Brodbeck, 2005, on the “Timber Industry Consolidation and the need for Scale Appropriate Harvesting Systems mechanisms in Alabama’s Black Belt” in the black belt region of Alabama provides numerous references and citations which support the need for scale appropriate harvesting systems. Private property has been fragmented over the generations, and the growing size and production constraints of logging crews and the sawmills have left increasing number of small timberland owners without a timber market. Nationwide corporate consolidation has also decreased the number of mills over the years while maintaining constant production which has narrowed the market for small timberland owners. This led to reduced employment in the mills and reduced number of small scale harvesting systems.

Conventional logging crews cater to the needs of large sawmills, and pulp and paper mills, which need tree length systems which resulted in elimination of the shortwood harvesting operations (Brodbeck 2005). The final consequence greatly reduced timber management options available for small land holdings of size lesser than 50 acres. Further, the industralization of timber production process excluded the small logging operations unable to compete with limitations set by modern samills. Small logging crews generally are not as cost effective as the larger operations using modern and advanced techonology. Only portable sawmill operators with lowest cost per ton are able to remain in the business since the mills have reduced the delivery prices to afford competitive stumpage prices. The outcome of this scenario is a need for scale appropriate logging operations alongside a viable market to provide small timberland.

Increasing technology use and decreasing size of land ownerships makes the harvesting of the smaller tracts costly (Greene et al. 1997). The options available to these small land owners have disappeared with the loss of the shortwooders, animal loggers, and small more manual oriented operations such as portable sawmills which are needed to make the small tracts profitable (Greene et al. 1997, Toms et al. 2001).

Significance of Small-Scale Products and Small Landing Management

The development of small scale technology can go far in appreciating the small forest land holding values. Besides the economic opportunity for the utilization of unmerchantable material, other reasons include improvement of forest health and protection from forest fires. The material obtained locally needs to be processed with machines which can meet the local market needs. This proposes the theory that small and less complex machines can be developed or put to use which match the demand for local products. Economic feasibility of products from small-diameter timber is possible which advocates the use of this material successfully.

Forest Health and Useful Products

Small diameter timber which exists in dense forest plantations can be removed economically and utilized with generation of profits (Spelter et al. 1996). Materials considered difficult to harvest due to high harvesting and transportation costs are defined as unmerchantable materials. The technical report on the economic feasibility of products from the inland West analyses the use of small-diameter timber successfully with positive revenue (Spelter et al. 1996). Evenly-aged dense trees which are the result of the recurring fires in the Midwest had been considered an economically challenging endeavor. But, studies done in such areas show that it is feasible to harvest trees from such stands with positive income (Spelter et al. 1996). This resource can be used to generate numerous kinds of wood products such as oriented strand board (OSB), stud lumber, random length dimension lumber, and laminated veneer lumber (LVL), and market pulp. The investment risk was found to favor the lower-cost lumber alternatives over the high cost alternatives. This behavior is found because it decreases the losses incurred due to the fluctuating market prices. In Spelter's paper, each product was studied with the costs incurred in processing of raw material into final products. The possible revenue generations was also estimated.

Spelter, 1996, documents the facts showing that positive profit can be generated if engaged into these processes. In each product, returns ranged between $1.24- $3.60 / bf depending on the product manufactured and the cost scenario. This shows there is a possibility of material to be utilized which is considered un-merchantable in most scenarios. Portable sawmills can be used for initial processing of some of these saw logs into merchantable material depending upon the scale of the operation.

Small diameter material can be utilized for numerous purposes. The paper by Levan-Green and Livingston, 2001, explores the use for small-diameter trees. The small-diameter material and underutilized (referred as SDU in literature) can be utilized for generation of marketable products. SDU material cannot be processed with the existing local capacity or which is not economical to remove from the forest due to high harvesting, handling and processing costs. There are numerous beneficial forest management reasons which make the removal of this kind of material necessary. These include reducing fire hazards, alteration of the stand species and quality mix to more desirable composition, provision of healthier wildlife habitat, and watershed protection.

A dense understory creates a ladder-type fuel that leads to crown fires (Levan-Green and Livingston 2001). The fires can alter the watershed and vegetative structure of the forests as they can spread really fast. To restore the optimum conditions, these forests need thinning and possibly prescribed burning. This forest first needs to be mechanically thinned before any prescribed fires could be set. The cost effective and value-added uses for the thinned SDU material could offset the forest management costs and economic opportunities would be created for rural forest-dependent communities. Management issues arise in such stands either because they are small-landings or their distance from the processing plants is higher to meet the transportation costs. Portable sawmills can be used for the processing of such material onsite. The harvesting on such sites can be performed by tractor mounted equipment which is a cheaper alternative for obtaining the material locally.

Numerous benefits can be achieved by value addition for SDU material. (Levan-Green and Livingston 2001) Stand species and quality mix can be improved, forest resiliency can be increased, risk from insects and disease as well as catastrophic wildfires can be reduced, wildlife habitat can be made healthier, watersheds can be improved and protected, and the economic vitality can be restored for many forest dependent communities. This can lead to provision of supply of wood and fiber to our nation. Emergency legislation was enacted in the 2001 fiscal year to provided funding to the forest service to increase firefighting response, restore landscapes, and rebuild communities. The government's funds can act as a catalyst in such situations but we need real solutions to economically restore our forests to a healthy and productive condition. The estimates predict that even if 20-30 percent of the thinned material can be utilized for higher value, the economics of forest management can be improved tremendously. And, also there would be 40-50 percent of this thinned material available for traditional log markets, for dimension and non-dimension lumber.

This SDU material can be put to a number of uses. They are dimension and non-dimension softwood lumber, engineered wood products, glued-laminated lumber, structural round wood, wood composites, wood fiber/plastic composites, wood fiber products, pulp chips, compost, mulch and energy uses (Levan-Green and Livingston 2001). The logs can be used widely into three major forms. The first being used as value-added uses, second in traditional uses and third in the form of residues. The value added uses include flooring, paneling, cabinets, furniture and millwork. They consist of the most expensive market uses of log products. The traditional uses consist of saw logs, structure lumber, nonstructural lumber, poles/posts and pulp chips. The residue uses consist of biomass energy, ethanol, firewood, pulp and composting. There have been efforts to characterize the engineering properties of wood from SDU trees; we need to continue these efforts to fully understand the resource.

Rural Development

The management and use of SDU material is also important to bring a social change in the rural and under-developed societies of the United States. Community based forest stewardship is a collaborative program between the forest industries and local communities which play a major role in creating partnerships with forest agencies and new ways of doing businesses. They help to cope with the problems of declining forest budgets, staff, declining timber supplies, loss of jobs, high unemployment, and social ramifications associated with these issues.

Community–based forest stewardship is defined as “a process of scientists, governments, and citizens working together to agree upon and attaining goals and objectives that are environmentally responsible, socially acceptable, and economically viable” (Susan and Jean 2001). The success of these programs depends upon the interaction of the community members. Social change and technological advancements are opening new windows for communities to develop rural enterprises that add value to SDU material. The members of these communities contribute in a variety of ways such as knowledge about ecology, funding in form of grants, cost-shares, matching services, project administration, consultation, technical assistance, and field coordination. The economic diversity of rural communities can be improved, and new jobs can be created if efforts are in the right direction.

This paper also discusses the fact at the end of the 20^{th} century; there were tremendous technological advancements for the utilization of SDU material for both the traditional lumber and new potential value-added uses (Susan and Jean 2001). Conventional mills are still in operation by most of the companies and there has been increase in the equipment processing SDU material over the past decade. The technology advancements and changes are helping open new avenues for rural communities and develop rural enterprises. Jobs created because of the development of new forest based industry will help diversify the economic conditions of farmers and forestland owners.

The report by Perkins et al., 2008, discuss that small diameter hardwood timber is often of a lower quality and value than larger saw timber. This resource has been traditionally utilized only for pulpwood, but it can be utilized also for lumber and residue production. For increasing the use of this material by sawmills, analyses need to be conducted. These will include the resource analysis, yield analysis, economic analysis, and finally the market analysis. This report just proposes the methodology for conducting the research but does not provide any results (Perkins et al. 2008). The survey can be put out which can collect the following information about the scope of development of markets for such material.

Success Stories

Government funding can play an important role in starting a new innovative business. USDA Forest Service projects can help to restore forests by creating markets for thinned material. Whether the material comes from hurricane blown trees, overstocked trees or small landings, some forest workers are succeeding by using small-diameter and low-valued trees. The technical report by Livingston published in 2006 documents numerous case studies of such successful businesses which have been based on small-diameter timber. The material is generated by technical modifications of conventional farm equipment available with the farmers for harvesting, processing and handling on smaller scale. These businesses are taking junk or low-value wood and helping to make a product such as pulp, poles, posts, flooring, molding, millwork, wood pellets, or biomass energy.

This report emphasis that even if 20 percent of the low-value wood can be turned into value added material such as flooring, paneling, and art work, it would defray some of the forest management costs (Livingston 2006). In the thesis work of this project, the portable sawmill owner surveyed were using regular wood obtained from their local lands or neighborhood lands. The wood on these lands is considered junk in the sense that costs incurred for harvesting and processing were discovered to be high.

Forests Jobs and Revenue Generation

Forests can be a source of revenue which can lead to employment generation by creating new job options (Rolfe 2000). The forests can be managed with objectives of revenue generation. A study done in Western Queensland, Australia gives an account of such a scenario in which pros and cons of grazing versus timber generation were studied.

A financial model was developed to facilitate a comparison of private profitability of small-scale timber production from remnant woodlands were compared against clearing for pasture development in western Queensland. Four small scale timber production scenarios, which differ in target markets and extent of processing (value-adding), were explored in the model. The overall conclusion of the study was that net present value per hectare (2.475 acre) of selectively harvesting and processing high-value clear wood from remnant western woodlands was higher than clearing for grazing. The Acacia and eucalyptus woodlands were considered an impediment to agricultural productivity particularly pastoral development due to lack of information about the resource, the scarcity of straight-bole trees, their typically small stem diameters, the prevalence of timber defects, and remoteness from major timber markets, resulting in lowered private landholder valuation of these woodlands. The drought and low commodity prices furthered pressured pastoral farmers to increase productivity for staying economically viable.

Land clearing became highly emotive and politically charged issues in western Queensland; clearing was an activity encouraged by government. The short term productivity gains outweigh the longer term costs of continued land clearing. The geographical distribution of merchantable wood volumes, wood properties of selected tree species, estimate costs and recoveries, and identification of potential markets was research performed by Queensland Forestry Research Institute (QFRI). The problems with these trees were higher densities, greater hardness, more defect, less shrinkage, shorter log lengths and small log diameters. These issues are also seen in the United States forests, but the tree species do differ in the United States due to geographical variations. Venn et al., 2003, states that "The processing trials did indicate that low cost and low-technology timber processing methods such as portable sawmilling and protected air drying is suitable for western Queensland hardwoods." This can be a great example of processing the woods in our country's local wood resources available in similar conditions or scenarios where small-scale wood management is required.

