SPATIAL COMPETITION AND PRICING IN AGRICULTURAL CHEMICAL INDUSTRY:

EMPIRICAL EVIDENCE FROM GEORGIA

by

ROBERT LEE HALL

(Under the direction of Jeffrey H. Dorfman)

ABSTRACT

Little attention has been paid to spatial competition in the agricultural chemical market. This study uses a primary data set to investigate the extent and importance of spatial competition in the major row crop-producing region of Georgia. The distance to closest competitor, number of competitors within a 15-mile radius, number of farms, number of commercial farms, and gross row crop sales are variables included in the study. Price was collected through a survey of agricultural chemical retailers. The results reveal demand shifters are statistically significant, but not economically significant and the spatial variables are insignificant in both respects. These results are generally in agreement with a limited number of other studies that conclude local retailers have little impact on pesticide pricing.

INDEX WORDS: Spatial competition, Pesticide industry, Agricultural inputs, and Imperfect competition

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CHAPTER I

INTRODUCTION, DEFINITIONS, OBJECTIVES, AND ORGANIZATION

Introduction

The U.S. Department of Commerce (2001) estimates the United States farm production expenses for the fertilizer and chemical industry at $18.5 billion dollars in 1999. Insecticides, herbicides, pesticides, and fungicides are all vital inputs and major expenses, $8.8 billion in the U.S. in 1997, in order for farmers to produce and protect their crops. Approximately 600 species of insects, 1,800 species of plants, and numerous species of fungi and nematodes are considered to be serious pests to United States agricultural crops (Klassen and Schwartz, 1985). If these pests were not controlled, serious damage to crops would result, causing a drop in both quality and yield.

Pesticides have been a growing source of crop protection since the post-World War II era, and have contributed to the high productivity of U.S. agriculture (ERS, 2000). The National Academy of Sciences (1995) reveals U.S. farmers began shifting to chemical methods of controlling pests after the successful use of an arsenic compound in Colorado for potato beetles in 1867. The United States Department of Agriculture began a chemical research program in 1881 (Klassen and Schwartz, 1985). However, it wasn't until the 1940's that farmers started widespread adoption of the use of chemicals on crops (MacIntyre, 1987). Since the adoption of pesticides, use has steadily increased over the years, with fluctuations correlated with crop prices.

A study by Knutson & Associates in 1990 described the possible effects of a ban on pesticides. The study found that U.S. farmers would be less competitive in a global market and major exports, such as corn, wheat, and peanuts, would drop by 27%. The study also revealed farmers in warm climates, i.e. the southern United States, would be harmed more because warm weather promotes higher pest populations. In another study, conducted by GRC Economics (1989), which focused on a ban of only fungicides, the authors found that if fungicides were not used in the U.S. production of peanuts production would decrease by 68%. The study also revealed that overall consumer food prices would increase by 13%. Therefore, both farmers and consumers are affected by these inputs.

Definitions

Before going any further it is important define key terms used throughout this thesis. Listed below are these terms as defined in the *Agricultural Resources and Environmental Indicators,* Chapter 4.3 (2000):

> **Pesticides** – any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest, and any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant.
>
> > **Fungicides**—Control plant diseases and molds that either kill plants by invading plant tissues or cause rotting and other damage to the fruit and after it can be harvested
> >
> > **Herbicides**—Control weeds that complete for water, nutrients, and sunlight and reduce crop yields
> >
> > **Insecticides**—Control insects that damage crops. Also include materials used to control mites and nematodes.
> >
> > **Other pesticides**—Include soil fumigants, growth regulators, desiccants, and other materials not otherwise classified.

Objective and Scope of Study

Now with an understanding of how important pesticides are in farming, the history of pesticides, and basic differences of pesticides types, we can focus on the scope and objective of the current research. Consumers, in this case farmers, have two basic decisions to make when purchasing pesticides: where to buy and how much to buy.

The farmers' decision of how much to buy is a function of acreage grown, types of crops, and economic conditions[1] (McEwan and Deen, 1997). Acreage planted and types of crops grown are yearly factors controlled by the farmer. The health of the agricultural economy is a macro environmental factor that lies outside the realm of an individual farmer's control. Once the farmer has determined the acres and crops to be grown he is able to estimate his chemical expenses for the growing season. The makeup of the chemical bundle to be purchased will change throughout the growing season based on pest cycles, weather conditions, and commodity prices. These three factors help makeup the economic thresholds[2] to determine if pesticide applications are economically justified. For example, it would be unjustified to apply a pesticide to a crop if the cost of the application would exceed the benefit obtained. This could be this case in if the crop price was extremely low, pests could not be controlled, or drought had caused excessive crop damage.

Throughout the growing season farmers will make numerous purchases of chemicals. The decision of where to purchase inputs is not, and should not be, straightforward. As any savvy consumer understands, it is important to compare prices and shop around. With lower farm prices across the board for all commodities it is

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[1] Economic conditions are mainly in reference to the economic conditions in agriculture.
[2] Economic threshold is loosely defined as where cost equals benefit of a decision.

extremely important, now more than ever, for farmers to comparison shop for the best price of inputs.

One of the objectives of the present study is to use a primary data set to examine agricultural chemical prices at the retail level as observed by the farmer in the major crop-producing region of Georgia. The relationship between the price, competition, and certain county level attributes will be studied to determine the impact each of these variables on the average retail price of various widely used chemicals. The county level attributes to be examined in the study are the number of farms, the number of large farms, and gross agricultural sales within each county.

