EFFICIENCY ANALYSIS OF COFFEE PRODUCTION IN VERACRUZ, MEXICO

by

GABRIELA CARDENAS

Under the direction of Dmitry V. Vedenov

ABSTRACT

Governmental support for coffee production in the 1980’s drove farmers in lesser developed countries to increase plantings of this commodity. In the early 1990’s, most supports ended, and coffee prices hit historical lows. The International Coffee Organization has proposed quality and diversification programs to combat the crisis. Coffee is still a main economic activity for producers in Veracruz, Mexico. In this thesis, the production systems of coffee producing villages after the support era are investigated with a production frontier in order to determine how their productivity has been affected. Also factors such as quality, cash crops production and access to markets are tested with respect to how they affect efficiency of production. Results show that access to markets and producing cash crops make villages more technically efficient. Economies of diversification exist between coffee and cash crops and, in general, productivity of these villages is decreasing during the period studied.

INDEX WORDS: Coffee, Distance Function, Productivity, Technical Efficiency, Mexico.
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MEXICO, 1999.

A Thesis Submitted to the Graduate Faculty of the University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

August, 2004
DEDICATION

I would like to dedicate my work to my family, who always gave me the love and understanding that helped me to continue through my studies, to my mother and my father, Lulu and Arturo; my sisters, Jenny and Arely, and my grandparents, Sara and Juan. They gave me the inspiration and strength I always needed in though times. I also want to thank and dedicate my work to Dwight my best friend and partner for all his caring love, his patience, and great humor that made everything easier.

Thanks to all my friends in Conner Hall for sharing the days and nights in 305 and the grad lab making the weekends better even though we were working. Special thanks to Mawar, Vanessa, Sarah, and Jackie. Finally I would like to recognize the memory of those who are not with us anymore but whose courage and dedication I remember, Raul and Liz.
ACKNOWLEDGEMENTS

This work couldn’t have been possible without the help of Dr. Vedenov, my major professor. I am thankful for his professionalism, positive attitude, and support through my graduate studies. I also would like to express my appreciation to the members of my committee: Dr. Barnett and Dr. Houston.

The study abroad Dr. Houston undergoes every year in Mexico is invaluable because it allows many people to gain knowledge about my country, creating understanding and education opportunities. I am thankful for these opportunities that allowed me to study in UGA.

My sincere gratitude to Dr. Lovell, his interest in my project and his disposition to help were vital for my work completion. Many professors fulfilled with their knowledge and genuine interest my education for that I would like to thank Dr. Ames, Dr. Gunter, Dr. Escalante, Dr. Wesztein, Dr. Marlowe, and Dr. White.
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CHAPTER 1
INTRODUCTION

Overview of World Coffee Market

Production of cash crops such as coffee is one of the alternatives that farmers in developing countries have to improve their income. A characteristic feature of coffee is the high demand for it in developed countries while its production takes place in developing countries\(^1\). One reason for this pattern is that coffee needs special climate, altitude, soil and other physical requirements to grow profitably, and countries that have the desired conditions to grow coffee are those located between the Tropics of Cancer and Capricorn (Graaff, 1986).

In 1984, the world indicator price for coffee was US $144.63 cents/lb paid to producer countries. The high price gave rise to various rural development programs that encouraged production of coffee, as governments in Latin America, Asia, and Africa tried to increase agricultural growth through coffee production (Maizels, Bacon and Mavrotas, 1997; Pendergrast, 1999). An example of such a policy was the 1980’s Vietnam governmental program to reach a total planted area of 180,000 hectares (VICOF A, 2004). By 2002, the goal was surpassed and tripled, reaching a total of 520,000 hectares of coffee planted that produced an estimated 900,000 tonnes of exportable product. Total exports of major coffee producers for the 1983 to 2001 period are shown in Figure 1.1; the boost of production in Vietnam is clearly evident.

\(^1\) There are approximately 25 million producers in the world (International Coffee Organization).
In many developing countries (e.g., El Salvador, Tanzania, Vietnam, Brazil), networks of institutions were created in order to help farmers to market, sell and distribute their products. Technical training, research, improved seeds and many other supports created by public institutions induced farmers to specialize in coffee and boost productivity.

At the international level, support to coffee producers was mainly provided through the International Coffee Organization (ICO). ICO was created in 1963, recognizing the importance of the industry of coffee for developing countries. Its members were governments from among the coffee producer and consumer countries supported by the United Nations. Since its foundation, the ICO worked through agreements that would impose quotas and other regulations.
on the coffee market in order to ensure stable prices. While the quota system came to an end in 1989, the Organization continued to work on agreements that would encourage better practices in coffee production.

In the early 1990s, there was a push to deregulate agriculture in developing countries caused by agreements with the International Monetary Fund and the World Trade Organization. In Mexico, this process was accelerated due to the signing of the North American Free Trade Agreement (NAFTA). One of the objectives of the market reform along with the disintegration of the ICO quotes was to transition to free determination of market equilibrium, thus avoiding damaging distortions in factor markets and their prices. The price changes would then result in reallocation in the production level according to demand. As a consequence, agricultural production in this country entered a new stage as all previous forms of support and governmental interventions no longer existed.

Coffee producing countries have relied on coffee’s export potential as the main driving force of their economies. During 1996-2000, one third of all coffee producing countries (51 in total) had a share of coffee exports in total exports earnings ranging from 5 to 20 percent (UNITC, 2002). The foreign exchange and gross national product of countries such as Burundi, Ethiopia, Nicaragua and El Salvador are tied extremely closely to coffee commercialization. However, the various forms of supports intended to increase coffee productivity resulted in a coffee supply that exceeded demand by 13 million bags of coffee. While the world production of coffee has increased by 3.6 percent, the demand has presented a slight increase during the same period of 1.5 percent (ICO, 2004).

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2 One bag of coffee beans is approximately 60 kilos or 132 pounds.
In 2000, the average price of coffee in the world market was US 37.97 cents/pound paid to producer countries\(^3\). Concerns about smallholder producers in developing countries have promoted the creation of new and different rural development programs. On October 1, 2001, the ICO launched a “Coffee Quality Improvement Programme”, and later diversification strategies were addressed. The various strategies can be summarized in two main policies for all countries: to diversify coffee production and to increase the quality of coffee. Diversification is recommended as a risk management tool because coffee has been traditionally associated with mono-cultivation, and higher quality is the main characteristic of coffee receiving premium prices in the world market.

**Mexican Case**

In 2000, coffee in Mexico ranked second in place among the highest currency earning agricultural products, generating $613.8 million in export revenues and representing 14.5 percent of the total agricultural exports. From figure 1.1 it is noticeable that between 1983 and 2001 Mexico has been among the major seven coffee exporter countries. About 85 percent of the total coffee production in the country is exported (CMC, 2004). Coffee production is highly fragmented, providing income for 700,000 family households in Mexico (66 percent of which are indigenous) on which approximately 3,000,000 people are directly dependent (Claridades Agropecuarias, 2002). There are four main producing regions of coffee in Mexico — Chiapas, Veracruz, Oaxaca, and Puebla — accounting for 85 percent\(^4\) of the country’s coffee production. From the total coffee production in Mexico 85 percent is exported (CMC, 2004). In the figure 1.2 a map of the coffee producer states in Mexico and number of producers in each region is depicted.

\(^3\)US dollars at 1984 prices (ICO).

\(^4\) Based on data from Sagarpa, 2002.
Figure 1.2 Coffee Producing States in Mexico

1) Nayarit
   P-73,742
   H-228,254
2) Jalisco
   P-12,920
   H-23,702
3) Colima
   P-783
   H-2,776
4) Guerrero
   P-10,497
   H-50,773
5) Oaxaca
   P-55,291
   H-173,765
6) Chiapas
   P-73,742
   H-228,254
7) Tabasco
   P-955
   H-2,236
8) Veracruz
   P-67,227
   H-152,457
9) Puebla
   P-30,973
   H-62,649

\(^a\) P stands for number of producers and H for hectares planted.
The government has facilitated the planting of coffee since the 1950’s. The Instituto Mexicano del Café (INMECAFE) provided support, beginning in 1973, in the form of machinery, technical packages and floor prices, along with marketing and organizational structures (Salazar, 1992). However, all of these support mechanisms have been shown to be a contributing factor in misallocating resources, such as land, in the distorted markets (Saudolet and De Janvry, 1995; Helberger and Chavas, 1996). One of the results of these distorting policies was that many small landowners, mainly in south Mexico (Chiapas, Veracruz, Oaxaca), devoted most of their land only to coffee, even though environmental conditions were not suitable to grow quality coffee. Simultaneous production of high- and low-quality coffee resulted in a practice of mixing coffee of different grades that gave Mexico a bad reputation as a producer (Lopez, 2002).

In 1992, coffee production in Veracruz\(^5\) comprised 67,227 small holders owning 152,457 hectares with an average of 2.2 hectares per producer (CMC, 2004). In 2000, this region was the second largest producer of coffee in Mexico, with coffee representing the third most planted agricultural product after corn and sugar cane. Foreign currency earned from coffee production has followed a negative trend, declining from 150 million dollars in 1998 to 42 million dollars in 2001 in real prices. A typical coffee producer in Veracruz would have received $27.10 for a metric tonne (mt) of coffee in 1998, but only $14.72 per mt\(^6\) in 2002.

While various solutions to the coffee price crisis have been suggested by international and national organizations and governments, the ICO approach has become particularly popular in Veracruz, and diversification towards the production of commercial crops and forest products

\(^5\)The state of Veracruz will be a subject of closer analysis in the remainder of the thesis.
\(^6\) One ton is equivalent to 2,204.62 pounds.
is now the target of new policies. At the same time, quality has been emphasized through certification of coffee planted at high altitudes hence promoting coffee production in those areas. Nevertheless, no specific program has been dedicated to boosting commercialization and/or improving access to markets for isolated villages.

The theory of economic growth recognizes the fundamental role of output increase in order to achieving rural advancement (Johnston and Mellor, 1961; Johnston and Nielsen, 1966; Ohkawa and Rosovsky, 1960). Under the new economic conditions combined with an ongoing price crisis, coffee producers face a free market that can either boost this growth or suppress it. Households that are exposed to more risk lack easy access to markets might respond to these conditions by increasing output and concentrating production towards food crops as a self-insurance mechanism (DeJanvry, Fafchamps and Saudolet, 1991.) Such a phenomenon, which has been observed in some of the coffee producer villages and documented in Lopez (2002), may carry negative outcomes for the environment. The lack of support to acquire inputs and the decrease in technology subsidies might also depress commodity production (Johnston, 1970). On the contrary, households that have easier access to markets and producing high quality coffee might increase their efficiency by using the best production practices, thus exploiting their comparative advantage. In addition, their reliance on subsistence cropping may shift towards commercially orientated agriculture driven purely by the market demand (Winters, 2002).