One option which can help the business is selling products from such trees in high-value niche markets, such as manufactures of musical instruments that can pay high prices to timber merchants for sawed and dressed wood. Similar markets need to be created in the United States also, so that high value addition can be done. Venn et al. 2003 also emphasize that timber production is likely to generate considerable economic benefits in rural communities, including employment creation and local skill development, income diversification and tourism opportunities. They can be considered as a form of liquid asset for landowners who can tap into it for extra cash. The portable sawmilling trials have indicated that saw log volumes in these woodland types are likely to be about $1m^3 ha^{-1}$ (Venn et al. 2002). Processed lumber is used for green off saw ungraded boards, VS boards for internal wall paneling, clear wood for high-value domestic and export markets, parquetry flooring (multi-landholder cooperative), harvesting and processing operation in the timber processing scenarios. The production can be aimed at high-value domestic and export clear wood (defect free) markets, such as knife handle and musical instrument manufactures. For the flooring option, cooperatives can be developed which can result in job generation for local or regional people involved.

The research of Venn, 2004, in Queensland, Australia saw sawmills as a way of harvesting limited timber volumes by bringing the mills to the landowner, eliminating the transport costs, increasing the lumber recovery from the logs, limited labor, low equipment set-up costs, and low cost of entry into the market (Venn et al. 2004). As mentioned above, the research by Venn et al. in Queensland found that milling costs were extremely high due to the inexperience of sawmillers and difficulty of sawing irregular logs, and thus a need for low volume, high-value niches, where the buyers are able to pay for the unique properties of these timbers. The success of these sawmillers varies due to competition with the foreign and softwood markets, and the use of non-forestry products (Smorfitt 2003).

Portable sawmills can provide a future role in the timber supply chain as discussed by Smorfitt et al., 2003. Markets for rainforest cabinet timbers are currently limited in north Queensland but the niche market can be developed for the exotic cabinetry. There has been an interest in the use of portable sawmills in relation to farm forestry in Australia. The various types of chainsaw, circular saws and band saws are available. The advantage of them is that they can be readily moved between the sites. Fortech, 1994, pointed out that portable sawmilling in Australia is a highly informal sector, thus its characteristics are hard to quantify. The milling costs of the operation are an important element in cost structure of the saw millers. The millings costs are different from other costs such as log acquisition, felling and haulage and other value adding activities such as drying, timber treatment and other processing. The other major advantage discussed in the paper comes from the fact that they offer low equipment and operating costs, and have higher environmental benefits (as biomass can be left on site).

Another issue that these portable mills face in Australia is that quality is considered incomparable with that of the fixed site mills. Some produce lower quality wood but there are examples of sawmills supplying high quality woods to the Brisbane markets over the past 10 years (Smorfitt et al. 2003). The costs of sawmilling by portable sawmills is impacted by timber source, the type of the species milled, and recovery rates. Most of the sawmillers from the conducted survey obtained their logs for processing from private landowners. Sawmillers like many small businesses operators do not keep records necessary to allow the estimating the costs of sawmilling.

The limited existence and the increasing need for these small-scale harvesting operations provide both an opportunity and challenge for rural communities of America. The introduction of micro level industry options in form of micro-enterprises allows local people to provide small-scale services to timberland owners. The major challenges begin with the limitations small-scale sawmill operators have with delivering woods to the mills. Transportation costs constitute the major costs (Brodbeck et al. 2005).

Thus, this leads to the need of small-scale consumers of raw products, such as portable sawmills, which can process logs and produce lumber which can be sold and used locally. Research has been conducted in third world countries and remote parts of Australia, where the markets are limited and poverty is common, like rural parts of America. But the limited successes of these enterprises are a cause of concern for looking at ways to implement them in the United States. There is an understanding that these enterprises operate in very specialized markets and on the edge of profitability, especially when efforts are made to move them outside the local or international markets. The hope is that communities can possess portable sawmills, and use them in conjunction with small-scale sawmill operators for utilization of local timber for the improvement of the dilapidated housing. The primary products such as sawn lumber can be used for furniture wood, paneling, flooring, molding etc; which could be sources for additional employment and local business (Brodbeck et al. 2005, John Bliss 1994).

CHAPTER II

RATIONALE AND JUSTIFICATION

Although there are large mills available for processing of log wood, there are currently few options available to process small loads of locally available material. High transportation costs and minimum load requirements for processing by larger saw mills, which are characterized with large economies of scale makes them unable to process wood available from smaller tracts. Therefore, a small portable sawmill may be an easily available option to add value from locally available wood resource. The portable nature of these sawmills have an added advantage to serve multiple small plots.

The data obtained from the nationwide portable sawmill users survey was used to generate cost and demand functions for portable sawmills as a microenterprise. Results give a picture of the current situation, and information for further improvement of the condition of these microenterprises. In addition, it provides evidence on feasibility of such operations and could motivate other entrepreneurs with similar economic circumstances to successfully utilize existing opportunities. This will help the economic and social development of the communities.

The production and the cost data collected from the surveys from the use of the portable sawmills provide data on what is the best use of equipment on small tracts all over the U.S. A small, less expensive portable sawmills with reasonable operating and ownership costs and productivity matching the volume of the locally available material may be a useful processing alternative. The results of this study will assist sawmill operators in deciding whether a small portable sawmill can be integrated into a small business. Identifying the optimal scale economies could help current portable sawmill owners to decide if further expansion of the operations is possible and economically justifiable.

The analysis of cost function in this study leads to identifying the nature of current operations and if microenterprises experience increasing, constant or decreasing returns to scale. This will help to clear how the capital and the labor part of the operations affect the output. They can be further analyzed to calculate the elasticities of substitution i.e. how much labor can be substituted with the capital to make the operation more profitable. The numbers documented in the survey will be analyzed to see that if these operations are making profit and if yes, how much space is available for expanding their businesses successfully by improving efficiency and cutting back costs. The inflection point for the cost curve will help to access the optimal scale of operation for such kind of businesses. This will give the point where the costs can be cut by expanding the business at profit levels.

Objectives

1. *The economics of scale for portable sawmills will be estimated from the survey which can help in decisions regarding the extension and contraction of the businesses.*

2. *The elasticities of substitutions between the inputs can be generated which can affect the input decisions. This will be established with the estimation of translog and Cobb-Douglas cost functions.*

3. *The economic status of portable sawmill owners may be helpful in developing extension programs promoting the increased use of portable sawmills*

Theoretical and the Conceptual Model

In this particular case we have businesses with cost data collected from a survey. Useful concepts in economics used here are expenditure function or cost function. They can be used in a variety of settings and are useful in measuring a number of phenomena such as welfare, efficiency, technical change, input substitution and economics of size, scope and scale (Pope and Chavas 1994). The cost minimization assumed and used in this thesis is an appropriate efficiency criterion applicable to enterprises in a variety of conditions such as competition, monopoly, and non-profits.

The approach for this thesis is similar to work done by James and Karen in 2006, on sawmill industry in Michigan, Minnesota and Wisconsin. The main behavioral assumption in this study is that sawmill owners try to manage their cost to minimize them with respect to a given output level and factor prices. By doing so, sawmill owners and operators are assumed to be both technically and allocatively efficient given an output level and input prices. When relative input prices change the rational producer will use different portions of each input to produce given level of output at minimum cost. The assumption that both the input and output markets are competitive also holds.

Estimation of factor demand using the cost function is based on the dual relationship between the production and the cost functions. Instead of estimating a production function, the dual-cost function model estimates costs function related to the production structure of the industry.

The implicit production function is

$$[1]\ Q = f(L, K, M)$$

where, Q is the lumber output (board-feet), L is the labor ($), K is capital ($), M is the material (number of sawlogs).

Labor, capital and materials are variable inputs and the rational producer adjusts the use of these inputs based on their relative prices to minimize the costs for a given level of output (Q). The dual cost function for the above mentioned production function is

$$[2]\ VC = f(Q, P_L, P_K, P_M)$$

Or

$$TVC=f(P_L.W_L, P_K.W_K, P_M.W_M, P_Q)$$

Or

$$TVC=f(S_L, S_K, S_M)$$

Where VC is the variable cost ($) defined as the sum of the labor, capital costs and the material costs.

$$VC= \sum P_i W_i$$

$$I = L, M, \text{and } K$$

W_i is the cost-minimizing variable factor quantities, P is the variable factor prices ($), Q is the quantities of the various inputs and the S are the cost shares of the three inputs which includes their prices multiplied with their quantities.

The costs mentioned in the conceptual model are sub grouped further into two main cost categories. The first category is defined as labor share cost which constitutes of the cost being paid for hiring of labor operating the equipment. The other major component of this cost included the insurance for the labor. There is a great deal of risk involved and safety issues dealt with the operation of these machines. So insurance becomes an important component of the labor costs.

The first property of cost function is that if there is production, meaning the output is positive ($y>0$), positive costs will be incurred during the process. The second property says that for the production of zero output, the cost-minimizing costs will also be zero. The third property explains that as output increases, the costs holding everything else constant will also be higher. The fourth property means that increasing one factor price will increase the costs which can be illustrated by input choices. The fifth property means that doubling all the factor prices or the factor shares in our problem, will double the costs. This is defined as the property of homogeneity of a function. The next property follows by the convexity of the isoquants and the linearity of the cost function i.e., as factor prices changes continuously, there is continuous substitution along the isoquants, and by linearity costs change continuously.

The second category costs consist of the operating costs on the machine. These costs range from the fuel and lubrication costs, repair and replacement costs and routine maintenance costs and transport costs. The repair and replacements costs means if the machine gets run down due to any reasons, it requires money to repair it. The blades on the mills need to sharpened on regular intervals and also replaced after certain wear and tear. These components constitute the costs involved for the routine maintenance of the machines. The last component of these costs is the transport costs. The transportation costs are the costs required to move the machine from one location to the other. These costs may vary from a location to a location depending on the distance travelled. The final costs which may enter the cost function are the procurement costs. The mill owners reported in the survey spent money to procure wood for running their equipment. The costs involved in purchasing wood from external sources are defined as procurement costs. All the costs were reported in dollars spend in each category on annual basis.

A cost function is very useful tool to analyze

[3] $C(P, Y) = \text{Min}\,[PX: X \in V(Y), P > 0]$

Cost Function:

$TC(y) = VC(y) + FC$

Where, TC = Total Cost =TC(Y, P,w) + Fixed cost

VC = Variable cost (y, wl, wk-Comprises of the Working costs), FC = Fixed cost (Cost of Portable Sawmill).

In addition

WL = cost of labor + insurance /# persons working,

and WK= working capital= {Costs on the capital (fuel, repairs, maintenance, transport cost)}, and WP = Expense on the sawlogs (yearly)

Empirical Model

The above cost functions were estimated as an unrestricted Translog variable cost functions and Cobb-Douglas. Applied economics research has been undertaken in various areas based on these functions because of their versatile properties and nature of the cost function. The production functions which represent a relationship between outputs to inputs can be estimated using two functional forms namely, the Cobb- Douglas and Translog cost function. The Cobb- Douglas was proposed by Knut Wicksell (1851–1926) and was tested against statistical evidence by Charles Cobb and Paul Douglas in 1900-1928.