In 1999, agricultural chemicals and fertilizer made up 8.6% of all farm production expenses in Georgia (The Georgia County Guide, 2001). This translates into approximately $408 million farmers are spending annually on these inputs in Georgia alone. In the counties this study surveyed, the percentage is much greater than the average Georgia County. The 66 counties included in the survey spent approximately $366 million on fertilizer and agricultural chemicals, or 90% of the statewide fertilizer and agricultural chemical expenses (The Georgia County Guide, 2001).

The majority of pesticide research is concentrated on environmental concerns, health issues, and production/benefit issues. Research into pricing of farm chemicals has not been performed in Georgia and no literature pertaining to the United States could be obtained. Agricultural chemicals play a vital role in the production of both food and fiber in the United States, and agriculture plays an essential role to the economic stability of many Georgia counties. It is important, if not essential, to better understand factors influencing the price of farm chemicals.

There are many factors influencing pesticide prices. A partial list includes: health of the agricultural economy, regulation and standards, marketing and advertising, effectiveness of the product, and safety of the product. These factors have a macro effect on price, meaning most of these factors are included in price whether the pesticide is purchased in California or Georgia. The current study focuses on micro level factors affecting the chemical price, including spatial competition and demand shifting components. The main objectives of the study are the following:

1. Provide a general overview and analysis of the current pesticide industry within the United States
2. Provide a literature review of spatial economic theory, and a review of articles pertaining to the pricing of pesticides
3. To test the hypothesis that spatial competition in the agricultural pesticide market has a significant affect on the price of chemicals.
4. To test the hypothesis that number of farms, number of commercial farms, and gross agricultural sales have a significant affect on price of chemicals.

CHAPTER 2

OVERVIEW OF THE AGRICULTURAL CHEMICAL MARKET

Scope and Depth of the Pesticide Industry

In 1996, ten large chemical manufacturing firms existed internationally and had worldwide sales of $25 billion annually (Clay, 2001). Today, these ten firms have been reduced to six: Bayer Crop Science, Syngenta, Monsanto, DuPont, Dow AgroScience, and BASF. The annual sales of these six companies were $22.70 billion for the year 2000 (Clay, 2001). The consolidation of the firms is moving the industry more into an oligopoly market structure[3]. The consolidation of firms seems to be beneficial to consumers. From the business point of view, most experts agree that the concentration of the firms has been positive for consumers. Chemical input prices have dropped and yields have increased due to the rapid improvements in technology (Clay, 2001). The rapid improvements of technology in the chemical industry can be attributed to increased economies of scale after the consolidation of firms. It is estimated that it requires a cash outlay of between $70 and $100 million dollars to research and develop a new chemical compound for the global market. This creates an obvious incentive to consolidate and gain scale economies.

The improvements in the technology of crops and the increased productivity of chemicals associated with mergers of agrichemical firms are positive for consumers. However, not all events as a result of the recent mergers are beneficial. Leroux, Wortman, and Mathis (2001) state, "The consolidation of the pesticide industry has

[3] Oligopoly market structure will be defined in a later section.

allowed the companies to more thoroughly control prices both through online outlets and through local outlets."

United States' Expenditures on Pesticides

The United States is the largest purchaser and user of pesticides in the world, with 33% of all pesticides sold within the U.S. borders (McEwan and Deen, 1997). The USDA's Farm Production Expenditures report for the 2001 crop estimates the United States' farm production expenses at $197 billion dollars, up 3.9% from the 2000 total. Agricultural chemicals made up 4.4% or $8.6 billion. The average expenditures per farm in 2001 were $91,547 and $3,996, or 4%, was spent on chemicals and chemical application for crops. However, the statistics are much higher for crop farms in the United States. The average crop farm spent $113,425 on production expenditures and agricultural chemicals made up 7%, or $8,170. The Southeast Region, which includes farms in Alabama, Florida, Georgia, and South Carolina, had much lower total farm expenses than the national average. The average total farm production expenses were $72,970, and average chemical expenditures were $3,818 or 5% of total expenses. In Georgia, the farm production expenses totaled $3.13 billion in 2001, and pesticides made up 4.1% or $76.34 million in expenses (NASS, 2001).

Farms in the Southeast Region have lower chemical expenses than the rest of the regions. This could be attributed to several causes. First, farms in the southeast region have a higher percentage of retirement farms[4]. These farms often have a high proportion of farms raising beef, which requires less chemical inputs than most row crops. Second,

[4] Small farms whose operators report they are retired.

the large and very large family farms[5] are concentrated in the central United States. These farms have little beef production and a high proportion of cash grains, which are somewhat chemical and fertilizer intensive. The Southeast region also has a larger number of limited resource farms, which are small farms with sales less than $100,000 and total operator household income of less than $20,000. Limited-resource farm income is often supplemented with off-farm income. Farm make-up and size are generally attributed to the average farm size and average chemical expenses in the Southeast region to be less than the remainder of the country (Hoppe, 2001)

Demand for Pest Control

Studies of the demand for pest control have generally concluded farmers' pest control purchasing decisions are relatively inelastic with respect to product price (Fernandez-Cornjeo and Jans, 1995; McIntosh and Williams, 1992), meaning that faced with higher pesticide prices farmers typically reduce their purchases of pesticides by a smaller proportion than the price increase.

Norgaard (1976) argued farmers also appear to be "irrational" in their pesticide use. He defined irrational behavior to mean the contribution of incremental changes in pesticide use to total revenue are not equal to the incremental effects of the pesticides on costs. Thus, profits will be not be maximized. This irrational behavior is most likely attributed to risk aversion on the part of the farmer. The farmer would rather be "safe than sorry."