Objectives

This study aims to contribute to the understanding of the production system of coffee farmers in Veracruz, Mexico. The production system of the coffee farmers is analyzed during a period when governmental support has been significantly reduced, and the pressure on international prices
also burdens rural producers. The general purpose of the study is to characterize the system of production is characterized by inputs and outputs used by the coffee producers. The specific objectives are to: (1) measure the change in productivity in agricultural production; (2) assess the existence of economies of diversification between coffee and other crops, in order to identify products that could bring more growth to the region; (3) identify characteristics (e.g. access to markets) that may provide comparative advantage in production, and determine to what extent these factors impact productivity; and 4) investigate possibility of production of commercial crops other than coffee.

Methods and Definitions
In order to address the above issues, the methods of production theory are applied and a production function is estimated. In order to capture the dynamics of production in the coffee-producing villages, a multi-output function is utilized that accounts for interaction between different crops. The definition of productivity used in the analysis accounts for both technical efficiency and technical change. Quality of production is approximated by the altitude at which coffee is produced. The analysis relies on concept of diversification consistent with theory of economic production.

Change in productivity is estimated by decomposing it into two major components, technical efficiency and technical change. In this context, technical efficiency measures to what extent farmers are using the best practice to produce coffee without wasting inputs. Technical change refers to the shift of production function over time and can be related to better organization of the inputs, better quality of inputs or technological advances (Intriligator, 1978).
Using altitude as an approximation to quality is consistent with the most commonly used approach to classify high quality coffee (altura) (de Graaff, 1986; UNITC, 2002). It is this criterion that is used in Mexico in order to separate high- and low-quality producers; (COVECA, 2004).

Diversification refers to possibility of producing cash crops other than coffee and corn, which may result in gained efficiency. The concept of diversification in production economics stems from the known postulate about cost reduction in multi-product operations and is commonly associated with economies of scope. In the same way, a producer who is planting coffee and plans to introduce oranges or bananas may either increase or decrease his/her efficiency due to complementarity of these products through use of the same factor inputs or technology.

Five hypotheses are tested in this framework:

H1: Coffee farmers had lower productivity during the period following the deregulation process.

H2: There exist economies of diversification between coffee and the production of other market-oriented crops.

H3: Coffee farmers that diversify towards market-oriented crops have higher efficiency than those who do not.

H4: Coffee-producers located at higher altitude have higher efficiency than their lower-altitude counterparts.

H5: All things being equal, coffee producers with access to market are more efficient than their counterparts.
The next chapter presents an overview of theoretical foundations of efficiency and diversification measures, as well as a review of empirical results with emphasis on developing countries. Chapter 3 outlines the relevant topics of production theory, followed by description of data and methods used in chapter 4. Chapter 5 summarizes and discusses results of estimation and hypothesis tests. Finally, chapter 6 presents general conclusions, policy implications, and limitations of this study.
CHAPTER 2

LITERATURE REVIEW

Production Efficiency

The theory of production is a primary framework within which efficiency of production is usually measured. The concept of efficiency was first defined by Koopmans (1951) and Debreu (1951); their focus was on what is known now as technical efficiency. In particular, Debreu introduced a coefficient of resource utilization as a measure the efficiency of the economy. In his work, the coefficient of resource utilization is defined in terms of an optimal situation associated with a particular vector of resources. The efficiency is measured in the commodity space. Only the technically efficient producers will attain the maximum level of production, placing them on the best-practice frontier. Technical inefficiencies are then measured as the equiproportionate change required to reach the best practice frontier, and can be cast either in terms of the maximum feasible expansion of outputs for a given input vector or the minimum feasible decrease in inputs for a given output vector.

The definition and measurement of efficiency was further developed by Farrell (1957) by including prices in his analysis. He proposed an overall measure of economic efficiency, computed by adding technical efficiency and allocative efficiency. After Farrell development, more efficiency measurements have been introduced into production theory. Production efficiency has been disaggregated into the result of other measures, such as technical change, changes in scale efficiency, economies of scope, and “pure” technical change by Nishimizu and
Technical change is a time-related measure that describes the efficiency gained or lost by shifts in the best practice production frontier (Nishimizu and Page, 1982). Technical change implies a change in productivity, but productivity changes do not necessarily affect technical change. Given the technological frontier, technical efficiency will refer to the rest of the productivity change factors such as education, improved organization or managerial practices that will approximate a producer to the best frontier practice.

Another measure of efficiency obtained from specifying an input distance production technology is economies of diversification or output complementarity. Output complementarity exists when there is a possible gain in efficiency brought by expanding the production to more than one product, and it is calculated as the second derivative of the distance function with respect to the outputs. The information we get from this elasticity can be explained as the increase in input share needed in order to produce a second product (Paul and Nehring, 2002).

**Measurement of Efficiency**

An input distance function is a representation of a production process where the technology is defined in terms of a vector of outputs and inputs (Shephard, 1953). For the purposes of the present analysis, a production system described with a multi-product function is the most appropriate, since coffee-growing farmers can expand in diverse products and hence increase their efficiency. Theoretical advances in the duality of production, which started with Shephard (1953), led to extensive empirical work incorporating multi-output, multi-input production analysis (Brummer, Glauben, and Thijseen, 2002; Hattori, 2002; Coelli and Perelman, 1996; Färe and Primont, 1995). The classical representation of a multi-product function adds all
outputs in an index or uses two or more separate functions for each process (Antle and Capalbo, 1988). On the other hand, the distance function, either input- or output-oriented, allows for the representation of the multi-product technology in a quantity space. The distance function characteristics make it ideal to measure efficiency, due to its relation with the Debreu (1951) efficiency definition. Other applications also include index construction, welfare measurement, shadow price calculation, and cost-benefit analysis (Malmquist, 1953; Färe, Grosskopf and Lovell, 1993; Lovell, Richardson, Travers and Wood, 1994; Färe, Grosskopf, Norris and Zhang, 1994). For example, many studies have utilized the non-parametric index approach introduced by Malmquist (1953) that makes use of the distance function (Ball, Färe, Grosskopf, Zaim and Nehring, 2001; Umetsu, Lekprichakul, and Chakravorty, 2003, Armah, Park and Lovell, 1999). Although relatively easy to measure, the index approach assumes all producers are fully efficient.

In order to construct the best practice frontier required to calculate various efficiency measures, the two principal methods have been used: the Data Envelopment Analysis (DEA) and stochastic frontier analysis. The DEA is a non-parametric approach that uses linear programming in order to construct a piece-wise frontier. It was first introduced by Charnes, Cooper, and Rhodes (1978). A comprehensive reviews of DEA theory and methodology may be found in Førsund and Saraflogu (2002), and Charnes, Cooper, Lewin and Seiford, (1995). In application to agricultural production, DEA has been used by Gillespie, Schupp, and Taylor (1997) and Hailu and Veeman (1998).

The parametric approach uses classical econometric techniques in order to build production functions, which can be either deterministic or stochastic. A parametric model was
first estimated by Aigner and Chu (1968). The stochastic frontier analysis, developed by Aigner, Lovell and Schmidt (1977) and Meeussen and Van den Broeck (1977), has been used frequently in empirical works in the agriculture field (Kumbhakar, 1987; Kalijaran, 1990). The stochastic frontier analysis is a parametric method that specifies a particular form of error component in order to measure the producer inefficiency (Coelli, Rao and Battese, 1998). The method can accommodate various distance functions and different measures of efficiency can be derived from the estimated functional forms. Compared to DEA, the stochastic frontier model has three significant advantages. In particular, (1) the stochastic frontier model accounts for measurement errors that could interfere in the process of shaping the frontier, (2) tests of hypotheses can be implemented, and (3) the stochastic frontier model can accommodate different assumptions about returns to scale.

**Empirical Applications**

Empirical applications concerning efficiency measurement methodologies are grouped by geographical zones and represent studies relevant to the present analysis.

**Asia and Pacific**

Countries of Asia and the Pacific region were the subjects of several studies applying frontier techniques (Bravo-Ureta and Pinhero, 2001). The four papers discussed below specifically relate to the subsequent analysis, because (1) the unit of analysis is a farm or a rural region, (2) the environmental conditions are similar to the areas studied in Mexico, (3) similar functional forms and variables are used.

Battese and Coelli (1992) measured technical efficiency using 10 years of panel data for paddy farmers in Indonesia. They used a Cobb-Douglas production function in order to estimate
a stochastic frontier model. The main assumption of the model was that the farmers’ technical efficiency depends on an exponential time variant function. The independent variables included total land, work animals, and costs of inputs used in production. The dependent variable was the total value of output (rice). The production frontier was estimated with maximum likelihood estimators comparing five different specifications concerning the errors distribution and time effects. The best fit for the data was the model with half-normally distributed errors and time-variant yearly farm effects. The time-variant efficiency was found to be positive, implying that the farmers improved their methods of production during the period under consideration. The variables that tested significant and had positive effect on paddy farmers’ productivity were ratio of irrigated land to total land, labor, and work animals. The technical change as measured by the time variable resulted in total output increase of 5.4 percent during the 10-year period. However, the model seemed to overestimate technical change and did not account for technical efficiency correctly. The authors suggest that a possible reason could be that the independent variables used were too broad and could not capture specific effects.

Battese and Broca (1997) measured technical inefficiencies for wheat farmers in Pakistan using two models developed by Battese and Coelli (1992, 1995) and a model by Huang and Liu (1994). They estimated a stochastic production function with translog and Cobb-Douglas functional forms. The dependent variable in all models was output (quantity of harvested wheat). The independent variables or inputs were a dummy variable for fertilizer, the log of total land area, total labor in man-days, log of fertilizer amount if applied and zero otherwise, wheat seed sown, and the year of observation. The Cobb-Douglas specification was tested against the translog formulation and was rejected. In contrast with the Indonesian paddy case, the authors
tested for time as a valid variable to explain technical change, and rejected the hypothesis of its significance. Instead, they estimated a model where the mean of technical inefficiency depended on exogenous parameters such as age, education, year, land ownership, and credit constraints. All these parameters tested to be significant in explaining technical inefficiencies.