For a production, the functional form is

$Y = AL^{\alpha}K^{\beta}$,

And the model for the above function in its dual cost version is given by the following equation-

$$[4]\ \ \ln c = \beta o + \beta y \ln Y + \sum_{i=1}^{n} \beta i \ \ln P_i + \varepsilon_c$$

$S_I = \beta_I + \varepsilon_I,\ \ i = 1,\ldots,M.$

By construction, $\sum_{i=1}^{n} \beta_i = 1$ and $\sum_{i=1}^{n} S_i = 1$. The cost shares will also sum identically to one in the data. It therefore follows that $\sum_{i=1}^{n} \varepsilon_I = 0$ at every point so that the system is singular. But if we drop one of the equations and estimate the rest of them then the system reduces to a non-singular one (Green 2003). Then the model reduces to the following

$$\text{Log}(C/P_M) = \beta o + \beta y \ln Y + \sum_{i=1}^{n} \beta i \ \ln (P_i/P_M) + \varepsilon_c$$

In this model the last parameter is estimated with the $1-\beta_i$

where:

- Y = total production (the monetary value of all goods produced in a year)
- L = Labor input
- K = Capital input
- A = Total Factor productivity
- β_i ‘s =give the output elasticity of labor and capital, respectively. These values are constants determined by available technology and can be computed with the available data and statistical software packages.

The output elasticity which is computed with this function measures the responsiveness of the output to change in the levels of either labor or capital used in production, ceteris paribus. For example if $\alpha = 0.30$, 1% increase in labor would lead to 0.30 % increase in output.

The coefficient in front of the Y (output) can be used to determine the scale of operation. If this coefficient is equal to 1 than it’s a Constant Returns to Scale and if beta is less than 1, then it is increasing returns to scale and if beta is greater than 1, then it is decreasing returns to scale.

By duality property of the cost function we can also obtain a production function. Duality theory advocates that we can derive the underlying production function parameters from the cost functions. Therefore, in a production function the following is the method to analyze the returns to scale. Further, if $\alpha + \beta = 1$, the production function the constant returns to scale. That is, if L and K are each increased by 20%, Y increases by 20%. If $\alpha + \beta < 1$, returns to scale are decreasing, and if $\alpha + \beta > 1$, returns to scale are increasing. And if we assume that there is Perfect Competition and $\alpha + \beta = 1$, α and β can be shown to be labor and capital's share of output.

Cobb and Douglas were influenced by statistical evidence that appeared to show that labor and capital shares of total output were constant over time in developed countries; they explained this by statistical fitting least squares of their production function. There is now doubt over whether constancy over time exists. Cobb-Douglas and some other similar specifications imply constant elasticities of substitution between the inputs and homotheticity of technology.

The Translog functional form is another cost function used for the analysis. The unrestricted Translog cost function form was chosen for its flexibility with regards to returns to scale, elasticities of substitution, and the ability to incorporate biased technical change. The validity of all these properties can be tested by using likelihood-ratio test between the restricted and the unrestricted model. The restricted model is one which is restricted to constant returns to scale, unitary elasticities of substitution, and unbiased technological change in turn.

The restricted model which will be used for this thesis is illustrated as following -

[5] $LnTC= \beta_0+ \beta_q lnQ+ \beta_L lnPK+ \beta_K lnPL+\varepsilon$

$LnTC= \beta_0+ \beta_q lnQ+ \beta_L lnPK1+\beta_K lnPL+\varepsilon$

$Ln'(TC/PL) = \beta_0+ \beta_q lnQ+ \beta_k' ln(PK/PL)+\varepsilon$ (Direct Constraint Model)

The unrestricted model used in this thesis was -

[6] $LnTC = \beta_0 + \beta_q lnQ + \beta_L lnPK + \beta_K lnPL + 1/2(\alpha_{QQ}\ lnQLlnQ + \alpha_{LL}\ lnPLlnPL + \alpha_{KK}\ lnPKlnPK) + \gamma_{qL}\ lnQlnPL + \gamma_{qK} nQlnPK + \gamma_{LK}\ l\ lnPKlnPL + \varepsilon$

$LnTC = \beta_0 + \beta_q lnQ + \beta_L lnPK1 + \beta_K lnPL + 1/2(\alpha_{QQ}\ lnQLlnQ + \alpha_{LL}\ lnPLlnPL + \alpha_{KK}\ lnPK1lnPK1) + \gamma_{qL}\ lnQlnPL + \gamma_{qK} nQlnPK1 + \gamma_{LK}\ l\ lnPK1lnPL + \varepsilon$

$Ln'(TC/PL) = \beta 0 + \beta q lnQ + B_k' ln(PK/PL) + 1/2(\alpha_{QQ}'\ lnQLlnQ + \alpha_{KK}' ln\ (PK/PL) ln\ (lnPK/lnPL) + \gamma_{Qk}' Qln(PK/PL) + \varepsilon$ (Direct Constraint Model)

Where

P_L is the labor price ($/hr)

P_K is the capital price defined as the ratio of costs spent on equipment/current capital stock price ($) (Straight Line Depreciation)

P_{K1} is the capital price defined as the ratio of costs spent on equipment/current capital stock price ($) (Hyperbolic Deprecation)

Q is the quantity of the bf produced /year

The parameters to be estimated are defined by the α, β, and γ. The cost function can be estimated on its own but estimating the parameters in form of systems of two or three linear equations or system of equations improves the efficiency of the estimates. The cost shares on the three inputs sum to one, so only two are linearly independent, therefore one must be dropped and rest can be estimated by Seemingly Unrelated Regression (SURE) model.

SURE model is the means for estimating the share equations (Green 2003).The unrestricted model can be estimated with a system of share equations. A single model may contain a number of linear equations simultaneously. In this model, it is often unrealistic to expect that the equation errors would be uncorrelated. Seemingly Unrelated Regression can be defined as systems of equations in which the regression equations are related through the correlation in the errors.

Elasticities

Elasticities are calculated from the estimated cost functions to describe the sawmill industry of the United States of America. The elasticities of substitution between the input pairs were calculated to determine the range to which the inputs are technically substitutable for each other. The two common forms of these elasticities are: AES and MES. The AES (Allen and Hicks 1934, Uzawa 1962) has been conventionally used, but following Blackorby and Russell, 1989, there has been increasing use of the MES. In addition to these two elasticities the other elasticities which were calculated were the own-price and the cross-price elasticities. The methods by which the AES and MES elasticities of substitution are calculated are described below along with the methods for calculating the own- and cross-price elasticities.

Following from the Nautiyal and Singh, 1985, the own (ξ_{ii}) and cross price elasticities (ξ_{ij}) are calculated as

[7] $$\xi_{ii} = A_{ii} S_i$$

$$\xi_{ij} = A_{ij} S_j$$

Where S_i and S_j are the cost shares for the inputs i and j (i ,j =L,M, and K), respectively, and A_{ii} (own price) and A_{ij} (cross-price) are given by the following

[8] $$A_{ii} = \frac{\gamma_{ii} + S_i^2 + S_i}{S_i^2}$$

$$A_{ij} = \frac{\gamma_{ij} + S_i^2 + S_i}{S_i S_j}$$

The important point to notice here is that AESs will change with the relative factor shares S_I and S_j , so its value will depend on whether it is calculated at mean factor share levels of with the individual yearly observations (Nautiyal and Singh 1985). In this thesis the approach which was adopted was that mean factor share levels were used for the estimations of the parameters.

From the Blackorby and Russell, 1989, the MESs are calculated by the following formulas

[9] $$M_{ij} = \xi_{ji} + \xi_{ii}$$

$$M_{ji} = \xi_{ij} + \xi_{ii}$$

Once the estimation is done, the estimated parameters will be used to calculate the own- and cross-price elasticities using the above formula.

CHAPTER III

DATA AND METHODOLOGY

The primary emphasis in this chapter is to explain the data used in this thesis, and how the variables are defined. There are thousands of portable sawmills throughout the country. Cross sectional data from a national portable sawmill survey developed by a group of researchers and Extension professionals at Auburn University in 2009 was used for research from a survey conducted by Lupo, 2010, as part of her dissertation research. The questionnaire was sent out to people all over the United States who are currently utilizing such machines in many different ways. Cost data from this survey were used to specify a cost function. The response rate was for this study was 79% of those who responded to the initial postcards inquiring as to whether they would be interested in completing the survey. After the initial survey inputs, the postcards were sent to 4947 people. Out of the total of 4947 only 1196 people agreed to complete the survey and of them 79% actually did respond (949 people).

Respondents provided information on the costs of sawmills industry price, which brands they were using, variable costs incurred, and the output produced per unit labor. The advantage of the data set was that it is nation-wide sample from the most comprehensive list of possible sawmill owners that we could identify. There is no spatial or time correlation between the reported observations. The main disadvantage of the data is that very few people actually reported the cost number which made the analysis harder with missing values. However, it is also likely that very few sawmill owners actually are aware of the potential benefits of running more commercially oriented portable sawmill operations, thus results from our analysis could be helpful to owners. The sawmill's size in the analysis is with machines with price range between $5,000-$35,000.

The major challenge to this research is that most of sawmillers did not keep a track of their expenses which is normal behavior seen in many small-scale business enterprises. The other reason is that a lot of owners used the portable sawmill as a hobby. In hobbies we hardly keep the tract of expenses. The analysis of the distribution of hobby versus business is reported by Lupo, 2010. Roughly 40% of those surveyed indicate that they currently use their portable sawmills for hobby only, with the other 52% utilizing their mills for part time income and 7% as full time source of income (Lupo 2010).

The main purpose of this thesis is to analyze the cost function of owners who use their portable sawmills as part time or full time income generating business. For that we assume that these businesses try to minimize costs, and achieve an optimal scale of operation. Two standard functional forms, the Cobb-Douglas and the Translog cost functional forms, were examined with the data available from the survey. The best specification of these two functions is then used to analyze the costs and report the elasticities and the optimal scale of operation.

The cost functions are specified as a function of one output and two input prices as the independent variables. The *TOTAL COST* is the dependent variable and is measured in dollars. It is generated as sum of all the input costs times input quantities. The input costs come from the following inputs– *Labor Costs, Repair and Replacement Costs, Routine Maintenance, Fuel and Lubricants for the Machine, Insurance* (liability and health), *Cost of Transporting* from the mill to a location or *Purchase of Timber* for milling. These costs components were added to generate the total cost variable for the thesis. By estimating the variable total cost, we can generate another very important variable for the thesis, the share of input prices. The variable of share of input will be utilized for constructing a share equation for calculation of Allen Elasticity of Substitution (AES). Each such variable illustrates the input share of the total cost.

The detailed definition of the other variables output, labor and capital used as the independent variables follows. First, *OUTPUT (Y)* is the board feet of logs sawn into lumber by mill owners. This variable is directly available from the survey and is the output yield by mills reported on the annual basis. Next, there two kinds of inputs are used: Labor (Wl) and Capital (Wk). And there are two input prices: Labor Price (Pl) and Capital Price (Pk).

PRICE OF LABOR (PL) is easy to understand but subject to data constraints. This variable was defined as the hourly wage paid to the employees for each mill. It is normally calculated by dividing the sum of wages (and labor insurance) by the number of employee hours. In the particular case of portable sawmills production process one person works with the mill (with a few exceptions reporting two people) therefore labor costs are dollars calculated per one person.