Fox and Weersink (1995) define pesticides as a class of inputs called damage control inputs. These types of inputs act indirectly to control the incidence of a damage

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[5] A large family farm has sales between $250,000 and $500,000; a very large family farm has sales over $500,000.

vector. Normal, or conventional, inputs directly affect the output. Damage control inputs are used in a wide variety of circumstances ranging from the security systems in banks to national defense for a country. These inputs are a type of insurance for the producer.

However, damage control inputs have increasing returns up to a specific point where they are no longer effective and additional expenditures would result in no additional benefits. A simple graphical illustration of this is provided in Figure 1.

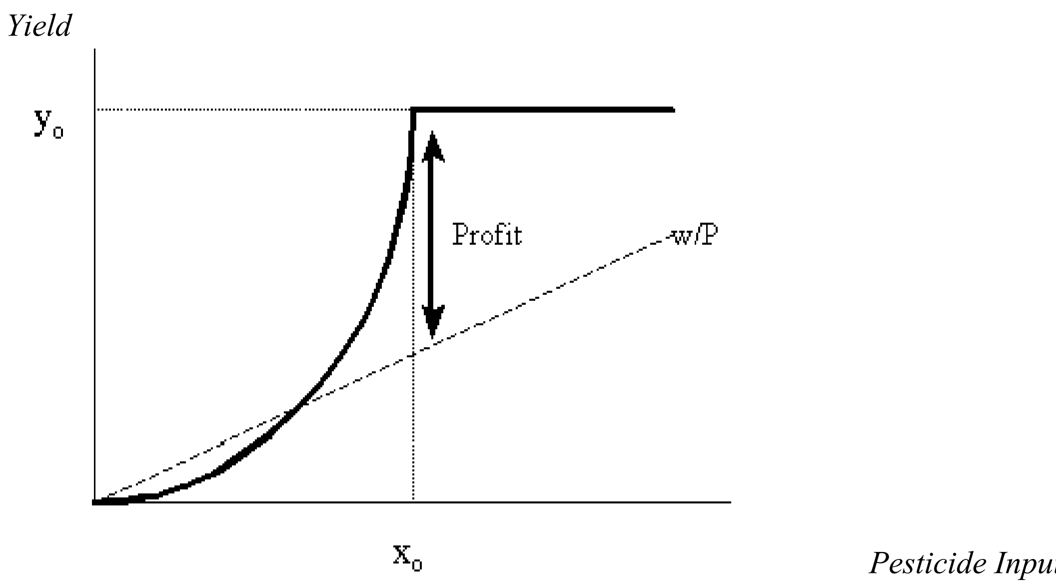

Figure 1: Returns with Damage Control Inputs

Figure 1 shows that as damage control inputs are initially applied, output increases at an increasing rate. This continues until the pest is controlled and further applications are fruitless. X_0 represents the amount of damage control input used, Y_0 represents the yield or benefit, and the w/P line shows the ratio of the price of the pesticide to the price of the commodity. As one can tell from the graph further application of a damage control input past X_0 would be irrational.

Purchasing Factors of Pesticides

The use of individual products varies depending on the needs of the farmer. Different weather patterns, and pest variations from season to season have a dramatic affect on the purchasing decisions farmers make about pesticides. Also effecting the purchasing decision is the farmers' ability to alternate perfect or near-perfect substitutes for chemicals. Small price changes can result in significant changes in the mix of products used as farmers attempt to maximize profits. For example, a farmer may choose between Orthene 75S or Dipel to control an insect problem depending on price of each product. Both products control many of the same pests and the only difference may be in the price. However, even though the pesticide mix may change, the aggregate remains close to the same year-to-year (ERS, 2000).

Purchasing Process

The agricultural chemical market is a high touch industry. A high touch industry is simply an industry requiring large amounts of customer service and customer interaction. Farmers are accustomed to one-on-one, face-to-face transactions whenever making business decisions such as purchasing chemical inputs. Farmers are dependant on retailers to provide the products needed and advice on using the products in the most beneficial way in their area. So much so, that in many cases a farmer relies more on trusted individuals' recommendations than on published production information (Barry, et al., 1998). In many cases, retailers provide customer service representatives to visit farmers, provide advice, and make sure the chemical application process and rates are correct. In other cases, a representative from the chemical manufacturer will provide advice directly to the farmer or supply the retailer with information to pass on the customer. At any rate, customer service plays a vital role in the sales of chemicals.

Some argue that agricultural decisions are fundamentally driven by personal relationships (Moss, 2001). The current study does not take into account the role of customer service plays into chemicals sales. This is done for two reasons: 1) customer service is difficult to accurately measure and 2) customer service is of such vital importance firms would lose business without it. Therefore, we assume all chemical retailers provide adequate customer service to all consumers.

The process of purchasing chemicals is not extremely complex, yet not as simple as buying a gallon of milk at the market. However, the way rural and farming communities operate is still simpler than other areas of more urban commerce. Most chemical retail stores do not deliver, or at least do not deliver free of charge to the farmer. This means the customer, or farmer is responsible for the transportation, or transportation costs, of the product from the store to the desired location. Thus, an f.o.b. pricing scheme is followed. The transportation cost is basically a variable directly correlated with distance. Competition and transportation costs will be discussed in more detail in a later section.