In a study of the post-Green Revolution Vietnamese agriculture (1971-1990), Umetsu, Lekprichakul, and Chakravority (2003) estimated an input-oriented Malmquist index based on an input distance function for the 13 regions in Vietnam. This work is of particular interest, because it accounts for many different micro- and macro-variables influencing the productivity. The goal of the paper was to assess trends in productivity growth of rice production, which was considered an intensive monoculture system; i.e. no alternative crops were allowed. The input variables used to calculate the index were land under two types of rice, labor, work animals (heads per year), fertilizer per hectare, and hand tractors. Once calculated, the Malmquist productivity index was decomposed and used as a dependent variable in an ordinary least squares regression for four regions in order to identify the effect of inputs and other factors on productivity. The panel data was corrected by the Prais-Winston method and heteroskedasticity and autocorrelation were also accounted for. The variables found to contribute positively to the total factor productivity were higher education, the ratio of prices of land to fertilizer, irrigated area planted under rice, as well as availability of paved roads and transportation. The variables contributing negatively were weather, population in the studied regions, and the landlord share to crops.

The dynamics of cash crops (coffee) vs. subsistence production in Papua New Guinea were analyzed by Coelli and Fleming (2003). They measured the impact that the degree of specialization had on technical efficiency, and they searched for evidence of economies of
diversification for each household. The data used in the study comprised panel data with only 36 observations. In most studies focusing on diversification, economies of scope are measured by the second cross-partial derivatives of the cost function. However, Coelli and Fleming (CF) did not consider the cost minimization as a suitable assumption and also allowed for inefficiency in production. As a result, they used the duality on the input distance function in order to measure the economies of diversification. The multi-input, multi-output distance function was estimated as a Cobb-Douglas function extended to partial translog in order to allow for flexibility in output terms. Some of the variables used in the CF model included proportion of female labor employed in production, ages of the male and female household heads, education level of the male household head, accessibility to the main town, and household size.

The concentration was measured by an Ogive index that calculates the level of dispersion or concentration of activities in the household. The results indicated that smallholders benefited from scale economies with output elasticities found to be greater than one, a result different from those of Battese and Coelli (1992) and Battese and Broca (1997), who found scale economies to be constant. A possible explanation might be the use of a multi-output production function, i.e. accounting for more productive activities. The hypothesis that technical inefficiencies are not present in the sample was rejected at the 95 percent confidence level, which indicates that the stochastic frontier approach adds explanatory power to this model. The estimated economies of diversification for coffee and other crops studied were very small. The overall results conform to Fleming and Hardaker (1994), who found that smallholders smoothly adapt and diversify from subsistence production to cash crops. The concentration parameter was found to be statistically significant and positive, indicating its strong association with technical inefficiency.
Latin America

Studies of productivity for Latin America are few, with published applications available only for Brazil, Ecuador, Honduras, Guatemala, and Paraguay. Economies of scale are important factors in these studies, due to persistent changes in land division and patterns of ownership in Latin America.

Bailey, Biswas, Kumbhakar, and Schulties (1989) measured economic efficiency in Ecuadorian dairy farms. Their approach was to estimate a stochastic frontier production function along with the first order conditions for scale and allocation economies by maximum likelihood method. The farms were grouped by size into small, medium and large. The independent variables used were land, labor, capital, milking equipment, use of feed concentrates, and artificial insemination. Results indicated that profit losses due to technical inefficiencies were similar regardless of farm size, even though smaller farms had a higher average level of technical inefficiency. The profit losses due to scale economies were also estimated and were found to be higher for small and medium-size farms than for large farms. In general, medium and large farms tended to be more efficient and minimize costs better than small ones. However, expansion in farm production may be restricted, due to market imperfections, liquidity constraints or cultural behavior.

Gilligan (1998) tested for relationships between farm size and productivity present in the sample of Honduras small coffee planters. He estimated a non-parametric input-output distance function for a sample of 409 farmers during 1993-1994. He also estimated technical efficiency by using a linear programming approach and found evidence of decreasing returns to scale. A Tobit regression was used to find the relationship between technical efficiency and size returns.
Smaller farmers demonstrated relatively higher scale efficiency. The overall economic efficiency was explained by independent variables that included area, land quality, household labor, hired labor, and total credit. Gillian found that scale accounts for the fact that input inefficiencies are 58 percent higher and output inefficiencies are 70 percent higher for larger farmers. His results confirm the necessity of land reforms implemented in many Latin American countries, with land split into smaller holdings in order to improve production efficiency.

Finally, Helfand (2003) used a methodology similar to Gillian (1998) in studying the relationship between size and efficiency in central-western Brazil. In particular, he used the data envelopment methodology to calculate an efficiency measure, which was then regressed on possible explanatory variables. The study was conducted on farms of various sizes in an area of Brazil that was characterized by productivity growth higher than the national average. The hypothesis tested was that the inverse relationship between farm size and productivity might change when modernization is considered along with more broad measures of productivity such as total factor productivity. The analysis used county level data with 426 observations covering 15 farm sizes and four types of land tenure. The outputs were aggregated into a gross measure of production for crops and livestock that account for 90 percent of total agricultural production. Inputs used were area, aggregated labor, tractors, animals, and purchased inputs.

Helfand’s analysis of the representative farm used constructed variables, due to limited availability of farm-level data. The assumption of constant returns to scale was not tested but considered given. The findings indicated an increasing relationship between size and efficiency, albeit at a decreasing rate. Input and technology were the main variables explaining efficiency, followed by institutions, size of the farm, and composition of output (e.g., the kind of crops or
livestock held). To capture the modernization effect, Helfand used such variables as credit, use of electricity, technical assistance, cooperatives, and market access. The latter was used to capture the extent to which market-oriented farm behavior is more efficient. Larger farmers (2000 hectares or more) were found to be more efficient, but smaller farms (with 20-200 hectares) would do better in comparison, if they were situated in an environment with access to all services and market access.

**Developed Countries**

Paul and Nehring (PN) (2002) investigated performance of farm production systems in the corn belt of the U.S., as well as the role that off-farm income has as a component of the net farm income. They found that larger family farms accounted for 58 percent of total production, and hence economies of scale might put pressure on smaller farms. The authors estimated a multi-input and multi-output stochastic frontier model and measured farm productivity by calculating input and output complementarity, technical efficiencies, and technological change. PN had access to a large database, from which 20,810 observations were grouped into farm cohorts that resulted in a pseudo-panel of 650 observations. The translog functional form was chosen for the distance functions because of its flexibility and second degree approximation for all input-output variables. The model was estimated in two variants with and without off-farm work. The off-farm input model resulted in a better fit and had higher explanatory power. The model included more than 12 input variables, five outputs plus the aggregated output, and six fixed factors, such as debt and farm age, in order to represent farm- and farmer-specific characteristics. Output contribution and outputs jointness were found to give a better picture of the farms’ progress and productivity. Inputs in the farms studied did not vary as much as outputs;
and hence; economies of scope and diversification were found to be important factors in determining productivity.

The most significant inputs in terms of productivity contribution were land, capital, and labor, followed by variable inputs such as seed and feed. The off-farm activities represented an important resource of income and efficiency for small farms compared to the business oriented farms. The input jointness, which was called by Coelli and Fleming (2003) economies of diversification or output mix, was found to be mainly negative, implying productivity gains due to diversification among production activities.

Brummer, Glauben, and Thijssen (2002) compared productivity growth for dairy farms in Germany, Poland and the Netherlands. They used panel data and measured the so-called three-dimensional productivity index for farms in different countries over different periods of time. An output distance function was used in order to (1) demonstrate how the total factor productivity index can be decomposed, (2) account for multi-input, multi-output production technologies, and (3) compensate for questionable behavior assumptions of profit and cost maximization (mainly for Polish farms). The total factor productivity decomposition accounts for technical change, change in technical efficiency, and scale effects of inputs and outputs. The authors constructed four models, one for each country and one aggregated for all regions. Their results indicated that the Netherlands was ahead in the frontier production, with technical efficiency accounting for most of the positive changes during the period of the study. The factor allocation in the Netherlands was negative, indicating that an efficiency improvement was still possible and should focus on inputs and their use.
Empirical studies of agricultural production in various regions of the world suggest that stochastic frontier is a promising modeling approach that provides an advantage over non-parametric methods. In addition, the studies in both developing and developed countries suggest that the economic productivity might be better explained by incorporating variables other than those related solely to production. Existing market imperfections and involvement of public services in some productive areas have also to be considered (Umetsu, Lekprichakul and Chakravorty, 2003).
CHAPTER 3
THEORETICAL BACKGROUND

This chapter presents the basic theory of production and productivity leading to derivation of the distance function. Discussion of how technical efficiency and technical change measures can be obtained from the distance function follows, and a general model for an input distance function frontier is introduced. The chapter is based on Diewert (1976), Beattie and Taylor (1985), Färe and Primont (1995), Nicholson (1995), Coelli, Rao and Battese (1998), Atkinson, Cornwell and Honerkamp (1999).

Production Theory

A production decision unit (e.g., a farmer) uses inputs to produce one or more finished goods (outputs). In the most general case, a technology of production can be described by the input requirement set

\[ L(y) = \{ x | x \text{ produces } y \}, \]

where \( y \) is the vector of outputs, and \( x \) is a vector of inputs. This can also be presented as a simplified model, where the output is written in terms of inputs. Such a relationship between the inputs and outputs is called a production function, and can be written in a general form as

\[ y = f(x_0, x_1, x_2, \ldots), \]
where $y$ represents output (e.g., pounds of coffee produced over a specific period), while $(x_0, x_1, x_2, \ldots)$ are inputs required to produce $y$. For instance, $x_0$ may represent hours of labor, $x_1$ may represent machinery used in the process, $x_2$ may represent fertilizer, and so on.

Inputs used in the production process can be interchangeable or substitutes; e.g., labor can in some instances be replaced by machinery. Isoquants illustrate this relation of input substitution in producing a given level of output. More specifically, an isoquant shows various combinations of inputs that can be used to produce the same level of output $y = y_0$ (figure 3.1). The commonly assumed properties of isoquants are (1) convexity to the origin and (2) non-intersection.