Labor input prices are directly and indirectly obtained from the survey data. The reported costs contained labor and insurance values. These costs were added to obtain the annual expenses on labor components. However, some states do not require labor insurance for individually operated operations while others do it. The labor costs were not reported by many owners since they were working themselves on the equipment. But another variable reported in the survey COST PER BF incurred by these mills was used for generation of true labor costs. Two important articles (Kays and Drohan 2003, Gorman and Rusty 2002) have studied portable saw mills similar in the survey and estimate that they produce 125 bf/hr on an average. The COST PER BF reported by owners was multiplied by production per hour (assumed to be 125 bf/yr) to generate the labor cost incurred by these mill operators over the hourly basis and used in the remaining 197 observations.

After this the share of the labor was obtained and multiplied with the above created cost per hour observations. The total costs were subdivided into two main categories of variable cost. These were the costs incurred on the labor portion and the rest were considered costs of capital. These two add to give the total cost. The average of the labor was divided with the average of the total costs which gave the result that labor constitute 35% of the total costs. So the cost per hour variable was multiplied with factor of 0.35 to obtain the labor costs per hour variable.

Next, PRICE *OF CAPITAL (PK)* has two components. The first element consists of physical capital cost and the second is the financial capital cost. The physical capital cost contains the cost of the equipment which was depreciated for the years it has been used. The financial capital cost includes costs incurred on maintaining and running this piece of equipment which includes fuel and lube, repair and maintenance and routine maintenance. The price of capital is calculated by totaling the annual payment for capital divided by current market value of the equipment. Current market value of the equipment was calculated.

CAPITAL COST is measured by all capital expense divided by the value of the fixed capital. *CAPITAL COST* was calculated in two ways using two methods of depreciation. The first depreciation method is straight line, and the second method is hyperbolic depreciation. The straight line depreciation involves assuming 20% of the initial value as salvage value and then taking a mean of the difference between the two, with respect to the number of years of usage, while hyperbolic depreciation as established by the Bureau of Labor Statistics Procedures (McQueen and Witter, 2006)is defined as:

Formulae

Straight-line depreciation formula is:

[10] $$D_{x,d} = \frac{Mill\cos t - SalvageValue}{L}$$

This formula directly gives the current value of the machine. The mill cost is the purchase price. The salvage value is estimated amount the asset can be sold for at the end of its useful life. This is also referred as residual value. The salvage value as 20 % of the initial purchase price of the machine which was created by multiplying the median value of the range of price reported in the survey (Forestry Handbook). The L represents the useful life of the machines which is defined as the estimated amount of time that the asset will be used by a business. This is also called service life of the machine. In a straight-line depreciation, the machine life of forestry equipment is assumed to be 5-6 years. Since these machines are not used on the regular basis and mostly used for hobby purposes, another method of depreciation works better in with the current scenario.

Hyperbolic Depreciation formula:

$$[11]\ D_{x,d} = \frac{L-(x-1)}{L-\beta(x-1)} - \frac{L-X}{L-\beta x}$$

Where x=1, 2,…..L and β is the curvature parameter

Assuming hyperbolic depreciation, the capital retains more of its productive capacity in the early years and as the capital ages, its depreciation accelerates. This means that the depreciation is delayed in the early stages of equipment's life. The curvature parameter for depreciation of the equipment was assumed to be 0.5 and the equipment and machinery have a service life of 13 years. After D is derived for each of the reported data point or the saw machine, this is multiplied with the purchase price of the machine to estimate the depreciated value of the machine at the end of the service life.

The fixed costs or the fixed capital costs were the machine costs. The survey documented the purchase price of the machines and the year in which they were purchased and put in service. The numbers of years the machines have been used were also reported.

To summarize, the data required for the cost function estimation are the quantity of the labor and logs produced in the milling process, the cost portions of the inputs (Price*Quantity) used in the operation, new capital expenditures, the value of the capital stock of the milling industry, and the portion of cost (Price*Quantity) of logs used for the operation.

The left hand side of the translog cost function was obtained as variable cost by adding up the labor expenses multiplied with the number of persons on the operation, the operating capital for the machines, and the procurement cost portion spend on the sawlogs required for the operation. The years these machine were kept with the sawmill operators were used for the generation of the current value of the equipment. Since these machines are not used as a regular business, so they are not depreciated as easily as any other piece of equipment operated on other forestry operation.

CHAPTER IV

GENERAL MODEL ESTIMATION AND RESULTS

The survey data on the cost per board feet (bf) and the price per board feet were used to derive the gross revenue for sawmill owners. Cost per board feet is the cost they incur in processing per board feet of log, and price per board feet is the money charged if they saw the logs for other people. Two independent studies and other internet sources state the net production at around 300-1000 bf per 8 hr work day period. In this work, I assumed the production to be 125 bf per hour. Two extension studies which studied similar models of sawmills estimate the average production of these mills to be 125 bf (Kay and Drohan 2003, Gorman & Rusty 2002). The above cost numbers were multiplied with 125 to derive the production's cost per hour and gross revenue per hour for all observations reported by the respondents. There were only 197/949 observations which had the values to them and rest were missing. The missing values are not included in this general data analysis. The difference of the two numbers gave the profit per hour. The trends were analyzed in the Excel sheet graphically (Fig. 1). The trends show that as the costs increase, the profits also increase and the profit margin is highest just below the highest costs observed in the data. Previous studies show that if the products are sold in the range of USD 0.20-0.35 price per board feet, they are making profit. The higher costs numbers were later deleted to observe how the trends change. The trends don't change much as shown in (Fig. 2).

The data was studied graphically to see what percentage of sawmill owners use the equipment as a source of employment. Only 48 % use them as a source of full time employment, 42 % as both hobby and full time employment, and 2 % use them as a source of hobby only. 44% of the people who use it as hobby can be thought as the ones that are unlikely to provide the cost numbers on their equipment's usage (Fig. 3). The remaining 8 % sawmill owners use them as a source of part-time employment and hobby purposes.

The questionnaire on the returns on investment was plotted graphically to see the percentage of people who consider this business profitable (Fig. 4). 36 % of the respondents over the United States said that they make money, and 15 % broke even. The interesting point to note is that only 42 % of the respondents said that they do not make money. The respondents who did not answer the questions were later deleted from the data to see what percentage of people who reported made money. The (Fig. 5) shows that 39 % of the respondents did make money with this business and 16 % broke even.

An interesting relationship was discovered between the profit per hr per board feet production of lumber (Fig. 6). The profit per hr per bf was derived from the cost and gross revenue calculated earlier. The respondents had given the board feet production annually. Assuming they work 60 hrs a month and 12 months a year, the board feet per hr was derived. These were plotted against the profit which gives us a linear relationship between the profits and the hourly production. Microeconomic theory supports this trend between production and profits. The respondents have increasing profit as they increase the production. There is a window for increasing the production with positive returns. This shows that there is a positive scale of operation in this business. The individual trends were plotted on the same graph to see the trend variations. These trend lines show that as the output increased after a certain point, the profits show a negative trend and start decreasing (Fig. 7).

CHAPTER V

EMPIRICAL RESULTS

The flexible Translog Cost functional form was compared with the more Cobb-Douglas cost function. Cobb –douglas is more specific form of cost function which doesn't include any non-linear or the interaction terms. The properties of cost functions lead us to the fact that there are several restrictions which are imposed on the model in order to conform to these theoretical requirements of the cost function.

This thesis adopts two cost function models-the restricted model which is Cobb-Douglas and the unrestricted cost model which was explained in the Empirical model section. The approach to analyze the cost function is similar to the Nerlove study of economies of scale (1963). These two models will be utilized to estimate the parameters and to obtain the elasticities of substitution. They were compared with an F test to obtain the best model. The log-likehood of both the models were obtained. The log likehood test was done to pick the best model. Both the models will be used to estimate the economies of scale.

The output coefficient can be tested to be equal to one. If it is equal to one, then we can see that constant returns to scale exists in the system and can estimate the value of output at which the average microenterprise achieves optimal scale, or minimizes costs. Hypotheses for existing positive or negative economies of scale will be tested. The data set contains country wide mill operations data. There is one output and two inputs in both the cost functions. The interactions of these three variables enter the translog function. The output is board feet of sawn lumber annually. The input prices are the price of the labor(PL) and price of the capital(PK). The real values for the parameters are the same in both the cost functions. Because all the variables are in form of logarithms, input price parameter can be interpreted as the elasticity of the independent variable with respect to the change in the total cost.

In theory, all variables entered in the cost function need to be strictly positive in order to satisfy the log function. In addition, the total cost will increase when the output and input prices increase. This condition restricts the parameters for the output and input prices to be positive. Therefore, the three parameters for one output and two input prices must be positive. In reality, the regression results for the Cobb Douglas cost function also shows that all the parameters have positive signs.

Several tests were done to investigate the model specifications. The first test was:

1. The test for constant return to scale (CRS) was done for the first Cobb Douglas model with straight line depreciation reject the null of CRS.

2. The test for constant return to scale (CRS) was done for the first Cobb Douglas model with hyperbolic line depreciation reject the null of CRS.

3. The test for constant return to scale (CRS) was done for the first translog model with straight line depreciation fail to reject the null of CRS.

4. The test for constant return to scale (CRS) was done for the first translog model with hyperbolic line depreciation fail to reject the null of CRS.

The second test was done to test the hypothesis of constant variance (Breusch-Pagan Test/Cook-Weisberg test for heteroskedasticity).

1. The Hettest was done for the first Cobb Douglas model with straight line depreciation did fail to reject the null of constant variance.

2. The Hettest test was done for the first Cobb Douglas model with hyperbolic depreciation reject the null of constant variance.

3. The Hettest was done for the first translog model with straight line depreciation did not accept the null of constant variance.

4. The Hettest test was done for the first translog model with hyperbolic depreciation accept the null of constant variance.

The third test was the Ramsey tests on two different cost models. The Ramsey test was done for the first Cobb Douglas model with straight line depreciation fail to reject the null of no omitted variables. The Ramsey test was done for the first Cobb Douglas model with hyperbolic depreciation fail to reject the null of no omitted variables. The Ramsey test was done for the first translog model with straight line depreciation fail to reject the null of no omitted variables. The Ramsey test was done for the first translog model with hyperbolic depreciation fail to reject the null of no omitted variables.

The residual plots from all the four models were plotted against ln Q and did not show any pattern, so no square terms were added in the Cobb Douglas model. The hypothesis that economies of scale do exist in this type of business was found in Cobb Douglas models but not in the translog models.

When testing the null hypothesis of constant return to scale (CRS), the CD form results in an F-stat of 127.1 and a p-value of 0.0000, and the TL form results in an F-stat of 37.68 and a p-value of 0.000. We reject the null of CRS but see that the F-stat reduced significantly from 127.1 to 37.68 from the CD model to the TL model. These results are from hyperbolic depreciation model.