As in any industry, retailers have to meet the needs of the customers. One way the agricultural chemical retailers do this is through establishing a line of credit for farmers, or allowing the farmers to charge items to an account. This is done for two reasons. First, the farmers may not have the cash to pay for the products at the time of purchase. Most chemicals are purchased during the growing season, and it has been a nearly a year since last season's crops have been sold which could cause a cash flow problem. The second reason is convenience. During the time when most chemicals are needed farmers are extremely busy and do not have time to waste. By allowing the chemicals to be charged, the time spent at the store is decreased. Also, it allows farm workers, who are not responsible for payment, to charge to the account.

However, in the world of chemical sales, like most industries, not everyone is equal. Farmers who purchase large quantities of product normally receive a bulk discount. Bulk discounting is a common occurrence in most purchases in all industries. In other words, farmers who purchase large amounts of chemicals throughout the year are likely to pay less than those who purchase smaller quantities. Thus, smaller farmers may be placed at a disadvantage when bargaining for the best prices on chemicals.

Payment Options

Once the chemical purchase has been made the farmer normally has three payment options. The first is to pay at the time of purchase. This method of payment is rare for credit worthy clients. The second is to pay the bill at the end of the month. Paying the bill at the end of the month saves money by not having to pay interest charges on the balance of the account. Most agricultural chemical stores charge an interest expense on balances not paid at the end of each month. The other payment option is to pay the balance at the end of the season, when the crop(s) have been sold. The advantage of this option is it allows farmers to pay when cash flow is available. The downfall is farmers have to pay the balance plus the accrued interest on the account.

Rebates to the Retailer

It is common for manufacturers of chemical products to provide a rebate to the retailer at the end of the season. Most chemical retailers purchase pesticides at a distribution center such as *ChemNut*, Inc. in Albany, Georgia. The retailers pay the specified price of the product within fifteen days of the purchase to the distributor. The retailer in turn charges the farmer the distribution price plus their mark-up. However, included in the price of the product is often the amount of the rebate expected from the manufacturer at the end of the year. The chemical sales representative for each company provides each individual store with amounts of rebates to be given. It is unclear whether every store receives the same amount or whether different stores receive different amounts. It is extremely unlikely that firms would provide this type of financial information for the study; therefore this series of questions was not part of the survey. However, it is important to understand that manufacturers most likely play a vital role in the pricing of pesticides.

The current study does not focus on the distributor price, but the price paid by the farmer at the retail level. There is no question that the manufacturers' price and supplemental actions do have a dramatic affect on the price paid by the farmer. However, this research simply looks at price differences at the retail standpoint across the study region instead of the prices charged from the distribution.

Labeling

Most chemicals are available in most areas, but in many cases pesticides are labeled for different crops in different areas. For example, Temik® is labeled for application to tobacco crops in North Carolina. However, it is not labeled for use on tobacco in Georgia. Labeling for different areas usually only occurs at the state level. Therefore, labeling differences should not have a major impact on the results of the current study.

Intellectual Property

Many pesticides are available for patent protection for 20 years. The Patent and Trademark Office of the U.S. government grants patent protection. A patent basically excludes others from using or selling an invention for up to 20 years.

Patent protection does provide a limited amount of market power to manufacturers, but monopoly power is not normally gained. This is because for most pesticide markets a number of similar products are sold. A patent only ensures identical products cannot be sold.

Pesticide Sales on the Internet

Farmers in the United States are well in-touch with the technology revolution. Farmers are also some the users of this technology. A survey conducted by Agweb.com in 2000, found 85% of farmers use cell phones, 64% use a satellite information system, 49% use yield monitors, and 22% use GPS systems. The increase in the use of technology is not a luxury for farmers, but it is a necessity for survival to most farms. With depressed farm prices and unfavorable weather conditions over the last five years, farmers are forced to increase yield and simultaneously reduce costs.

The adoption of computers and the Internet are growing at a steady rate. Private and public policy analysts currently project that more than half of all Americans use the Internet. The adoption of technology is growing among the farming community as well as the rest of the rural areas of the United States. According the National Agricultural Statistics Service (2001) 55 % of farms have access to a computer in 2001, and 43 % of all farms have Internet access. For farms with sales of $100,000 or more 69% own a computer, 55% are using their computer for farm business, and 58% use the Internet.

As with most other industries, the agricultural retail market experienced a surge in companies offering products online. From 1998 to early 2001 online retailing sites began to offer agricultural chemicals, fertilizers, and seeds to farmers. These sites provided an alternative to local retail outlets, however the life of most of these sites was short-lived. Currently, there are only two retailers, XSAg.com and Directag.com, for which prices could be obtained to be included in the survey. However, the prices, in most cases, were more than 20% higher than the average local retailer included in the survey. Also, XSAg.com is a brokerage service. It simply puts buyers and sellers together so they can make a transaction. There are some drawbacks to making an online purchase. For instance, the chemical(s) is not available for inspection. Not being able to inspect the product has obvious drawbacks. The main two are the purchaser does not know the quality or the age of the chemical. Farmers have much hesitation when making sight-unseen purchases.

The online chemical retailers may soon have a positive and successful place in the chemical market. However, at this time they only have a marginal effect, at best, on chemical prices and they are not included in the analysis.