![Figure 3.1 Isoquant](image)

The isoquant shown in figure 3.1 represents all possible ways a producer (farmer) can combine inputs, such as machinery ($x_1$) and fertilizer ($x_2$), in order to produce a fixed level of output $y = y_0$. 
product (coffee) given by $y = y_0$. The extent to which the inputs can be interchanged is reflected in the slope of the isoquant. Formally, the rate of exchange, called the *marginal rate of technical substitution*, is defined as:

$$MRTS = \frac{dx_1}{dx_2} = \frac{MP_1}{MP_2}$$

(3.3)

In other words the marginal rate of technical substitution is the derivative of one input with respect to the other and can also be expressed as a negative ratio of the marginal products ($MP$) of input $x_1$ and input $x_2$. The marginal product of an input is defined as the partial derivative of the production function with respect to that input, (i.e., an additional output that can be produced by adding one more unit of that input while holding the remaining inputs constant).

**The Components of Productivity**

The production decision unit (e.g. farmer) may experiment changes in the process of production leading to variation in levels of output produced, or *productivity*. Given a well defined production relationship between inputs and outputs, e.g. (3.2), the rate of productivity change can be obtained over various time periods. Some changes in productivity may be attributed to better techniques, or discoveries of better practices to produce that shift the best production curve. All these factors together refer to as technical change. Other factors contributing to productivity changes such as improved organization or managerial decisions that move the producer closer the best practice frontier are referred to as technical efficiency changes.

The formal decomposition of productivity into technical change and efficiency change was introduced by Nishimizu and Page (1982). Given a complete production process represented
by a vector of inputs \((x)\) and outputs \((y)\) at time \(t\) for a producer \(s\), a production relationship as in (3.2) can be expressed as

\[
y(s,t) = f(x(s,t);s,t) < f(x(s,t);s^*t^*) = y^*(s,t)
\]  
(3.4)

The inequality in (3.4) will hold whenever a producer is not using its input mix \(x(s,t)\) with the best practice production. The producer obtaining the output \(y(s,t)\) has a potential level of productivity equal to \(y^*(s,t)\) that is obtained only by using the best practice. An output level comparison between the actual output and the best practice output given the inputs \(x(s,t)\) can be expressed as a ratio \(e(s,t)\), which represents the inefficiency present in the production process,

\[
e(s,t) = y(s,t) / y^*(s,t)
\]  
(3.5)

From (3.4) and (3.5), the rate of change in the production levels for the producer \(s\) can be expressed as

\[
\dot{f}(x,s,t) = \dot{y}(s,t) - f_x(s,t)x(s,t)
= \dot{f}(x,s^*,t^*) + \dot{e}(s,t) + [f_x(s^*,t^*) - f_x(s,t)]x(s,t)
\]  
(3.6)

where the dot represents logarithmic time derivatives and \(f_x(s,t)\) is the vector of output elasticities of the elements of \(x\). Thus the change in the productivity is given by three components: the best practice frontier change \(\dot{f}(x,s^*,t^*)\) (technical change), efficiency change \(\dot{e}(s,t)\), and the difference in the output elasticities for the best and inefficient practices.

The next section describes a complete representation of technology through a distance function, which can be then used to derive productivity change and decompose it into three components presented above.
Distance Function

An input distance function is often used to model production frontiers. The input distance function does not depend on units of measurement of inputs and outputs and can model a multi-input/multi-output production function. An input distance function characterizes the production technology by treating the output vector \((y)\) as given and looking at the minimal contraction of the input vector \((x)\) that the producer can make while still producing the given output vector. (Shephard, 1953; Färe and Primont, 1995). A general-form input distance function is given by

\[
D(y, x) = \max \{\lambda > 0 : (x / \lambda) \in L(y)\}
\]

(3.7)

where for a given output vector \(y\), the input set \(L(y)\) includes all feasible input vectors \((x)\) that can produce \(y\) (cf. (3.1)). It can be easily shown that the distance function in (3.4) is (1) non-decreasing in \(x\), (2) linearly homogeneous in \(x\), (3) concave and continuous in \(x\), and (4) decreasing in \(y\) (Färe and Primont, 1995).

Efficiency

Efficiency can be defined in input or output spaces and refers either to a vector of inputs that produces the maximum output possible, or a vector of outputs produced with the minimum of inputs (Fersund, Lovell, Schmidt, 1980). In the rest of this thesis, we only use input-oriented efficiency.

Technical efficiency is defined by the condition that the distance function in (3.4) is equal to one. An example of an input distance function is shown in figure 3.2 for the input set \(L(y^0)\) determined by the output vector \(y^0\). In order for an arbitrary input vector \(x\) to lie on the boundary of the input requirement set \(L(y^0)\), it has to be efficient with \(D(x, y^0) = 1\). The input vector \(x_0\) shown in figure 3.2, on the other hand, is located inside of \(L(y^0)\) and hence
$D(x^0, y^0) > 1$ indicating inefficiency. In practice, technical efficiency can be measured by estimating an input distance function (3.4). Higher values of the distance function indicate higher inefficiency in obtaining the output $y$.

![Figure 3.2 The input distance function and technical efficiency.](image)

In order to obtain an efficiency measure in the range between 0 and 1, with 1 indicating the highest efficiency, the reciprocal of the distance function can be used (Farrell, 1957). This measure of technical efficiency can be calculated as

$$(1/D(x, y)) = \min \{ \lambda : \lambda x \in L(y) \}$$

(3.8)

The latter is typically preferred used, because it provides an easier and more traditional way to relate increasing efficiency with a higher number on the scale from 0 to 1.
Decomposition of Productivity Change for Distance Function

The distance function is an equivalent representation of production technology and can be used to derive various measures of efficiency and productivity. The most common methods of measuring productivity are Malmquist index (Nishimizu and Page, 1982; Umetsu, Lekprichakul, and Chakravorty, 2003) and total factor productivity approach, introduced by Christensen, Caves and Swanson (CCS) (1981) and used in this study.

CCS defined productivity change (PC) in an input oriented multi-product function as the rate of change at which input can be decreased while holding outputs fixed and represented it formally as $-\frac{\partial \log x}{\partial t}$. Using the general approach to decomposition of productivity change outlined earlier, we can derive it through efficiency change (EC) and technical change (TC), which are calculated as part of the distance function estimation.

More specifically, a technically inefficient producer represented by a distance function $D(x,y,t) \geq 1$, where $t$ is a time argument. Let $b$ represent deviation from the most efficient isoquant of 1 as defined in (3.8) so that $D(x,y,t)b = 1$. The homogeneity in inputs allows us to write $\hat{x} = xb$. By totally differentiating the distance function, we obtain

$$\sum_{m} \frac{\partial D(\hat{x}, y, t)}{\partial y_m} dy_m + \sum_{n} \frac{\partial D(\hat{x}, y, t)}{\partial x_n} dx_n + \frac{\partial D(\hat{x}, y, t)}{dt} dt = 0$$

(3.9)

The distance function, by definition, reduces the input vector by holding outputs constant; thus, it is possible to set $dy = 0$. Multiplying and dividing the middle term in (3.9) by the scalar $x_n$, we obtain,
\[ \sum_n \frac{\partial D(\hat{x}, y, t)}{\partial x_n \hat{x}_n} d\hat{x} + \frac{\partial D(\hat{x}, y, t)}{\partial t} dt = 0 \]  

(3.10)

The denominator can be now expressed as \( \partial \ln \hat{x}_n \), and the scalar term can be taken from under summation sign

\[ \frac{d\hat{x}_n}{\hat{x}} \sum_n \frac{\partial D(\hat{x}, y, t)}{\partial \ln \hat{x}_n} = -\frac{\partial D(\hat{x}, y, t)dt}{\partial t}. \]  

(3.11)

Rearranging the terms and solving for the derivative of logarithm of \( \hat{x}_n \), we arrive at

\[ -\frac{d \ln \hat{x}_n}{dt} = \frac{\partial D(\hat{x}, y, t)}{\partial t} \sum_n \frac{\partial D(\hat{x}, y, t)}{\partial \ln \hat{x}_n} \]  

(3.12)

In the right hand side denominator of (3.12), we apply homogeneity again and rewrite the denominator in terms of \( D(x, y, t) \) reintroducing the inefficiency parameter \( b \)

\[ -\frac{\partial \ln x_n}{\partial t} - \frac{\partial \ln b}{\partial t} = \frac{\partial D(x, y, t)}{\partial t} \]  

(3.13)

Finally, representing the right-hand side as a time derivative of a logarithm and rearranging terms, we arrive at

\[ -\frac{\partial \ln x_n}{dt} = \frac{\partial \ln D(x, y, t)}{dt} + \frac{\partial \ln b}{dt}. \]  

(3.14)

The left–hand side of (3.14) is the productivity change (cf. (3.6)) expressed as a sum of two components

\[ PC = \frac{\partial \ln D(x, y, t)}{\partial t} + \frac{\partial \ln b}{\partial t} = TC + EC. \]  

(3.15)
The first term corresponds to technical change (TC), i.e. the change of the distance frontier over time, while the second term is the change in inefficiency parameter $b$ over time (EC). This decomposition of productivity change into technical change and efficiency change follows the work of Atkinson, Cornwell, and Honerkamp (1999). Note that the two measures (TC and EC) can follow different patterns through time. The technical change represents shifts in the best production frontier, while efficiency change reflects the movement towards or away the best practice.

**Parameterization**

The parameterization of the distance function is a relatively recent approach, with the majority of earlier studies using linear programming methodology (Lovell et al, 1994). Most studies using parametric frontier functions have opted for a Cobb-Douglas specification. The latter does not impose restrictions on output. However, it does have some restrictive properties, such as constant input elasticities and returns to scale, and elasticities of substitution equal to one.