[12] $$\ln C = \beta_Q \ln Q + \beta_L \ln Pl + \beta_K \ln Pk + u_i$$

Impose $\beta_l + \beta_k = 1$

or $\beta_L = 1 - \beta_K$

This can impose constant returns to scale on the Cobb-Douglas equation.

$$\ln C = \ln Q + (1 - \beta k)\ln Pl + \beta_k \ln Pk$$
$$\ln C = \ln Q + \ln Pl - \beta_k \ln Pl + \beta_k \ln Pk$$
$$\ln C - \ln Pl = \ln Q + \beta_K \ln Pk - \beta_k \ln Pl$$

[13] $$\ln(C / Pl) = \ln Q + \beta_k \ln(Pk / Pl)$$

Similarly, we can impose the restriction of the constant returns to scale on the translog cost function which is more flexible form of the function and that equation will look like following-

[14]

$$\ln(C / Pl) = \ln Q + \beta k \ln(Pk / Pl) + \alpha_{qq} \frac{1}{2}(\ln Q)(\ln Q) + \alpha_{kk} \frac{1}{2}(\ln Pk / Pl)(\ln Pk / Pl) + \gamma_{qk}(\ln Q)(\ln Pk / Pl)$$
$$+ \gamma_{lk}(\ln Pl)(\ln Pk) + \varepsilon_i$$

The focus of this paper after doing all the general data analysis and analyzing the Cobb-Douglas and translog cost function ended up being the economies of scale similar to Nerlove paper, 1963. Here we chose a Cobb-Douglas function to model output as a function of capital, K and Labor, L:

[15] $Q = \alpha_O K^{\alpha K} L^{\alpha L} \varepsilon^{\varepsilon i}$

where Q is the output and e, embodies the measurement differences across the sawmill owners. The economy of scale parameter is r = $\alpha k + \alpha l$. The value one indicates that constant returns to scale. Here, we are going to test the phenomenon that these sawmill users enjoy substantial economies of scale. The production model being log linear, and also assuming that other conditions in a classical regression model are met, the four parameters can be estimated with ordinary least squares.

In a competitive market, the prices for the lumber are set by the market influence and they fluctuate regularly depending upon supply of lumber which depends on lot of other factors such as imports and domestic production. Thus, the firm's (sawmill operation) objective is cost minimization subject to the constraint of the production function. This can be formulated as Lagrangean problem,

[16] $Min_{k,l} P_K K + P_L L + \lambda(Q - \alpha K^{\alpha K} L^{\alpha L})$

The solution to this minimization problem is the two factor demand and the multiplier which measures the marginal cost. When inserted back into the total costs, this produces an intrinsically linear or log linear cost function.

[17] $P_k K + P_L L = C(Q, P_K, P_L) = rAQ^{1/r} P_K^{\alpha K/r} P_L^{\alpha L/r}$

or $\ln C = \beta_1 + \beta_Q \ln Q + \beta_K \ln P_K + \beta_L \ln P_L + \varepsilon_i$

where $\beta_q = 1/(\alpha k + \alpha l)$ is now the parameter of interest, and $\beta_j = \alpha_j / r, j = K, L$.

Thus, here the duality between the production and cost function has been used to derive estimates. The other assumption is that all these coefficients should sum to 1 $\beta_k + \beta_l = 1$. This was done is two ways in the model analyzed in this paper. This can be done directly in the statistical package and the other way to do that is described earlier as in equation [5].

The initial results from the Translog function did not make any economic sense. So to see the quadratic relationship between the dependent and independent variables model diagnostics were done. The scatter plots between the log of total cost and the other variables used in the cost functions were studied (Appendix B). Linear trend was observed between the log total cost and log output. The model diagnostics did not show any kind of non-linear relationship between the total cost and the output of the variables. This led us to infer that only a linear relationship exists between these two variables. Hence, a quadratic relationship cannot be established in this case from the observed data. Since, the translog cost function fits the quadratic form of these variables, the analysis of the coefficients of these variables do not make sense. Hence, in this cost function we cannot obtain an inflection point. Therefore, it leaves us with no results for the optimal scale. But, the analysis can be done with a function which contains the linear form of these variables. This has been explained earlier as Cobb-Douglas cost function.

The scatter plots between the price of labor and total cost does not show any kind of trend. But, the plot between the capital price and the total costs does show a linear trend between the two variables.

The Cobb-Douglas cost function produces significant results and can be analyzed for the scale of operations and demand elasticities of the inputs. Two types of this function were analyzed. The first one was done with straight line depreciation and the other one was done with hyperbolic depreciation. They both produce similar coefficients for all the parameters for the Cobb-Douglas specification of cost function but the estimates differ a lot for Translog Cost specification. The restriction PL+PK=1, was applied to these models. This restriction helps to capture the scale of the third variable. In this case that is the output variable. The estimate on this independent variable will be analysed to give the economies of scale for these type of small scale operations. Further in the results the elasticity of the output w.r.t to total cost was calculated and is explained in the later part of the results. The effects of the labor and capital costs were also analyzed.

The analysis of the first model shows that positive economics of scale exist in this operation. And it can be derived as 1/0.589= 1.69. This means if we increase both the inputs equally, the output increases more than double to the turnover of 1.69. Further analysis shows that capital plays a bigger role in the production process. The alpha value for the labor and capital can be obtained as following: r*0.406=0.689 and the alpha value for the capital can be obtained by r*0.594=1.0068. When compared with hyperbolic depreciation, these results give the scale of operation 1.79. By applying the constraint directly [5], it produces the same results of 1.60 and 1.69 respectively for the straight line and the hyperbolic deprecation.

Table 5 shows the results from the Cobb-Douglas estimation. The models (1) & (3) are models without the constraint and (2) & (4) are the models with the constraint PL+PK=1. This constraint is used to test the null hypothesis of constant returns to scale as explained in the previous page. Then, Table 6 shows the same models with additional interaction terms as explained in Translog Cost function. These both models present the results by applying the constraint, PL+PK=1, to the models so that the effects of the PL and PK can be monitored as well.

The machine life of portable sawmills can be assumed to any number of years depends upon their usage scenario. The data was studied to see how many people have used their machines for more than 13 years and the number came out to 118 out of 689. Since we are using only 77 observations, we choose to assume the straight line deprecation better method for the analysis of these machines. The results of the model with this type of depreciation method will be used for the further analysis of these machines and reporting of the numbers. So, models (2) from table CD (5) and (2) from the TL(6) table will be used for reporting of our results.

The Cobb-Douglas model gives the elasticities of both the inputs with respect to the total cost. Since both the total costs and the prices are in same units. The estimates were significant at 0.01 % significance level. This means they lie in 99% confidence level that the sample estimates can represent the population estimates. The elasticity of labor over total cost is 0.406. This means that if there is 1% change in the labor prices, the total cost is going to increase by 0.406. And the elasticity of capital is 0.594. This means that

1% change in the capital prices will increase the total costs by 0.594. The elasticity of the output was calculated with the help of the statistical software. And it was found to be 0.782 at the mean level. This means it is safe for the sawmill users to invest in these machines without increasing the costs 100%. This means that if they want to increase their output level by 1%, their total costs will increase only by 0.78%. There is potential in increasing the production without increasing our costs by the same level.

Last but not the least, optimal scale of operation was calculated for these sawmill operators. These were done in two ways; the quadratic term was incorporated in the best Cobb-Douglas model with the straight line depreciation method. Secondly, the Translog function with the same variables which is the unrestricted form of cost function was also used to calculate the optimal scale of operation. These valued were than compared to each other and also to the mean production levels of these machines at the sample level and also as the observation used in the regression analysis.

Straight line depreciation method gives an optimum scale value of 16,432 bf/year from the Translog- Cost Function. From the Cobb-Douglas Cost function the optimal scale of production was found to be 73934 bf/year . These can be compared to the fitted sample mean 46707.79 bf/yr and data sample mean 46182.17 bf/yr. All these 77 observations came mostly from people who were using them for some form of employment purposes. These are optimal scale from the translog cost function. These functions can be partially differentiated and when we equate the equation to zero, it gives us the point of min or max. This method was used to obtain that point.

The elasticity of substitution between Capital and labor from Cobb-Douglas with straight line depreciation was found to be 0.69. They means capital and labor are inelastic substitutes which implies we cannot replace capital with labor maintaining the same level of production. The elasticity of substitution between Labor and Capital from the Cobb-Douglas with the straight line depreciation was found to be 1.45. This means they are elastic substitutes. This means we can maintain the same output level by increasing the capitalization of the operation.

Indicator Variable effects

Four dummy variables were added to the final working Cobb-Douglas model resulting in their conversion to a log-level form. The estimate interpretation will also be done in log-level form of statistical model. For all the four types of dummy groups, a reference dummy is picked and the results are documented as we change the type from the reference dummy category. This is done as following –

[18] $$\partial(\log tc_i) = \partial R_i \beta_1$$

$$\frac{\partial tc_i}{tc} = \partial R_i \beta_1$$

We need to multiply both sided with 100 and rearrange.

$$\frac{\partial tc_i * 100}{tc} = \partial R_i \beta_1 * 100$$

$$100 * \beta_1 = \frac{(100 * \partial tc_i) / tc_i}{\partial R_i} = \frac{\% \Delta tc_i}{unit \Delta R_i}$$

Therefore, if R_i is the level variable, its coefficient can be interpreted as a percentage change in the total cost for unit increase in that variable.

The dummy variables were created for four different types of response of these microenterprise operators. The first dummy was created to see how different objectives for the operation of sawmill has an effect on the total cost of operating these sawmills. The five dummies for were the sawmill operators which were created were – operators who use it as a source of full time employment, operators who use it for full time employment and hobby, the third who use them as part-time employment option, the fourth for both part-time employment and hobby, and the last are people who use it only for hobby purposes.

The summary stats of these dummies in the fitted cost model were tabulated. 27% of the cost numbers in the regressed models were reported by respondents who use these sawmills for full time-employment and 44% came from who use them for both full time employment purpose and hobby (Table 10). 13% of the data for cost model came from respondents who were using these machines as a part-time employment source whereas only 6% cost numbers were reported by respondents who used it as part-time employment and hobby (Table 10). The data also included 7% cost numbers which came from people who use them for hobby purposes. These dummies were added to the estimated cost model to see the difference among these different categories of sawmill use. No significant effect is seen on the total cost across all these five categories.

The second dummy variable was added to see the effects on the total costs if these microenterprises were making or losing money. There were four different types of cases reported – the first if they made money using sawmill, the second if they lose money in the business, the third if they break even and the fourth type was in which they do not sell their mill products. 61% of the cost numbers in the fitted model came from the respondents who were making money from these sawmill use, 9% were the respondents who lose money, 15% were from who break even and 13% numbers also came from the respondents who do not sell their products (Table 11). The regression analysis was done by adding these dummies to the cost model. The regression analysis shows that microenterprises who reported that they make money when compared to the ones who do not sell their products are able lower their costs by 73% when they change their business type from not selling the products to making money. Also, this change is significant at $p<0.01$.

The third dummy type was based on the regions these sawmill operators were located. Maximum sawmill operators in the regression sample came from the Southeast region of United States. This makes the southeast an important source of cost numbers. 34% respondents who gave the cost numbers were from Southeast region. 19 % of the respondents were from Midwest (MW), 21% were from Northeast (NE), 22% were from the West (W) whereas only 2% came from Southwest (SW) region of United States (Table 12). There was no statistically significant difference seen between the costs among these five regions of United States.

The fourth dummy was added to see the effects of the type of wood on costs these sawmill operators saw (Table 13). The two dummy variables were – one who saw only hardwood and the second one was for operators who saw both hardwood and softwood. 83% of the cost numbers for the regression analysis came from the sawmill operators who use them both for sawing hardwood and softwood whereas only 16 % of the cost numbers came from who saw only hardwood. No significant statistical difference exists among the costs based on type of wood the portable sawmill operators saw.