CHAPTER 3

THEORETICAL AND EMPIRICAL ANALYSIS OF LITERATURE: SPATIAL ECONOMICS, DEMANDING SHIFTING ATTRIBUTES IN A MARKET AREA, AND PRICING IN THE PESTICIDE INDUSTRY

Classical Pricing for Perfect Competition

The basic concept of pricing in the neo-classical model is that firms are in perfect competition. That is, firms are price takers in the market where their product is sold. Under this perfectly competitive market structure firms have no incentive to alter prices for products. The firm simply takes the price of the market equilibrium, where supply equals demand. But in order for this situation to exist there are certain assumptions that must be true. Classical assumptions are as follows:

1. Firms sell a standardized product or homogenous product.
2. Factors of production are perfectly mobile in the long run. Firms can enter and exit an industry without extraordinary costs.
3. Firms have no market power. That is, any one firm's production will have a minuscule effect on overall price.
4. Both firms and consumers have perfect information. Consumers know substitutes and the price of the substitutes at any given time.

Given these assumptions there can be only one price for a commodity. This is termed the Law of One Price, and if the product were offered at different prices, buyers would simply purchase the commodity at the lowest price.

However, no market fulfills all the assumptions of the neo-classical model, and this makes perfect competition an improbable feat. Most markets are considered to be in imperfect competition. Imperfect competition is a broad term used to describe flawed market structures. Nevertheless, imperfect competition has one distinguishing feature, regardless of type, firms have some level of power to set price.

Many forms of imperfect competition exist and it is important to understand each type for this research. The region studied has many different market areas and within each of these is what could be considered one of the following forms of imperfect competition: duopoly, oligopoly, and monopoly. A general overview of each of these types of competition follows.

A duopoly occurs when there are only two firms serving a given market area. One model of a duopoly behavior is attributed to Cournot, and states each firm takes the other's output as given. Once the other's firm output is determined, the second firm chooses output by equating marginal revenue to marginal cost on the share of the market not taken by the other firm. However, a second duopoly model by Stackelburg states firms in a duopoly are either a leader or follower, in the sense of choosing their outputs. In the four possible scenarios of the Stackelburg model firms are either leader or followers. Equilibrium is not as easily obtained with the Stackelburg model as the Cournot model.

The Bertrand model has many of the same characteristics of the Cournot model. However, in the Bertrand model assumes that the other firms will not ever change price. Therefore, in this situation as long as price exceeds marginal costs firms will undercut rivals by offering a slightly lower price to increase sales. Bertrand firms will undercut each other's price until price falls to marginal cost, the same as under competition.

An oligopoly is a situation where a few firms exist in a given market area. Models of an oligopoly lie between models of duopoly and models of pure competition. One theory of an oligopoly is that there is a kink in the demand curve in an oligopolistic industry. Firms who chose to cut prices in order to increase sales find their rivals quickly cutting prices as well. As a result, a firm that cuts prices expecting its rivals to not respond will not see its sales expand as much as anticipated. Each firm in an oligopoly is therefore thought to face a less elastic demand curve with respect to decreases in prices. On the other hand, if a firm unilaterally raises prices, the other firms will not raise prices. By not raising prices firms, a firm will seek to expand their sales by having lower prices than rival firms. So, the firm faces an elastic response to price increases.

It is the general consensus of analysts that the agricultural chemical manufacturer market is an oligopoly. With only six major firms producing chemicals, it is believed that the firms have a considerable amount of influence on local price in all markets. That is, these firms are able to control the price which the local agricultural chemical retailer charges. It is also reported the consolidation of the industry has made each firm more efficient through increased economies of scale. This is passed along to consumers in the form of improved and more rapid innovations of technology (Clay, 2001).

A monopolist is a single firm that is the only seller of a product in a given market. A monopolistic firm is the exact opposite of a perfectly competitive firm. A monopoly is a price maker, whereas in perfect competition firms are price takers. The agricultural chemical industry is not generally considered a monopoly. It is true that each manufacturer sells specific chemical compounds, which are normally branded. However, consumers are somewhat able to substitute chemicals with similar characteristics. For example, a farmer could choose to apply, RoundUp® Ultramax, a herbicide, to control weeds or he could choose to apply another herbicide such as Glyfos® X-tra.

Classical microeconomic theory indicates that a firm may price discriminate[6] provided (1) the firm controls the means by which its overall market is separated into a number of distinct submarkets and (2) elasticity of demand varies between submarkets. Markets are naturally separable, whether based on distance, storage, waiting time, product variety, volume, and season. Condition two is easiest thought about in a spatial setting, distance costs have the effect of generating varying demand elasticities between spatially separated markets (Eaton and Lipsey, 1977).

Although, it is generally considered chemical makers are not monopolies, empirical research does show they do discriminate between markets. This type of price-discrimination is referred to as third-degree price discrimination. Third-degree price discrimination allows sellers who face two different demand curves to set to different prices in the market areas to maximize profits. An example of this is an international study by the Price Surveillance Authority (1993). The study shows clear differences in agricultural chemical prices despite limited, if any, trade barriers.

Figure 2, below, shows substantial differences in prices across countries, different market areas, for the same products. The reason for the differences is countries are largely insulated despite the fact free trade may exist. The current study believes price differentials between market areas are important, at any level no matter how far spatially separated the markets.

[6] Price discrimination is defined by Philps (1983) as implying that two varieties of a commodity are sold (by the same seller) to two different buyers at different net prices, the net price being the price (paid by the buyer) corrected for the cost associated with the product differentiation.