For the purposes of this study, the flexibility of the distance function is important, as it is used to estimate elasticities of scale and diversification. The transcendental logarithmic functional form (or translog) does not impose restrictions on substitution elasticities and is more flexible than Cobb-Douglas (Christensen, Jorgenson and Lau 1973; Fuss, McFadden and Mundlak, 1978). Therefore, we use the translog function in order to represent a multi-output technology that allows for direct estimation of crossoutput elasticity. A general-form translog distance function for $K$ inputs and $M$ outputs can be written as
\[ \ln D = \alpha_0 + \sum_{m} \alpha_m \ln y_m + \frac{1}{2} \sum_{m} \sum_{n} \alpha_{mn} \ln y_m \ln y_n + \sum_{k} \alpha_k \ln x_k + \]
\[ \frac{1}{2} \sum_{k} \sum_{l} \alpha_{kl} \ln x_l \ln x_k + \sum_{k} \sum_{m} \alpha_{km} \ln x_m \ln y_k + \varepsilon \]  

(3.16)

where \( \mathbf{x} \) is the input vector, \( \mathbf{y} \) is the output vector. Recall that any distance function has to be homogeneous of degree one in inputs. For this property to hold, the parameters of the translog function have to satisfy the following conditions:

\[ \sum_{n} \alpha_m = 1, \]

\[ \sum_{k} \alpha_{km} = 0 \quad \forall m, \text{ and} \]

\[ \sum_{k} \alpha_{kl} = 0; \quad \forall k \]

The homogeneity of (3.16) can be applied to normalize the function with respect to an arbitrary input. By definition, the distance function is greater or equal than one, and input homogeneity implies that \( D(\mathbf{y}, \lambda \mathbf{x}, t) = \lambda D(\mathbf{y}, \mathbf{x}, t) \) for \( \lambda > 0 \). Therefore, by choosing \( \lambda = 1/x_k \) for an arbitrary input \((x_k)\), one can define a new input vector

\[ \mathbf{x}^* = (x_k / x_K), \quad k = 1, 2, \ldots, K - 1, \]  

(3.17)

and rewrite the distance function as \( D(\mathbf{y}, \mathbf{x}^*, t) = x_K^{-1} D(\mathbf{y}, \mathbf{x}, t) \). The efficiency condition, \( D(\mathbf{y}, \mathbf{x}, t) = 1 \), then implies \( x_K^{-1} = D(\mathbf{y}, \mathbf{x}^*, t) \). The distance function in this form can be converted into a stochastic frontier form by adding a random component.

\[ x_K^{-1} = D_i(\mathbf{y}, \mathbf{x}^*, t) \exp(\varepsilon), \quad \varepsilon \leq 0 \]  

(3.18)
Under given distributional assumption about the error term, the parametric form in (3.18) can be estimated. The stochastic term in (3.18) can be represented as $\varepsilon = (\nu - u)$, i.e. decomposed into two random variables, $\nu$ and $u$. Note that originally the parametric production frontiers were estimated with a single error term and hence were called deterministic frontier functions. The introduction of the second error term $\nu$ allows one to account for measurement errors and various events, such as weather, that are outside of producer’s influence but impact performance of the firm and cannot be attributed to inefficiency.

The translog functional form in (3.14) has its own drawbacks. In particular, the number of parameters in the unrestricted model equals to $\frac{n(n+1)(n+2)}{2}$, where $n$ is the total number of inputs and outputs. If the homogeneity condition is imposed, the number of parameters drops to $\frac{n(n+1)}{2}$, but is still rather high. Thus, if the data set is limited in size (as it is in the case in the present study), a complete specification of the translog function cannot be estimated.

However, a modified version of the translog function can be specified so as to incorporate all the important technical relationships while keeping the number of degrees of freedom in a reasonable range (Coelli and Fleming, 2003; Lall, S., and Rodrigo, 2001). The technological relationships of interest for this study can be obtained from a partial translog specification where the coefficients of the second-order input terms are set to zero. The modification of (3.16) for $K$ inputs and $M$ outputs without second-order terms in inputs with homogeneity conditions, and a random error outputs can be written as:
\[
\ln(x_i^{-1}) = \alpha_0 + \alpha_x + \sum_{k=1}^{K} \alpha_k \ln x_{ik} + \sum_{m=1}^{M} \alpha_m \ln y_{im} + \sum_{k=1}^{K} \alpha_k \ln x_{ik}d + \frac{1}{2} \sum_{j=1}^{J} \sum_{m=1}^{M} \alpha_{km} \ln y_{ij}^* \ln y_{ij}^* + \alpha_d \ln y_{ij}^* \ln y_{ij}^* + \alpha_d \ln y_{ij}^* \ln y_{ij}^* + \alpha_d \ln y_{ij}^* \ln y_{ij}^* + \alpha_d \ln y_{ij}^* \ln y_{ij}^*
\]

where the asterisk by the input vector indicates imposition of homogeneity, and the last term is the stochastic frontier random component. The random terms \( u_i > 0 \) are producer-specific and assumed to be drawn from a truncated normal distribution \( N(\sigma_i, \sigma^2) \). The expected value, \( \delta_i z_i \), corresponds to deviations from production frontier due to producer specific explanatory variables and hence measures technical inefficiency.

The modified specification in (3.19) can be used to derive efficiency measures relevant for this study, in particular technical efficiency, technological change, efficiency change, scale elasticities, and economies of diversification. In order to estimate technical efficiency from (3.19), the random term \( \varepsilon \) can be used. While neither of the components of this random error are observable separately, the measure of technical inefficiency given by \( u_i \) can be predicted. By definition of the input distance function, technical efficiency refers to a vector of inputs that produces the maximum output possible. Therefore, the technical inefficiency for the \( i^{th} \) producer can be estimated by a ratio of the observed output relative to the potential output as given by the best practice frontier in (3.19). Note that this follows the same procedure used in (3.5). Thus, the prediction of technical efficiency (obtained by the inefficiency) can be calculated:

\[
TE_i = \frac{y}{\exp(D + v)} = \exp(-u_i) = \exp(-z_i \delta - W_i)
\]

(3.20)
The use of the expectation of $u_i$ as the best predictor of its real value was first introduced to stochastic frontier models by Jondrow, Lovell, Materow and Schmidt (1982). In this study, we use the derivation from Battesse and Coelli (1993), where the mean efficiency is related to the vector $z_i$ of explanatory variables. And $W_i$ which is a random variable such that the truncation of the distribution of $u_i$ equals $-z_i\delta$. In particular, vector $z_i$ will be used in order to find out how access to markets, altitude and commercial crop production impact technical efficiency and hence test hypotheses 3, 4, and 5. The expected values can be obtained by the maximum likelihood estimation methodology outlined in Battesse and Coelli (1993).

The total change in productivity in (3.15) is composed from technical change and efficiency change, and can be calculated in order to test hypothesis 1. Technical change is a time-related measure that describes the efficiency gained or lost by shifts in the best practice production frontier over time (Nishimizu and Page, 1982). Since shifts in technology for the frontier given in (3.19) are measured through dummy variables, the technical change can be obtained as a discrete approximation to (3.15). In particular, the difference between the estimated distance function in periods $t$ and $t+1$ can be computed while holding input and output quantities constant, or

$$
TC = \sum_k \gamma_{kt}(t-t_{i-1}) + \gamma_i - \gamma_{i-1}
$$

(3.21)

Efficiency change can be calculated from (3.18) as the change in technical efficiency

$$
EC = \Delta TE = TE_i - TE_{i-1},
$$

(3.22)

And the productivity change can be constructed as

$$
PC = TC + EC
$$

(3.23)
The last elasticity we are interested in calculating is the complementarity of the input set, called economies of diversification. This is required to test hypothesis 2. For economies of diversification to exist, the cross-partial derivatives of the distance function in (3.17) with respect to the outputs should satisfy the condition

$$\frac{\partial \ln D_i}{\partial \ln y_i, y_j} = \frac{\partial \ln (x^{-1})}{\partial \ln y_i, y_j} > 0.$$  (3.24)

The condition in (3.22) means that the share of inputs is decreasing when the output $i$ and $j$ are produced together. This measure is similar to scope economies, which exist when the second derivatives of the cost function with respect to outputs are negative.
CHAPTER 4

ESTIMATION METHODS

Data Set

Data used in this study represent production activity in the state of Veracruz, Mexico. This region experienced rapid growth of coffee production in 1970s and 1980s. Most of this growth was promoted by governmental subsidies and government-introduced technology. During the 1990s this boost started to decline as a consequence of the Mexican government’s change in agricultural strategies, disappearance of national and international institutions supporting coffee production and the Mexican economic crisis of 1994. These factors generated uncertainty for the coffee producers and together with an increasing international supply of the commodity, have impacted producers’ technology, input use, and output production.

The data were collected from the statistical yearbooks published by the Finance and Economics Secretary (FES) in Veracruz, which provides information on quantities of outputs produced and inputs used as well as environmental and socio-demographic information. However, the data do not include prices and are highly aggregated for certain variables.

Due to data limitations, the analysis at the household level was not possible. The smallest unit of aggregation available in the data set, and thus chosen for analysis, was a “municipio” or a village, which is a basic unit of local administration. The villages included in the sample were those that produced coffee, reported different growing altitudes, and produced all three outputs considered in this study.
A total of 15 villages were considered, accounting for 40 percent of the total production of coffee in the Veracruz region. The villages are listed in Table 4.1. The data for each village included inputs, outputs, and demographic variables. Table 4.2 provides descriptions of the variables and sample statistics. The FES database included data for only four growing seasons, namely 98/99, 99/00, 00/01, and 01/02. Therefore, a total of 60 observations were used in a pooled cross-section, time-series analysis.

The model presented in Chapter 3 was estimated with three outputs and five inputs. The outputs are corn, coffee, and other crops. Corn is the main staple crop produced in Mexico and is considered separately in order to account for small households that consume their own production. Corn output is measured in the total tons produced by each village. Coffee is the main cash crop of interest in this study. Coffee output is also measured in total tons produced by each village in an agricultural year. Finally, “other crops” account for all other production, which varies widely across villages, but mainly includes commercial, alternative, and traditionally marketed crops, such as mango, passion fruit, lime, tangerine, banana, pineapple, and rubber. The output of “other crops” is also measured in total tons produced by each village.