The cross sectional study was done to analyze the respondents who used sawmills for employment purposes were making or losing money (Table 14). Among the respondents which were using the sawmill solely for employment purposes, only 3/20 showed that they make money, 6/20 reported that they lose money, 7/20 breakeven, and it was unusual to notice that that 4/20 were not selling their products. Out of respondents who were using for full-time employment and hobby- 26/34 reported that they were making money from the portable sawmill business, 4/34 break even, 4/34 do not sell their products, and no one among them reported that they were losing money.

The respondents who were using the portable sawmills a part-time employment option 100 reported that they were making money from the business. The ones who used as source of part-time employment and hobby both 4/5 reported that they make money from them and 1/5 do not sell the products. No one reported that they lose money from them. Lastly, the operators who used them for hobby purpose 3/6 showed that they make money from their hobby. And 1/6 lose money, 1/6 breakeven, and 1/6 do not sell their products. This is interesting to note that the sawmill operators who use these machines for hobby purpose also sell their products and make profit out of the business.

CONCLUSION

The estimated model includes the restrictions on the input parameters that impose homogeneity of degree one in the production function. The portable sawing industry of the United States saw millers can be modeled with Cobb-Douglas cost function. The restrictions on the parameters (input prices) help to capture the economies of scale effect on the output. The findings of the study show that there exists positive scale of economies for these portable sawmill owners. This means they can expand their production levels with decreasing their costs until the optimum scale of production is achieved. This implies they can increase the size of the operation to exhaust these positive economies of scale. Government policies can help in the research and development for microenterprise innovations and applications through extension work in the regions where they have feasible and practical uses.

These small sawmill operators can find the specialized niches in current economic situations of recession, and can meet the specialized markets which cannot be met by the conventional forestry practices. In this thesis research, the surveys had examples of people who do high value addition via their hobbies. The hobbies can be pushed to professional level to create new local and regional markets. Since materials and their transport constitute one of the major input costs that go into the production, they can be offset with the help of portable sawmills. This survey shows that 73% of the portable sawmill operators obtain the material from their own land. This helps to cut back these costs. Additionally, it helps them to manage their small tracts of timber. This also provides them with extra revenue and employment opportunities. Moreover, they can provide material for theirlocal repair and housing needs. Either way, portable sawmills can help in the development of the rural communities.

It is evident from this research that these small scale sawmill operators and other sawmill operators who are interested in entering the portable sawmill business can utilize the available options and operate at positive profits. Last but not the least, government can come up with special insurance policy options for these micro entrepreneurs to encourage them to enter the markets.

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Appendix A

Tables

Table 1. Summary Statistics of Actual Data used in regression Analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
Total Cost($)	77	6391.91	15824.69	14.5	111000
Output(bf)	77	46707.79	68440.25	500	330000
Price of Labor($)	77	7.712672	6.90734	0.439745	35.17961
Price of Capital(1)	77	2.137263	3.341271	0.003077	17.96428
Price of Capital(2)	77	3.693726	7.642837	0.009231	51.07385

All values In dollars expect y (bf/yr)

Table 2. Summary Statistics of the Available Data on the same variables used in the regression Analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
Total Cost	698	3124.334	11346.89	10	165100
Output(bf)	176	46182.17	79040.97	30	500000
Price of Labor	194	11.62122	35.38265	0.439745	483.7196
Price of Capital(1)	663	1.837637	8.740026	0.001389	168.6071
Price of Capital(2)	663	2.53848	11.6402	0.000769	267.6923

Table 3. Summary Statistics of important variables used in the Analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
Total Cost	657	2841.07	9475.559	10	111000
costbf	178	0.272689	0.838691	0.01	11
pricebf	350	0.597914	2.927271	0.1	46
outputy(bf/yr)	163	46592.4	81317.64	30	500000
Labor Costs($)	69	3491.087	5494.554	15	30000
Insurance($)	95	1507.194	2335.582	4.45	15000
Repairs($)	464	429.7784	751.181	10	10000
Routine Maintenance($)	499	456.0001	839.735	5.5	8626
Fuel Lube($)	586	457.9105	1926.557	10	40463
Relocation Costs($)	100	405.686	529.9506	5	2500
Timber Costs	123	6286.896	13982.79	35	80000

All values In dollars expect y (bf/yr)

Table 4. Results of the Cobb-Douglas Model (Restriction applied by Statistical Package)

VARIABLES	Uncon	Constraint	Uncon	Constraint
β_q	0.645***	0.589***	0.614***	0.557***
	(0.0899)	(0.0897)	(0.0850)	(0.0885)
β_L	0.0911	0.406***	-0.0137	0.370***
	(0.144)	(0.0650)	(0.132)	(0.0657)
β_K	0.459***	0.594***		
	(0.0837)	(0.0650)		
β_{K1}			0.489***	0.630***
			(0.0752)	(0.0657)
Constant	1.060	1.125	1.325	1.217
	(0.922)	(0.952)	(0.870)	(0.925)
Observations	77	77	77	77
F	57.34	e(F)	67.07	e(F)
R-squared	0.702	.	0.734	.

*** p<0.01, ** p<0.05, * p<0.1
Standard errors in parentheses

Table 5. Results of Translog Model (Restriction applied by Statistical Package)

VARIABLES	Uncon	Constraint	Uncon	Constraint
βq	1.187	1.163	0.629	0.659
	(1.123)	(1.118)	(1.148)	(1.169)
β_L	1.643	0.806*	-0.855	0.793
	(1.319)	(0.447)	(1.057)	(0.602)
β_K	0.428	0.194		
	(0.567)	(0.447)		
αqq	-0.0518	-0.0599	-0.0330	-0.0101
	(0.114)	(0.113)	(0.111)	(0.113)
α_{KK}	0.0985	0.0654		
	(0.0973)	(0.0837)		
α_{LL}	-0.411	-0.354	-0.336	-0.454*
	(0.271)	(0.256)	(0.244)	(0.240)
γq_L	-0.0796	-0.00343	0.154	-0.00106
	(0.131)	(0.0660)	(0.116)	(0.0836)
γq_K	-0.0337	-0.00601		
	(0.0605)	(0.0443)		
γ_{LK}	0.249**	0.211*		
	(0.124)	(0.110)		
β_{K1}			-0.308	0.207
			(0.651)	(0.602)
α_{K1K1}			-0.0673	-0.0140
			(0.0759)	(0.0717)
γq_{K1}			0.0664	0.00949
			(0.0639)	(0.0574)
γ_{LK1}			0.100	0.128
			(0.0860)	(0.0863)
Constant	-2.265	-1.579	2.324	0.876
	(5.672)	(5.558)	(5.934)	(5.993)
Observations	77	77	77	77
R-squared	0.725	.	0.764	.
F	19.60	e(F)	24.04	e(F)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6. Results of the Cobb-Douglas Model (Restriction applied by Variable Transformation in the data itself)

	Straight	Hyperbolic
VARIABLES	CD	CD
β_q	0.589***	0.557***
	(0.0897)	(0.0885)
$B_{K'}$	0.594***	
	(0.0650)	
$B_{K1'}$		0.630***
		(0.0657)
Constant	1.125	1.217
	(0.952)	(0.925)
Observations	77	77
R-squared	0.762	0.774
F	118.6	127.1

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7. Results of Translog Model (Results of Translog Model (Restriction applied by Statistical Package)

	Straight	Hyperbolic
VARIABLES	**TL**	**TL**
β_q	0.759	0.325
	(1.153)	(1.222)
$\beta_{K'}$	0.450	
	(0.458)	
α_{qq}	-0.0179	0.0271
	(0.114)	(0.119)
$\alpha_{KK'}$	-0.0472	
	(0.0438)	
$\gamma_{qK'}$	0.00334	
	(0.0447)	
$\beta_{K1'}$		0.272
		(0.607)
$\alpha_{K1K1'}$		-0.0595
		(0.0535)
$\gamma_{qK1'}$		0.0264
		(0.0569)
Constant	0.308	2.157
	(5.747)	(6.215)
Observations	77	77
F	46.74	50.06
R-squared	0.767	0.779

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8. Cobb-Douglas cost function with straight line depreciation

VARIABLES	CD
β_q	1.046
	(0.992)
β_{qq}	-0.0466
	(0.101)
β_L	0.407***
	(0.0654)
β_K	0.593***
	(0.0654)
Constant	-1.057
	(4.820)
Observations	77
R-squared	.
F	e(F)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9. Constrained Cobb Douglas with indicator variables

VARIABLES	CD	CD	CD	CD	CD
β_q	0.589***	0.565***	0.622***	0.574***	0.604***
	(0.0897)	(0.115)	(0.0872)	(0.0947)	(0.0947)
β_L	0.406***	0.407***	0.375***	0.402***	0.409***
	(0.0650)	(0.0632)	(0.0602)	(0.0692)	(0.0655)
β_K	0.594***	0.593***	0.625***	0.598***	0.591***
	(0.0650)	(0.0632)	(0.0602)	(0.0692)	(0.0655)
Full time Employment		0.277			
		(0.569)			
Full time Employment and hobby		-0.539			
		(0.501)			
Part-time Employment		0.180			
		(0.523)			
Part-time Employment		0.498			
		(0.612)			
Make Money			-0.731**		
			(0.340)		
Lose Money			-0.705		
			(0.487)		
Break Even			0.558		
			(0.412)		
MW				-0.138	
				(0.357)	
NE				-0.166	
				(0.352)	
SW				0.556	
				(0.796)	
W				-0.0542	
				(0.342)	
Hardwood Only					0.179
					(0.340)
Constant	1.125	1.474	1.287	1.345	0.942
	(0.952)	(1.426)	(0.977)	(1.049)	(1.018)
Observations	77	76	76	76	77
R-squared	.	.	.	.	.
F	e(F)	e(F)	e(F)	e(F)	e(F)

*** p<0.01, ** p<0.05, * p<0.1

Table 10. Summary Statistics with Employment Dummy Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Full Time Employment	76	0.276316	0.450146	0	1
Full Time Employment and Hobby	76	0.447368	0.500526	0	1
Part Time Employment	76	0.131579	0.340279	0	1
Part Time Employment and Hobby	76	0.06579	0.249561	0	1
Hobby	76	0.078947	0.271448	0	1

Table 11. Summary Statistics with Profit or Loss Dummy Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Make Money	76	0.618421	0.489002	0	1
Lose Money	76	0.092105	0.291096	0	1
Break Even	76	0.157895	0.367065	0	1
Do not Sell	76	0.131579	0.340279	0	1

Table 12. Summary Statistics with Regional Dummy Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Midwest(MW)	76	0.197368	0.400657	0	1
Northeast(NE)	76	0.210526	0.410391	0	1
Southeast(SE)	76	0.342105	0.477567	0	1
Southwest(SW)	76	0.026316	0.161136	0	1
West(W)	76	0.223684	0.419482	0	1

Table 13. Summary Statistics with Wood Type Dummy Variables

Variable	Obs	Mean	Std. Dev	Min	Max
Hardwood	77	0.168831	0.377059	0	1
Hardwood and Softwood	77	0.831169	0.377059	0	1