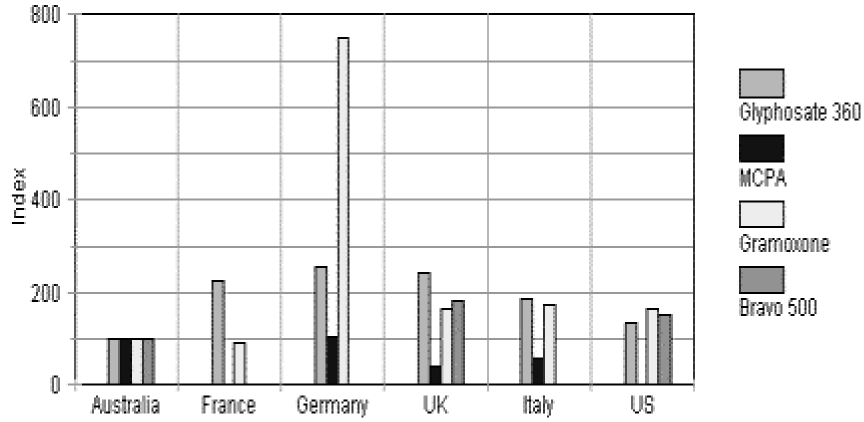

Figure 2: Overseas Price Index Comparison Source: Price Surveillance Authority, 1993

Greenhut, Norman, and Hung (1987) state an important characteristic of an otherwise homogenous product is the location at which it was purchased. Transporting a commodity from one location to another is one form of product differentiation. The location of the purchase does lead to the possibility of discrimination between spatially separated consumers and is termed spatially price discrimination.

This study compares certain county level attributes and competition variables to price. The county level attributes chosen for the study are the number of farms, the number of farms with over $250,000 in sales value, and gross row crop sales for the county. The competition variables used in the research are the distance to the closest competitor (in road mileage) and number of competitors within a fifteen-mile Euclidean radius.

Introduction of Space

The most natural criterion for the separation of consumers and individual consumer markets is a spatial criterion. Households, farms, and businesses exist, purchase and consume in a spatial environment. The products purchased by consumers are manufactured at one location and then distributed to various and numerous markets. When one includes factors such as transportation costs and general frictions of distance such as loss of information and inconvenience, markets are somewhat more clearly understood as separable by means of spatial environment.

Capozza and Van Order (1978) state two essential distinguishing features of spatial competition: transportation costs and downward sloping average costs curves over some range. Transportation costs have to exist or a firm 500 miles away or in another country would be a real competitor to the neighborhood store. Secondly, average costs curves have to be negatively sloped at some point or there would no advantage to concentrating production. The negative slope could come from either fixed costs of production or from economies of scale.

Hotelling first focused on the location of the firm in 1929 in his article entitled, “Stability in Competition.” In his article, Hotelling suggested that consumers do not always buy from the least expensive supplier because firms are differentiated by their locations or product characteristics. Hotelling describes the disutility of travel to make a purchase as different from simply a disparity of transportation costs. Thus, consumers at different locations pay different prices for the same good.

Hotelling’s initial model was extremely simple. It assumed perfectly inelastic demand and a uniform distribution over space. Hotelling’s theory found equilibrium when only two firms, or duopoly, exists. His theory placed the two firms “back-to-back,” or right next-door, to each other in order to split the market. Hotelling’s approach to business location decisions puts the competitors back to back by leapfrogging over one another until the two firms are in the center of the market.

Two basic, yet opposing, forces acting upon decisions to be made when choosing firm location: to cluster with competing firms or to disperse from them. The first force leads firms to locate near competitors in an attempt to capture, or steal, more customers. Pinske and Slade (1998) termed this effect the *market share effect*. Working against the *market share effect* is the *market power effect.* The *market power effect* relies on the theory that reduced spatial competition leads to overall decreased competition and increased sales. Basically, firms locate further away from competition in order to capture consumers within a specific area. Thus, the theory of the *market power effect* is for firms to locate further from rivals. Borenstein and Netz (1999) found in a review of empirical literature that the *market share effect* dominates over *market power effect.* That is, firms tend to cluster.

Netz and Taylor (2002) found in a study of Los Angeles gasoline stations that the stations tend to spatially differentiate as competition increases. The researchers believe since gas stations have to post prices and have a homogeneous product, the effects of price competition would tend to be strong. As a result, the *market power effect* is stronger than the *market share effect* in gasoline stations in the Los Angeles. In other words, gas stations would tend to locate away from competitors than locate in a cluster of competing firms.

The present study has two measures of competition in a spatial setting: distance to the nearest competitor and number of competitors within a 15-mile Euclidean distance. The distance to the nearest competitor is not a Euclidean distance, but rather a driving, or road distance, between firms. The measure of driving distance captures actual driving between competitors and should be directly correlated with driving time between firms. This is a more accurate measure to actually determine if two firms are substitutes. In the current study of the participating retail outlets the average distance between competitors is only 5.83 miles. The longest distance between competitors is 18.7 and the shortest distance is 0.3 miles.

The second measure of competition is the number of competitors within a fifteen-mile radius of a firm. This measure provides the number of possible alternatives to a particular firm. The fifteen-mile barrier was chosen because products are bulky and transportation costs may be excessive over fifteen miles.

Classical economic theory indicates prices under competition will be lower than prices under a monopolistic situation. In other words, competition forces prices to the lowest level for the consumer. However, research by Greenhut (1956) and Greenhut, Hwang, and Ohta (1975) indicate some forms of spatial competition will generate a higher price than that charged by a spatial monopolist. A spatial monopolist is a firm, which controls price within a market boundary. A market boundary is basically an area where it is cheaper to purchase from the spatial monopolist than pay transportation costs to purchase the chemical elsewhere. Also affecting price is how a firm in spatial competition will react to other firms' changes in price. Capozza and Van Order (1978) state the outcome of the competitive process, both in terms of impact on prices and changes in the economic environment, depends on the conjectural variations held by a firm regarding reaction of its rivals.