The input variables included fertilizer, machinery use, labor, technical support and utilization of improved seeds. The variables representing the inputs are proxies to the real inputs used, because there are not data on exact rate of inputs used or their quality. Fertilizer use is measured by total hectares fertilized per year. This includes both organic and chemical fertilizers and is used as a measure of technology use. Machinery refers to both tractors and all other mechanized tools used in production. Machinery use is measured as hectares per agricultural year using machinery. Data on labor used in production are not available, and therefore the
<table>
<thead>
<tr>
<th>Municipio/Village</th>
<th>Hectares of coffee per capita</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atzalan</td>
<td>0.107</td>
<td>48036</td>
</tr>
<tr>
<td>Chumatlan</td>
<td>0.004</td>
<td>3434</td>
</tr>
<tr>
<td>Coahuitlan</td>
<td>0.090</td>
<td>6868</td>
</tr>
<tr>
<td>Coxquihui</td>
<td>0.043</td>
<td>14407</td>
</tr>
<tr>
<td>Coyutla</td>
<td>0.051</td>
<td>21048</td>
</tr>
<tr>
<td>Filomeno Mata</td>
<td>0.055</td>
<td>10795</td>
</tr>
<tr>
<td>Juchique de Ferrer</td>
<td>0.322</td>
<td>18832</td>
</tr>
<tr>
<td>Mecatlan</td>
<td>0.110</td>
<td>10314</td>
</tr>
<tr>
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<td>Omealca</td>
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<tr>
<td>Tezonapa</td>
<td>0.259</td>
<td>50859</td>
</tr>
<tr>
<td>Coatepec</td>
<td>0.135</td>
<td>72178</td>
</tr>
<tr>
<td>Huatusco</td>
<td>0.211</td>
<td>46184</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
<td>Measure</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>CA</td>
<td>Planted area, corn</td>
<td>Hectares</td>
</tr>
<tr>
<td>COA</td>
<td>Planted area, coffee</td>
<td>Hectares</td>
</tr>
<tr>
<td>OTA</td>
<td>Planted area, other cash crops</td>
<td>Hectares</td>
</tr>
<tr>
<td>CV</td>
<td>Corn annual production</td>
<td>Metric tonnes</td>
</tr>
<tr>
<td>F</td>
<td>Area fertilized</td>
<td>Hectares</td>
</tr>
<tr>
<td>COV</td>
<td>Total annual production of coffee</td>
<td>Metric tonnes</td>
</tr>
<tr>
<td>OTV</td>
<td>Total annual production of other cash crops</td>
<td>Metric tonnes</td>
</tr>
<tr>
<td>TAIS</td>
<td>Area using technical assistance and improved seeds.</td>
<td>Hectares</td>
</tr>
<tr>
<td>L</td>
<td>Labor</td>
<td>Average Household size</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
<td>M</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td>Area using machinery input (tractors and other powered tools)</td>
<td></td>
</tr>
<tr>
<td>Measure</td>
<td>Hectares</td>
<td>1414.2</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>2882.94</td>
</tr>
<tr>
<td>S.D.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Min.</td>
<td></td>
<td>12294.25</td>
</tr>
<tr>
<td>Max.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
number of people per household was used instead. This is a reasonable proxy because the immediate family is the main labor resource in most of the households, with majority of family members working without earning salaries. This variable is particularly important, since the production of coffee is very labor intensive, with labor accounting for more than 50 percent of the total value of the factors used. Finally, technical assistance and the use of improved seeds are combined in a single variable and represent another measure of technology use. The variable is expressed in hectares that received technical assistance and/or improved seed per production year.

Model specification in (3.17) includes additional factors introduced in order to explain the mean of the inefficiency effects, $u_i$. In particular three variables were used as inefficiency factors in this study, namely a dummy for market access, percentage of commercial crops to total production, and altitude. The dummy for access to markets was constructed by combining kilometers of paved roads, number of households that own cars, and number of households with basic infrastructure in a single score variable. The village with the highest score was considered as a reference to classify the rest. The mean of the combined score was calculated. The dummy for market access was then set to one for villages with the score greater than or equal to the mean, and zero for those with the score less than the mean. This dummy is used to test whether there is any difference in efficiency for villages that are closer to main cities and are less marginal; hence, a value of one is expected to be related to higher efficiency.

The share of commercial crops in total production was used in the model in order to account for market-oriented production. In this specification, coffee and corn were considered as traditional crops, and production of other commodities was considered a diversification towards
commercial production. The share of commercial crops is expected to be positively related to higher efficiency.

Altitude is a commonly used proxy in the classification of quality of coffee grains (de Graff, 1986; UNITC, 2002). In particular, it has been used in designing policy instruments by the Mexican government and other coffee organizations. Higher altitudes are generally considered to result in higher quality (premium) coffee. Villages located at higher altitudes are generally discouraged from production diversification and instead should specialize in coffee. Therefore, it is important to know if these villages are more efficient because of their comparative advantage.

**Estimation**

The estimated model, as given by (3.19), was

\[
\ln(x_{k}^{-1}) = \alpha_0 + \alpha_a + \sum_{k=1}^{K} \alpha_k \ln x_{ik}^* + \sum_{m=1}^{M} \alpha_{m} y_{im}^* + \sum_{k=1}^{K} \alpha_{kd} d \ln x_{ik} + \frac{1}{2} \sum_{j=1}^{J} \sum_{m=1}^{M} \alpha_{lm} \ln y_{ij}^* \ln y_{jm}^* + \alpha_d + (v_i - u_i)
\]

\[d = 1, \ldots, T \text{ (Time trend)}\]

\[v_i \sim iid \{0, \sigma_v^2\}\]

\[u_i \sim id \{\delta_i z_i, \sigma^2\}\]

The vector \(x_k^*\) represents the normalized inputs, with labor used to impose homogeneity. The subscript \(i\) refers to the \(i\)th village and \(t\) is the time period subscript. The output vector consists of the three outputs, corn, coffee, and other crops. The variable \(t\) is a time trend introduced in the frontier as interacting with the input factors. The estimated distance function is used to measure technical efficiencies for the villages studied. The mean technical inefficiency term \(\delta_i z_i\), depends on the share of commercial crops variable \(c\), an altitude dummy \(l\), and the access dummy \(a\), which interacts with the commercial crop and altitude variables.
Technical change is calculated according to (3.19) in order to determine whether there was any time-dependent shift in the productivity during the period of study. Presence of economies of diversification between each pair of outputs is analyzed by calculating the cross-output elasticities and verifying condition (3.22). It is expected that the cross-output elasticities are positive; i.e., complementarity among inputs exists and farmers are gaining productivity from economies of diversification.

The stochastic input distance frontier (3.19) was estimated using the maximum likelihood technique. One of the characteristics of this model is that it relies on distributional assumptions about the random factor \( u_i \). The use of panel data in this situation has an advantage over time series because the noise is averaged in the entire residual and the inefficiency component is observed for different periods (Khumbakar and Lovell, 2000). In this study, the assumption about the distribution of random factor \( u_i \) follows Battesse and Coelli (1993). More specifically, the distribution of \( u_i \) is obtained by truncating the standard normal distribution \( N(\delta_i z_{it}, \sigma^2) \). The inefficiency term for the \( i \)th village in period \( t \) is given by \( \exp(-u_i) = \exp(\delta_i z_{it} - W_{it}) \).

The estimation of efficiencies is based on a conditional expectation of the efficiency term \( u_i \), given the model assumptions. The likelihood development is taken from Coelli and Battesse, (1993) such that the distance function can be rewritten as: \( D = x_{it} \alpha + \epsilon \), where \( D \) is the distance function, the \( \alpha \)'s are the parameters to estimate, and the error term is given as \( \epsilon = \nu - u \). The likelihood function is given in terms of the variance parameters:

\[
\sigma^2_x = \sigma^2_v + \sigma^2_v, \quad \gamma = \sigma^2 / \sigma^2_x,
\]
\[
L(\theta : y) = -\frac{1}{2} (\sum_{i=1}^{N} T_i) \{ \ln 2\pi + \ln \sigma_i^2 \} - \frac{1}{2} \sum_{i=1}^{N} \sum_{t=1}^{T} \{ D_{it} - x_{it} \alpha + z_{it} \delta / \sigma_i^2 \}
- \sum_{i=1}^{N} \sum_{t=1}^{T} \{ \ln \Phi(j_{it}) - \ln \Phi(j_{it}) \},
\]

where

\[
\theta = [\alpha', \delta', \sigma_i^2]
\]

\[\Phi(.) = \text{d as a standard normal}\]

\[j_{it} = z_{it}\delta / (\gamma \sigma_i^2)^{1/2}\]

\[t = 1, \ldots, T \text{ (time period)}\]

\[i = 1, \ldots, N \text{ (producing entities)}\]

The maximum likelihood and efficiencies were calculated by using the FRONTIER 4.1, Coelli (1996) software. Results and implications are discussed in the following chapter. Comparisons to results from similar studies will also be presented.
CHAPTER 5
RESULTS AND DISCUSSION

Distance Function Estimates

The equation specified in (3.19) was estimated for the data set comprised of four annual observations in each of 15 villages, or 60 total observations. Estimated coefficients and their t-statistics are presented in Table 5.1. The table indicates that 15 of 29 parameters are significant. The proportion of significant parameters is in concordance with distance function estimation reported in other studies (Brummer, Glauben, and Thijssen, 2002; Battese and Perelman).

Model (3.17) includes an intercept parameter for the villages with access to markets. The intercept parameter is intended to capture the productive differences in technical efficiency between the villages with and without market access. The estimated value of this parameter at 0.0995 for villages with access to city markets shows that there exists a significant and positive difference in the intercept. The interpretation of this result is that the same output is produced with less input for those villages that have easier access to markets.

Specification Tests

Several specification tests were performed on the estimated model. The first test was to determine the explanatory power of the frontier model under a null hypothesis that there are no technical inefficiencies; i.e., $H_0: \gamma \leq 0$ vs. the alternative $H_1: \gamma > 0$ (Battese and Coelli, 1995). The parameter $\gamma$ equal to zero indicates that the frontier deviations from efficiency are non-stochastic, and thus the model can be efficiently estimated with OLS. On the other hand, a positive value of $\gamma$ indicates that the deviations are due to technical inefficiencies.
Table 5.1 Parameter Estimates.