Table 14. "Employment Type" Versus "Making Money"

Categories	**Make Money**	**Lose Money**	**Break Even**	**Do not Sell**	**Total**
Full Time Employment	3	6	7	4	20
Full Time Employment and Hobby	26	0	4	4	34
Part Time Employment	10	0	0	0	10
Part Time employment and Hobby	4	0	0	1	5
Hobby	3	1	1	1	6
Total	46	7	12	10	75

Appendix B

Figures

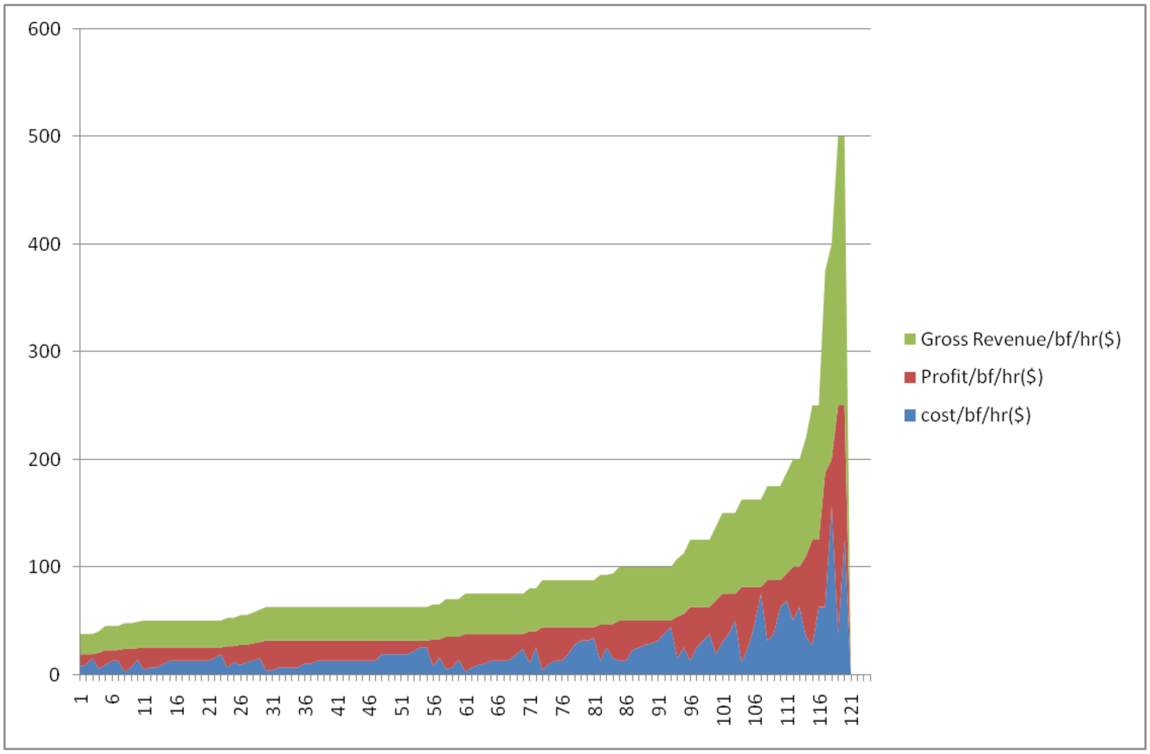

Figure 1. Trends in profits as the cost per bf increasing.

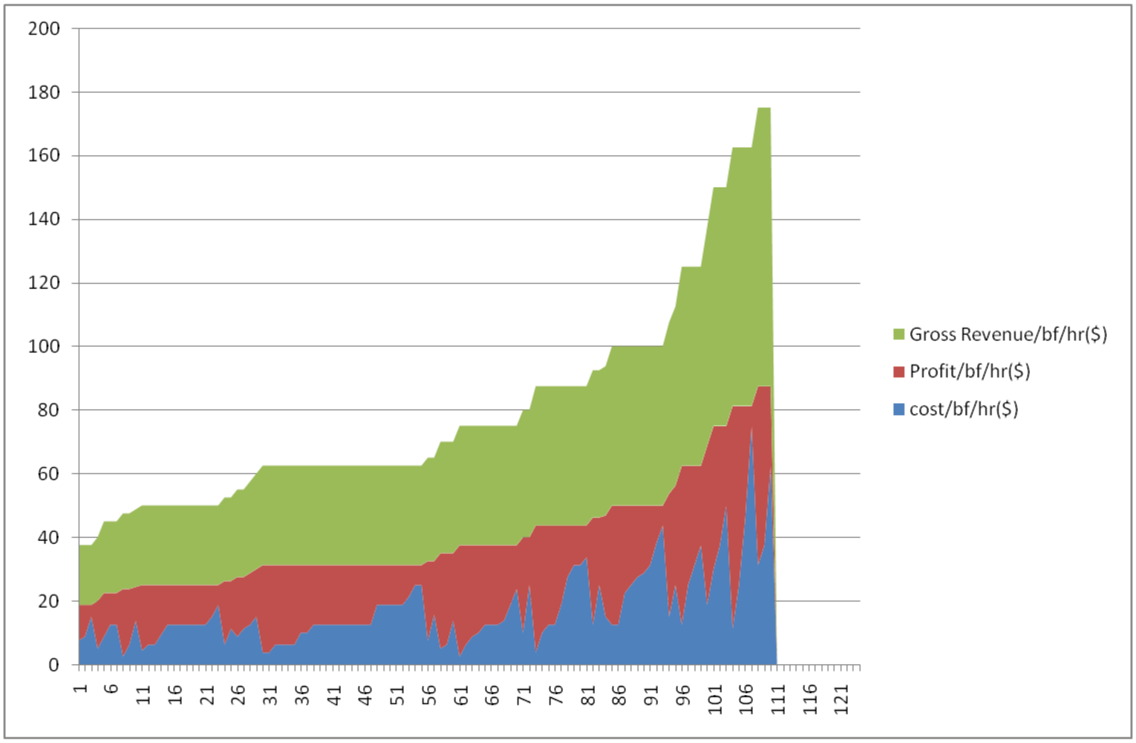

Figure 2. Trends same when higher values removed.

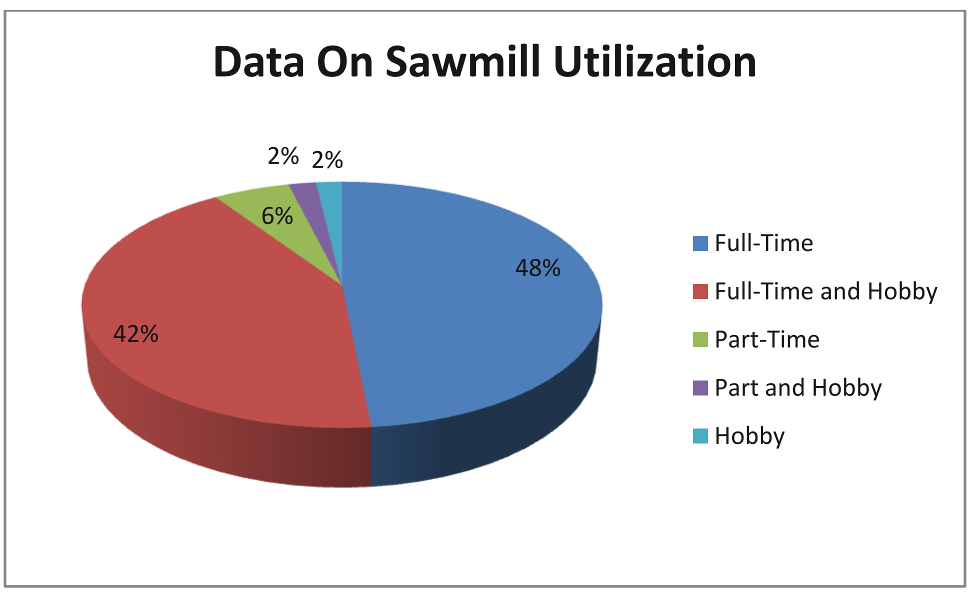

Figure 3. The sawmill employment objective (in %)