The three conjectural variations considered in the analysis of spatial economic theory according to Greenhut, Norman, and Hung (1987) are as follows:

1. Löschian competition: firms presume rivals will react identically to any proposed price change.
2. Hotelling-Smithies (H-S) competition: firms presume rivals will not react to any proposed price change.
3. Greenhut-Ohta (G-O) competition: the firm anticipates its price on the market boundary to be constrained to a known, fixed value.

The Hotelling-Smithies assumption is equivalent to the Bertrand-Nash assumption in the traditional, non-spatial analysis of an oligopoly. The H-S competition theory results in the fact that market prices could be higher or lower, and G-O competition theory leads to the lowest of the competitive prices. The Hotelling-Smithies and Greenhut-Ohta lead to the following theoretical predictions:

1. As transport costs and/or fixed costs approach zero, nonspatial perfect competition results, and the firm's price approaches marginal costs.
2. Increases in fixed costs, marginal costs, and transport cost all lead to the classical-theory result of an increase in price.
3. As more firms enter the industry or market, the increased competition lowers price.
4. Price falls in the long run as population increases.

The Hotelling-Smithies conjecture assumes rivals will not alter price regardless of actions made by the firm. The H-S design operates under a more elastic overall demand than the Löschian approach. Firms believe that with price structures of competitors remaining constant, a lower price at their firm will expand their market area. This leads to the assumption that market areas are malleable and conditional upon the price elasticities of demand in conjunction with the related difference in price. Since each firm assumes the prices of competitors are fixed it expects to capture a portion of the competitor's market area.

The Greenhut-Ohta (GO) spatial competition model regards neither the firm's market area nor the rival price as fixed. According to Greenhut and Ohta (1975) and Ohta (1980) firms treat their market area and price as highly variable. The GO model assumes that each firm selects a pricing policy to maximize profits subject to a given price constraint at the edge of its market area and is the underlying and equilibrating force in the model (Fik, 1988).

However, the assumptions for Löschian competition lead to a contradiction of the expected outcome of the nonspatial competitive theory. The theoretical predictions for Löschian competition are as follows:

1. As transport costs and/or fixed costs approach zero, price will approach the nonspatial monopoly price.
2. As fixed costs and transport costs rise, price falls, whereas an increase in marginal costs leads to ambiguous results.
3. As firms enter and thus competition increases, prices increases.
4. Price increases as population density, or consumers, increases.

If the assumptions of the Löschian behavior are accepted then firms believe rival firms will not allow their market area to be altered. Thus, changes in prices will be matched exactly and immediately with zero lag in response time. In the short run, Löschian behavior will result in the highest profits for competitors by establishing a price as if it were a monopolist within the market area (Fik, 1988). However, these profits are soon depressed by the entry of new competitors.

Capozza and Van Order (1978) argued the spatial firm typically would not expect rival firms to react to its actions, because each firm constitutes only a small proportion of the total competition in the market. However, in the case of agricultural chemical retailers, this may not be the case. With approximately 200 firms in the area studied, in many cases only a few firms are in any given market. Thus, firms will have to react to another's change in price or lose sales.

Empirical Research in Spatial Studies

In 1988, Timothy Fik studied spatial competition in food markets or supermarkets. He believed that price competition in the retail food markets is highly dependent on the location and/or the distance to rival firms. He also studied the price differences not related to space: the socioeconomic attributes of the areas studied. His results concluded a solid link between price, space and the intensity of price reaction as a decreasing function of distance.

Durham, Sexton, and Ho Song (1996) examined the role of spatial pricing in the allocation of tomatoes from farms to processing facilities across the state of California. The aim of the study was to determine if the tomato farmers were shipping the product to the most profitable processing facilities. The results indicated farmers were hauling the tomatoes an extra 10 miles per trip to the processing plant. This misallocation was estimated to cost an extra $7.41 million dollars in transportation costs. However, overall the industry's profit maximizing and actual estimations of profit only differed by 1.9%.

Spatial competition encompasses nearly every industry. The healthcare industry is a prime example where competition does not lead to lower costs. According to the "medical arms race," or "MAR" theory, hospitals compete by providing too many high-tech medical services. The duplication of these capital-intensive services raises the costs of care. Therefore, a direct implication of hospital competition is a negative impact on consumers (Dranove, Shanely, and Simon, 1992).

Research Examining Pesticide Prices

There is an extremely limited about of research on the pricing of chemicals. However, in 1997, McEwan and Deen examined pesticide pricing in the Canadian pesticide market in a study entitled, "A Review of Agricultural Pesticide Pricing and Availability in Canada." The researchers state it is the manufacturers that decide on how to best position the pesticide in the market place and the pricing of the product is influenced only marginally by the costs of production, rather it is based on what the product brings to the target market. The challenge for the manufacturers is then to determine the value the product brings to a market compared to similar chemicals sold in the same market area.

The article also states that competition at the distributor level and retail level only has a modest impact on product pricing at the respective level and price is set using a cost plus basis platform. However, the price impact in Canada at the retail level not controlled by the manufacturer is termed a function of 1) the ability of retailers and distributors to take advantage of manufacturer programs and 2) the level of competition within a specific trading region or market area. However, the article emphasizes the impact to the consumer of the pesticide product is only marginal.

These findings are important to the research in the current study because the level of competition is a factor in pricing pesticides at the retail level, if only at a marginal level. The level of competition is measured in the current study by incorporating the number of firms in a given market area.