<table>
<thead>
<tr>
<th>Variable</th>
<th>coefficient</th>
<th>standard-error</th>
<th>p-value</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.6019</td>
<td>0.4793</td>
<td>0.0023</td>
<td>3.3422b</td>
</tr>
<tr>
<td></td>
<td>0.0995</td>
<td>0.0356</td>
<td></td>
<td>2.7944b</td>
</tr>
<tr>
<td>Access to markets (ATM)</td>
<td></td>
<td></td>
<td>0.0091</td>
<td></td>
</tr>
<tr>
<td>Technical assistance &amp;</td>
<td>-0.0009</td>
<td>0.0046</td>
<td>0.8547</td>
<td>-0.1847</td>
</tr>
<tr>
<td>Improved seeds (TA,IS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td>-0.0013</td>
<td>0.0040</td>
<td>0.7528</td>
<td>-0.3180</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>-0.0343</td>
<td>0.0052</td>
<td>0.0001</td>
<td>-6.6534b</td>
</tr>
<tr>
<td>Corn</td>
<td>0.1480</td>
<td>0.0842</td>
<td>0.0894</td>
<td>1.7573c</td>
</tr>
<tr>
<td>Coffee</td>
<td>0.0799</td>
<td>0.0949</td>
<td>0.4068</td>
<td>0.8418</td>
</tr>
<tr>
<td>Other crops</td>
<td>-0.1616</td>
<td>0.0133</td>
<td>0.0001</td>
<td>-12.1214b</td>
</tr>
<tr>
<td>Corn $^2$</td>
<td>-0.0102</td>
<td>0.0080</td>
<td>0.2145</td>
<td>-1.2690</td>
</tr>
<tr>
<td>Coffee $^2$</td>
<td>-0.0083</td>
<td>0.0102</td>
<td>0.4210</td>
<td>-0.8162</td>
</tr>
<tr>
<td>Other crops $^2$</td>
<td>-0.0027</td>
<td>0.0017</td>
<td>0.1161</td>
<td>-1.6198</td>
</tr>
<tr>
<td>Corn*Coffee</td>
<td>-0.0260</td>
<td>0.0075</td>
<td>0.0017</td>
<td>-3.4612b</td>
</tr>
<tr>
<td>Corn*Other crops</td>
<td>0.0208</td>
<td>0.0045</td>
<td>0.0001</td>
<td>4.6363b</td>
</tr>
<tr>
<td>Coffee*Other crops</td>
<td>0.0223</td>
<td>0.0035</td>
<td>0.0001</td>
<td>6.2929b</td>
</tr>
<tr>
<td>Time 2</td>
<td>0.0301</td>
<td>0.0532</td>
<td>0.5763</td>
<td>-0.5652</td>
</tr>
<tr>
<td>Time 3</td>
<td>-0.0557</td>
<td>0.0463</td>
<td>0.2383</td>
<td>-1.2041</td>
</tr>
<tr>
<td>Time 4</td>
<td>-0.0855</td>
<td>0.0781</td>
<td>0.2827</td>
<td>-1.0947</td>
</tr>
<tr>
<td>Time2*(TA,IS)</td>
<td>-0.0095</td>
<td>0.0048</td>
<td>0.0573</td>
<td>-1.9800c</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Time2*Machinery</td>
<td>0.0022</td>
<td>0.0025</td>
<td>0.4016</td>
<td>0.8512</td>
</tr>
<tr>
<td>Time2*Fertilizer</td>
<td>0.0022</td>
<td>0.0066</td>
<td>0.7387</td>
<td>0.3368</td>
</tr>
<tr>
<td>Time3*(TA,IS)</td>
<td>-0.0044</td>
<td>0.0038</td>
<td>0.2608</td>
<td>-1.1469</td>
</tr>
<tr>
<td>Time3*Machinery</td>
<td>-0.0208</td>
<td>0.0074</td>
<td>0.0084</td>
<td>-2.8263b</td>
</tr>
<tr>
<td>Time3*Fertilizer</td>
<td>0.0252</td>
<td>0.0049</td>
<td>0.0001</td>
<td>5.1613b</td>
</tr>
<tr>
<td>Time4*(TA,IS)</td>
<td>0.0023</td>
<td>0.0045</td>
<td>0.6122</td>
<td>0.5125</td>
</tr>
<tr>
<td>Time4*Machinery</td>
<td>0.0356</td>
<td>0.0181</td>
<td>0.0593</td>
<td>1.9632b</td>
</tr>
<tr>
<td>Time4*Fertilizer</td>
<td>-0.0322</td>
<td>0.0243</td>
<td>0.1963</td>
<td>-1.3226</td>
</tr>
<tr>
<td>Efficiency</td>
<td>0.1424</td>
<td>0.0169</td>
<td>0.0001</td>
<td>8.4281b</td>
</tr>
<tr>
<td>Cash crops</td>
<td>-0.0760</td>
<td>0.0051</td>
<td>0.0001</td>
<td>-14.9570b</td>
</tr>
<tr>
<td>Altitude</td>
<td>-0.0001</td>
<td>0.0000</td>
<td>0.0013</td>
<td>-3.5584b</td>
</tr>
<tr>
<td>Cash crops*(ATM)</td>
<td>-0.3158</td>
<td>0.0645</td>
<td>0.0001</td>
<td>-4.8979b</td>
</tr>
<tr>
<td>Altitude*(ATM)</td>
<td>-0.0003</td>
<td>0.0000</td>
<td>0.0001</td>
<td>-8.5694b</td>
</tr>
</tbody>
</table>

b Significant at a 5 percent level.
c Significant at a 10 percent level.
The statistic used to test this hypothesis is the one-sided generalized maximum likelihood-ratio test,

$$
\lambda = -2 \left[ \ln \left( \frac{L(H_0)}{L(H_a)} \right) \right]
$$

(5.1)

where \(L(H_0)\) and \(L(H_1)\) are the values of the maximum likelihood function (ML) under the null and alternative hypotheses respectively. Parameter \(\lambda\) is distributed as a chi-square, with the number of degrees of freedom equal to 6. The results of the test confirm that, at a 95 percent significance level the model with technical inefficiencies rather than random shocks explains the efficiency of the production technology observed in the Mexican villages (Table 5.2).

<table>
<thead>
<tr>
<th>Table 5.2 Hypotheses Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>(\gamma = \delta_0 = \delta_d = \delta_h = \delta_{da} = \delta_{ha} = 0)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>(\delta_d = \delta_a = \delta_{da} = \delta_{ha} = 0)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>(\alpha_k = 0 \forall k)</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

The second test determines whether the explanatory variables \(z_\alpha\) introduced to explain the mean technical inefficiencies \(u_\alpha\) enhance the explanatory power of the model. The null hypothesis is that the coefficients by all the introduced factors (except for the intercept) are zero. Once again, the result of the ML ratio test rejects the null hypothesis at a 95 percent significance level.
level (Table 5.2), thus supporting introduction of altitude, share of commercial crops produced and access to markets as explanatory variables.

The last test determines if the technological change is not biased towards any of the inputs in particular. The null hypothesis (also known as non-neutral Hicksian change) is that all the coefficients by interaction terms between inputs and time are zero. This test rejected the null hypothesis at a 95 percent significance level. Thus, the frontier with interactive inputs and time must be estimated.

Overall, the tests emphasize the importance of accounting for technical inefficiencies in order to explain the technological relations in Mexican crop production. They also demonstrate the need for including specific explanatory variables (e.g., access to markets) and biased technical change in the model.

**Economies of Diversification**

The economies of diversification can be computed from the distance function in order to determine existence of complementarity among production factors that may help to increase the output. This measure is of particular interest, as it indicates whether implementing crop diversification practices in the region would result in efficiency benefits to producers.

The cross-output elasticities are in the range of 2 percent (Table 5.3) and show the existence of economies of diversification between other crops and corn, and other crops and coffee. The implication is that for a given input, production of other crops and coffee will generate efficiency benefits through a reduced input share used in production. This result is expected, as coffee allows for mixed crop production (shade-grown coffee), creating a symbiosis with the crops planted (de Graaff, 1986). However, there exists evidence of diseconomies of diversification between coffee and corn. Since both corn and coffee are the basic products for the
poorest producers, this puts limitations on efficiency level that may be achieved by such producers, because no complementarity exists between the two crops. Hence diversification away from the traditional combination of corn/coffee into coffee/other crops (as defined in this study) appears to be the best practice in terms of productivity.


<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>Other crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee</td>
<td>-.0259</td>
<td>.0223</td>
</tr>
<tr>
<td>Other crops</td>
<td>.0208</td>
<td></td>
</tr>
</tbody>
</table>

Technical Efficiency

To find differences in levels of productivity among coffee producing villages in Mexico was one of the main goals of this study. Recall that technical efficiency is a measure that ranges from 0 to 1, with all villages measured against the most technically efficient village of the sample. Higher measures of technical efficiency (closer to 1) mean more productive villages, while lower values (closer to zero) indicate possibility for improvement in the inputs use.

<table>
<thead>
<tr>
<th>Municipio</th>
<th>Seasonal Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>98/99</td>
</tr>
<tr>
<td>(1) Atzalan</td>
<td>0.996</td>
</tr>
<tr>
<td>(2) Chumatlan</td>
<td>0.838</td>
</tr>
<tr>
<td>(3) Coahuitlan</td>
<td>0.866</td>
</tr>
<tr>
<td>(4) Coxquihui</td>
<td>0.902</td>
</tr>
<tr>
<td>(5) Coyutla</td>
<td>0.911</td>
</tr>
<tr>
<td>(6) Filomeno Mata</td>
<td>0.974</td>
</tr>
<tr>
<td>(7) Juchique de Ferrer</td>
<td>0.915</td>
</tr>
<tr>
<td>(8) Mecatlan</td>
<td>0.884</td>
</tr>
<tr>
<td>(9) Yecuatla</td>
<td>0.997</td>
</tr>
<tr>
<td>(10) Zozocolco de Hidalgo</td>
<td>0.830</td>
</tr>
<tr>
<td>(11) Zongolica</td>
<td>0.962</td>
</tr>
<tr>
<td>(12) Omealca</td>
<td>0.999</td>
</tr>
<tr>
<td>(13) Tezonapa</td>
<td>0.810</td>
</tr>
<tr>
<td>(14) Coatepec</td>
<td>1.000</td>
</tr>
<tr>
<td>(15) Huatusco</td>
<td>0.998</td>
</tr>
<tr>
<td>Average</td>
<td>0.925</td>
</tr>
<tr>
<td>Inefficiency min</td>
<td>0.000</td>
</tr>
<tr>
<td>Inefficiency max</td>
<td>0.190</td>
</tr>
</tbody>
</table>
The calculated measures of technical efficiency are shown in table 5.4. Note that these results reflect technical efficiency relative to the best practice used in this sample. During 1998-1999, inefficiencies\textsuperscript{7} ranged from zero (maximum efficiency) to 19.1 percent (least efficient).

During 1998-1999, inefficiencies ranged from zero (maximum efficiency) to 19.1 percent (least efficient). The next period (1999-2000) was characterized by the smallest inefficiency gap between the most and least efficient villages for all four periods considered. The least efficient villages in that period could still decrease their input usage by 13.8 percent. In the last two periods, the inefficiency gap increased again reaching the level of 1998-1999. However, there appears to be no clear pattern in inefficiency changes in the whole sample.