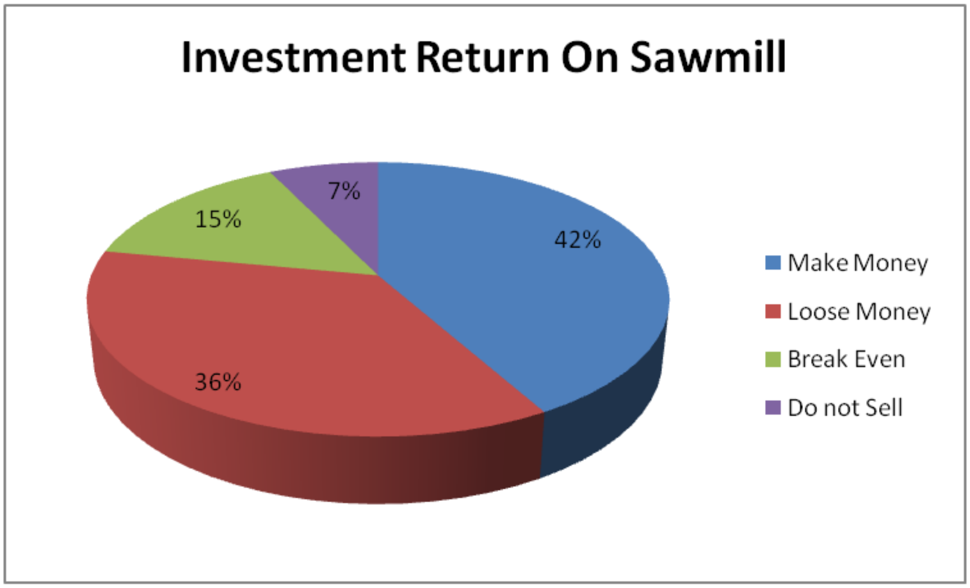

Figure 4. Return on Investment as reported in the survey

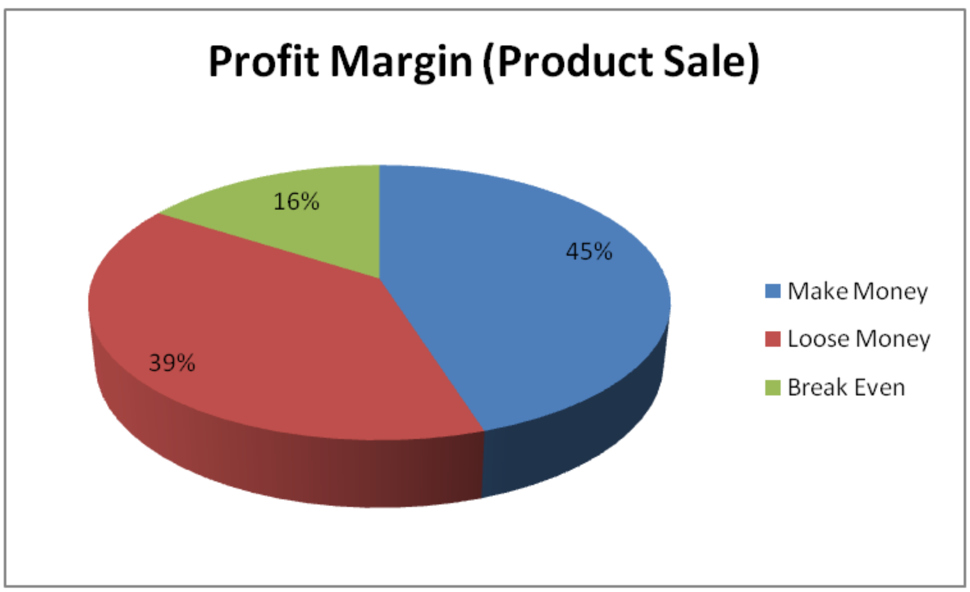

Figure 5. Return on Investment who sell their products

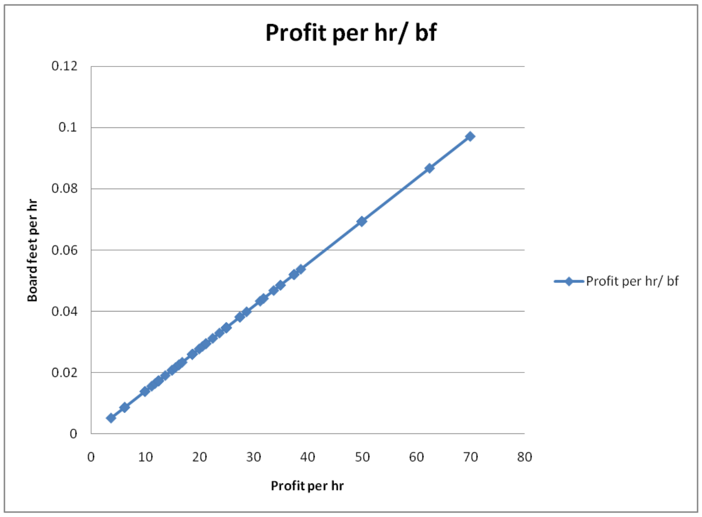

Figure 6. Relationship between the profit and production per hr.

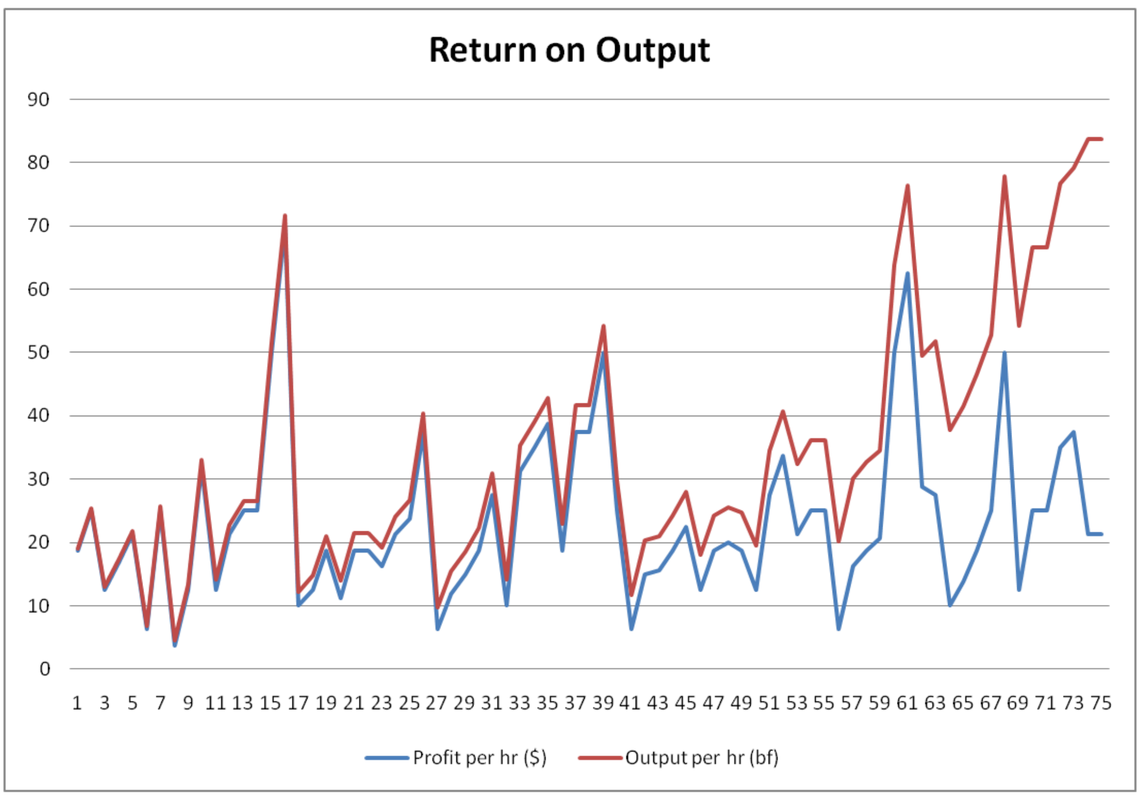

Figure 7. The trends in the profit and the output.

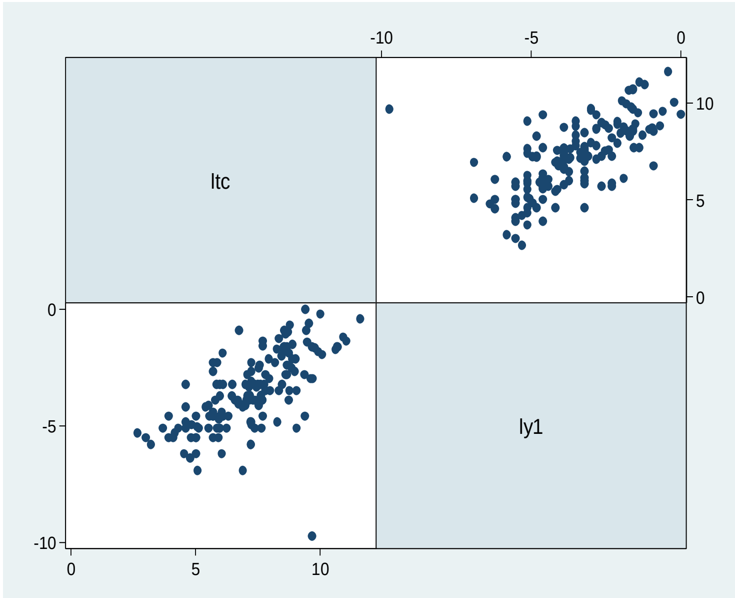

Figure 8. Shows Linear Relationship between the ltc and ly1, makes impossible to exploit the quadratic relationship with output.

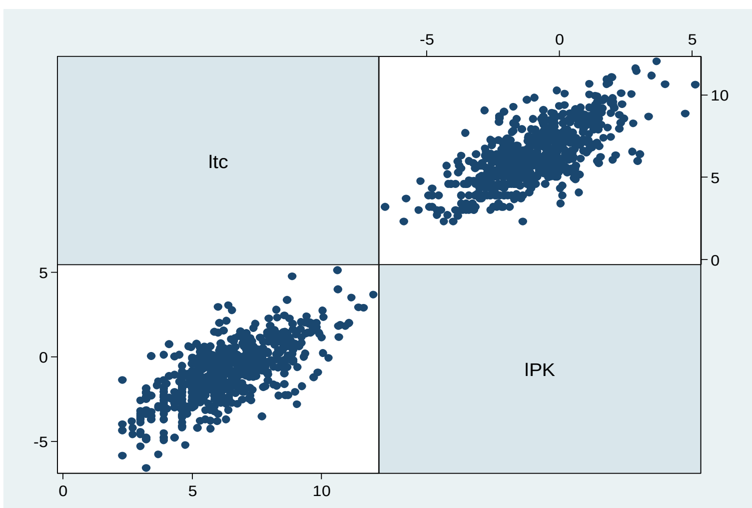

Figure 9. Shows Linear Relationship between the ltc and lpk(straight line depreciation), makes impossible to exploit the quadratic relationship with output.

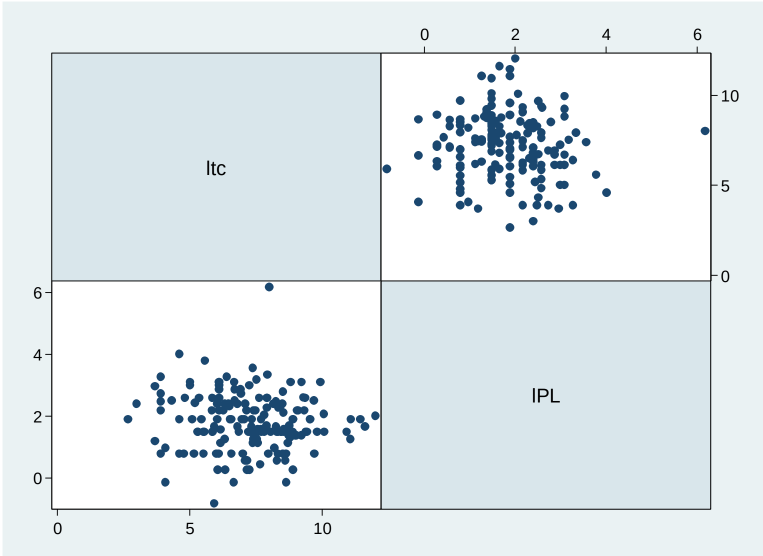

Figure 10. Shows Linear Relationship between the ltc and lpk(straight line depreciation)

Figure 11. Shows Linear Relationship between the ltc and lpk (hyperbolic depreciation)

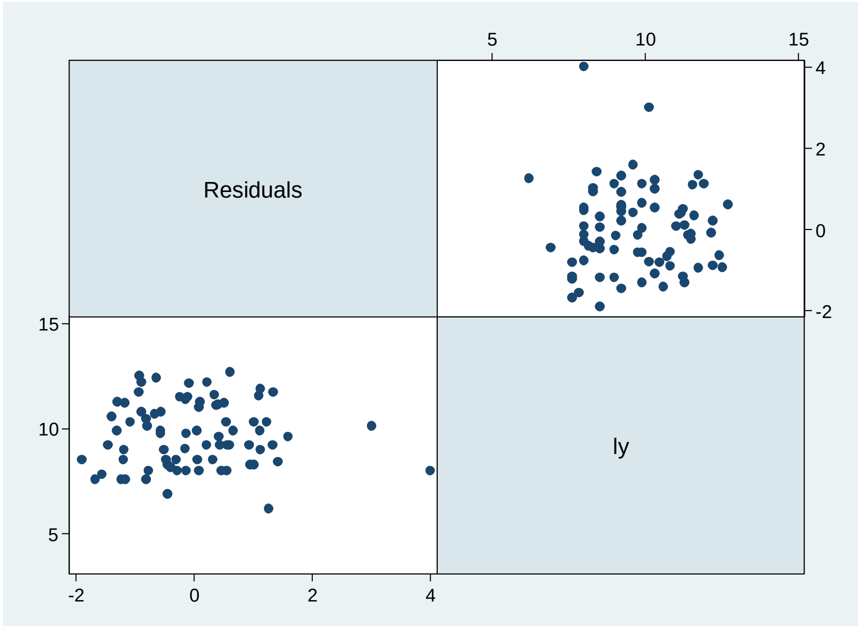

Figure 12. The residuals plots do not show any kind of relationship and they are scattered.