Among the individual villages (Table 5.4), Coatepec (14) and Huatusco (15) are known for their old traditions and good practices in producing high quality coffee. As expected, these villages along with Atzalan (1) rank as the most technically efficient compared with the rest of the sample. These most efficient villages and the most inefficient villages maintain their rankings over the four year study period, i.e. less efficient villages have not improved their situation with respect to the group. This would mean that the level of efficiency of the village at the beginning of the period will determine their relative efficiency at the end.

\textsuperscript{7} Inefficiency is defined as the difference between the maximum efficiency of one and the calculated measure in table 5.4.
Productivity Change

Considering 1998 as a base year, the measures of the technical change calculated according to (3.19) indicate a technological regress during the subsequent years. Table 5.5 shows the results for technical change, efficiency change, and productivity change (3.21). Efficiency increased only during 1999-2000 growing season. For the same period the component corresponding to technical change showed a negative rate of change. This decline in technical change was expected as a result of the disinvestment in the agricultural sector and scarce update of technology by governmental and private sources.

The overall productivity change was constructed from its components (technical change and efficiency change) for the period studied. The results indicate that agricultural productivity
has been decreasing for the coffee-producing villages over the four year period (1998-2001). Technical change is the main factor explaining productivity decrease, although a decrease in efficiency, albeit small, also contributed in the last two years of study (Table 5.5).

### Table 5.5. Productivity Change and its Components for Veracruz Villages, 1998-2001<sup>e</sup>.

<table>
<thead>
<tr>
<th></th>
<th>99-00</th>
<th>00-01</th>
<th>01-02</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Change</td>
<td>-0.040</td>
<td>-0.016</td>
<td>-0.074</td>
</tr>
<tr>
<td>Efficiency Change</td>
<td>0.012</td>
<td>-0.001</td>
<td>-0.006</td>
</tr>
<tr>
<td>Productivity Change</td>
<td>-0.028</td>
<td>-0.017</td>
<td>-0.080</td>
</tr>
</tbody>
</table>

<sup>e</sup> Based on 98-99 as 100.

**Inefficiency Factors**

The explanatory variables included in the model in order to explain mean inefficiency were altitude, the share of commercial crops to total production, and corresponding interaction terms with the dummy variable for access to markets. The estimated coefficients for these variables are presented in table 5.6. The altitude variable reflecting quality coffee growing conditions showed a significant and negative impact on the mean; i.e., expected inefficiency decreases with the altitude. Considering that higher altitude reflects also higher quality of coffee, we can also conclude that higher altitudes mean higher efficiency for producers. Some authors have documented that coffee producers at higher-altitude locations exhibit more commercial-oriented
behavior in comparison with their lower-altitude counterparts, because they know that free market can pay better for their high quality coffee (Vitantonio, 2000). Another important phenomenon that may be captured by the altitude variable is a longer family history of cultivating coffee in villages with better environmental conditions, and hence better methods of production and organization achieved.

Table 5.6 Factors Explaining Efficiency for Veracruz Villages, 1998-2001.

<table>
<thead>
<tr>
<th></th>
<th>Intercept</th>
<th>Altitude</th>
<th>Mix</th>
<th>Access*Mix</th>
<th>Access*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient</td>
<td>.1420</td>
<td>-.0001</td>
<td>-.0760</td>
<td>-.3158</td>
<td>-.0003</td>
</tr>
<tr>
<td>P-value</td>
<td>(.0001)</td>
<td>(.0013)</td>
<td>(.0001)</td>
<td>(.0001)</td>
<td>(.0001)</td>
</tr>
</tbody>
</table>

The interactive term between altitude and access to markets is significant and negative. As expected, the villages with access to markets located at higher altitude are more efficient than villages located at the same altitude but without good access to markets.

The coefficient of the variable representing share of commercial crops in the total production also was found negative and significant. This indicates that the overall efficiency increases as villages produce a higher share of market-oriented crops other than coffee. Therefore a shift towards crops different from the traditional plantations (corn and/or coffee) increases the productivity and is consistent with the found economies of diversification that
showed the existence of complementarity between cultivation of other crops together with either coffee or corn.
CHAPTER 6

SUMMARY, CONCLUSIONS, AND IMPLICATIONS.

Summary
Due to tradition and continuous support given by the government from 1970 through the first half of the 1990s, coffee production became a main part of the economic activities of southern Mexican villages. For three decades market distortions made coffee a preferred product for farmers to secure stable income flow. In recent years, the price of coffee has recorded at a 50-year historical low caused by distortion-free interaction between demand increasing only at 1.5 percent per year and supply increasing at 3 percent per year. The resulting price crisis and inexistent local market for coffee in Mexico have impacted producers. While price fluctuations in commodity markets are common, this is the first time that coffee producers in Mexico and the world have had to deal with a crisis without government or ICO intervention.

Due to the severe economic crisis that impacted coffee producers around the world, the International Coffee Organization proposed two major solutions: diversification and production of high quality coffee. These recommendations reflect the fact that many smallholders have planted coffee as their only cash product, making them more susceptible to market fluctuations, and that coffee produced under optimal conditions has received price premiums compared to the non-differentiated coffee.

Given this market environment, important questions are (1) how the farmers’ production systems have responded to external and internal changes in the coffee market? (2) has their
productivity changed? (3) have producers with better access to markets performed differently than those with less access? and (4) are the ICO recommendations, namely diversification and shift toward higher quality, helping to increase efficiency in production and boost economic growth?

The present work attempted to address the above questions. Specific objectives of the study were to determine the productivity change and its components for coffee as a system, to determine if there exists a relationship between level of market access and gained efficiency, to determine the relationship between increased efficiency and complementarity of coffee production and other cash crops, and finally to determine the impact cash crop production, access to markets, and altitude on overall efficiency.

In order to examine the hypotheses proposed in the first chapter, the production systems of coffee for 15 southern villages in Mexico were analyzed over the 1998–2001 period. The model specification relied on a multi-input, multi-output production function. The main conclusions and implications of the results are presented in the next two sections.

Conclusions

First Hypothesis

The estimated values of productivity change provide evidence of negative trend in productivity in coffee-producing villages during the period studied. What is most important to note is that this loss in productivity is mainly due to the technical change component. Technical regress may be a result of the decrease in inputs provided by the government, such as public research directed to development of new agricultural technologies, technical assistance, and organization and marketing support. However, the decrease in productivity is consistent with
empirical evidence for other developing countries, e.g. Philippines and Botswana, over the last 10 years (Umetsu et al., 2003, Fulginiti,).

Second Hypothesis

Efficiency due to output complementarity is gained with mixed production of coffee and cash crops through a decrease in the share of inputs. The magnitude of efficiency gain was about 2 percent when planting coffee and other crops or corn and other crops. This finding is important, because it provides evidence that diversification towards cash crops along with coffee or corn production is a viable strategy in improving farmers’ efficiency. Thus, the ICO diversification plan for the region could rely on cash crop production as a means to improve efficiency of production technology. Note also that mixed planting of coffee and cash crops results in so-called “shade grown coffee”, which is considered a specialty product and typically commands higher prices over traditional coffee.

Third Hypothesis

The results of the study indicate that coffee farmers that diversify towards market-oriented crops have gained in efficiency. The farmers that are already producing cash crops, especially where production of these crops represents a higher share of total production, are less inefficient than their counterparts.

Fourth Hypothesis

Coffee farmers producing in villages located at higher altitude are more efficient than their counterparts in lower lands. The results suggest that coffee produced in higher-altitude villages is characterized by higher producers’ efficiency, although the efficiency gain is not as high as in producing a mix of crops.
**Fifth Hypothesis**

Better access to market appears to contribute positively to overall efficiency regardless of other factors. In particular, villages that diversified toward cash crops and had access to markets were more efficient than those that produced mixed crops but did not have easy access to markets. Therefore, if diversification towards cash crops is an efficiency-improving alternative for coffee producers, it is not an answer by itself. Rather the producers need appropriate infrastructure channels (e.g., roads to the city, transportation, etc.) to take full advantage of this alternative. In the same way, the efficiency gains associated with production at higher altitudes are further amplified when producers have better access to markets.

**Implications**

Productivity change of coffee-producing villages in Veracruz, Mexico, composed of the change in technical efficiency and technical change, exhibited a negative trend at an average rate of 3 percent per year from 1998 to 2001. Productivity is a measure of economic growth that provides dynamism to local economy through the increase in income and employment, hence stimulating economic development. The observed contraction in productivity thus carries negative effects to the precarious regional economy both through direct consequences, such as loss in agricultural jobs and depressed incomes, as well as indirect ones, such as deficient nutrition and drop in education level. However, this measure has to be considered in a wider framework, as farmers may be shifting to off-farms jobs which are not accounted for in this study.

In the international arena, food marketing is changing rapidly, with an increasing proportion of consumers buying specialty coffee products such as shade-grown and organic coffee: two types of coffee that are typically sold at higher prices in the international markets. This market orientation could open alternatives for the villages studied here, because they may
be able to achieve productivity gains by producing cash crops mixed with coffee or producing coffee at higher altitudes. Policies directed towards increasing mixed production of cash crops and coffee would result in higher the efficiency of producers as well as higher income due to premium price received for organic and/or shade grown coffee.

The results also point at the importance of infrastructure and easy market access for agricultural producers. Policies directed toward improving access to markets in this context would have great impact, because they might mean reduction of inequalities, such as transaction costs, due to better transportation or decreasing role of intermediaries. Access, as measured in this work, reflects availability of roads, vehicles and basic services that seem to give to the villages studied better chances to produce in more efficient ways. Other studies have reported similar results for other developing countries producing different products (Helfand, 2003). Therefore, it seems that a policy directed to improvement of infrastructure does not have to be related to particular crops, but rather create conditions of equality where producers can decide what to produce.

Limitations
The measure of producer efficiency in this study is based on total production, i.e. quality and differentiation of products are not considered. Also, the study would benefit from additional data on off-farm activities and longer data series. Nevertheless, local studies on productivity are not conducted for agricultural production in Veracruz, and the findings obtained in this work are part of an effort that can be extended to contribute to creation of suitable policies focused at a regional level. Collection of data for micro-regions in Mexico is a recent effort, so further opportunities may be exploited as more data become available.
Further Research

The modeling approach developed here can serve as a framework for analysis of agricultural production comparing different coffee producers within Mexico or around the world. Information on types of farm organization, types of coffee, specific cash crops, human capital and value produced can be used in order to find a better measure of efficiency and its determinants. The analysis can also be enriched by using later developments that introduce risk management to the frontier analysis of production process.
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In order to find if there exist economies of scope in the coffee production a multi-output, multi-input distance function was