Demand Shifting Variables

The section above concerned space and competition variables involved in the study. These two variables mainly focused on the supply of the product within a market area. The county level attributes, or demand shifters, discussed in this section will mainly focus on the demand of the product in a market area.

Classical economic theory suggests more demand in a market area should result in a higher price. There are a whole array of factors that influence how much of a product will be demanded in a specific market area: the average level of income, the size of the population, the prices and availability of related goods, tastes and preferences, other special influences. These are all factors that either shift in or shift out the demand curve for a given product.

The demand-shifting characteristics examined in this study will mainly focus on the size of the population in a given area and the annual sales of crops. This will be measured by the number of farms in a county and the average gross row-crop sales in a county. The number of farms will be measured by two separate variables: the total number of farms and the number of commercial farms. These two variables were chosen to see if the size of the farms made a significant difference in the price paid of the chemical bundle.

The number of farms and the number of commercial farms are two very different pieces of information and could lead to different effects on price. A farm is defined by the USDA for reporting purposes as “any place that $1,000 or more of agricultural products have been produced and sold, or normally would have been sold during the year.” The total number of farms includes many farms that are not purchasing many pesticide products. However, commercial farms, $200,000 or more in sales, in the study region should purchase a large quantity of pesticide products. These commercial farms have a sole purpose of turning a profit. Smaller farms, or pleasure farms, most likely are not as focused on turning a profit. However, both are measured to better understand how each effects price.

Depending on whether one follows Hotelling-Smithies or Löschian price conjectures, population has either a positive or negative affect on price. Under the Hotelling-Smithies conjecture, price will fall in the long run as population (demand) increases. That is, the higher the consuming population in a given area the lower the price. On the other hand, under the Löschian competition assumptions the effect is the opposite: price increases as population density increases.

The gross farm sales variable included in the survey is intended to proxy total demand for agricultural chemicals. The counties in the survey are major row crop producing counties and it is assumed most of the crops produced in this area are pesticide intensive crops. Row crop sales, excluding animals, were obtained through The Farm Gate Report[7]. It is believed that the gross agricultural sales could provide a measure of the chemical sales in each of these counties. The rationale here is that row crop sales are correlated with the sale of agricultural chemicals. Under classical economic theory, larger chemical sales would tend to lead to an increase in price. However, the opposite could be true: more sales in an area may lead to a decrease in price. The increased sales could allow retailers to pass along savings gained from bulk discounts and greater economies of scale.

[7] The Farm Gate Report is publication of the Center of the Agribusiness & Economic Development. The report relies on input from county extension agents for data collection.

CHAPTER 4

DATA COLLECTION AND THE MODEL

Data Collection for Empirical Testing

The data used for this thesis were collected through a survey entitled, "Competition in the Georgia Agricultural Chemical Market." The Georgia Department of Agriculture's list of restricted use pesticide dealers was a starting point for possible participants. The goal was to obtain a list of all dealers, who sell chemicals to farmers. Sixty-six counties in southern Georgia were chosen as the study area, designed to capture the major row crop producing area of the state. Of the sixty-six counties involved, fifty-eight of the counties had at least one restricted use dealer that sold chemicals for use on crops. The eight counties that did not have a restricted use pesticide dealer either were highly populated (such as Houston County) or were in areas where row crop production was low (such as Charlton County).

The RUP, restricted use pesticide, dealers were contacted via telephone and asked for two pieces of information. The first question was does your firm sell pesticides for use on farms. If the firm answered 'yes' then the firm was asked for their fax number. If the answer was 'no' then they were eliminated from the list of potential survey participants. Since the firms did not sell chemicals that were used by farms, it was assumed the firm either sold pesticides for home pest control or utilized pesticides not related to farming.

Once the fax number was obtained the next step was to send a fax asking for the firm to provide the retail price paid by the average farmer for twelve highly used chemicals. The survey was three pages in length and provided the necessary legal statements set forth by the Human Subjects Office at the University of Georgia. The survey is located in Appendix A. Of the 204 potential survey participants 65 responded. Not all the responses provided all the prices for all the chemicals. However, overall there were 552 prices responses from the 65 responding participants.

Figure 3, below, shows the counties selected for the survey. As mentioned earlier there are sixty-six counties involved. The map shows selected Farm Gate Value[8] for each county involved, and different colors represents differences in farm gate value in the counties. The research involves only pesticides; therefore the calculated farm value only includes crops benefited by these products. The 2001 Farm Gate Value Report used was a summation of the following values:

1. Row and Forage Crop Production
2. Fruit and Nut Production
3. Vegetable Production
4. Ornamental Horticulture Production
5. Forestry Production

In the counties below, there are 204 agricultural chemical retailers. The major pesticide market in this area is corn, cotton, peanuts, tobacco, vegetable crops, and ornamental horticulture crops. To be able to serve these markets, dealers must be licensed by the state of Georgia to sell Restricted Use Pesticides, or RUPs. However, not every county has at least one RUP. There are eight counties without a RUP licensed pesticide dealer that sell farm related products. These are Charlton, Clinch, Dodge,

[8] The 2001 Georgia Farm Gate Report is a publication of the Center for Agribusiness & Economic Development, College of Agriculture and Environmental Sciences, University of Georgia. The report relies exclusively on the Extension Service to provide production information for Georgia Counties.

Houston, Lanier, Evans, Montgomery, and Treutlen counties. These counties are in the lower income sections of Farm Gate value for the selected counties.

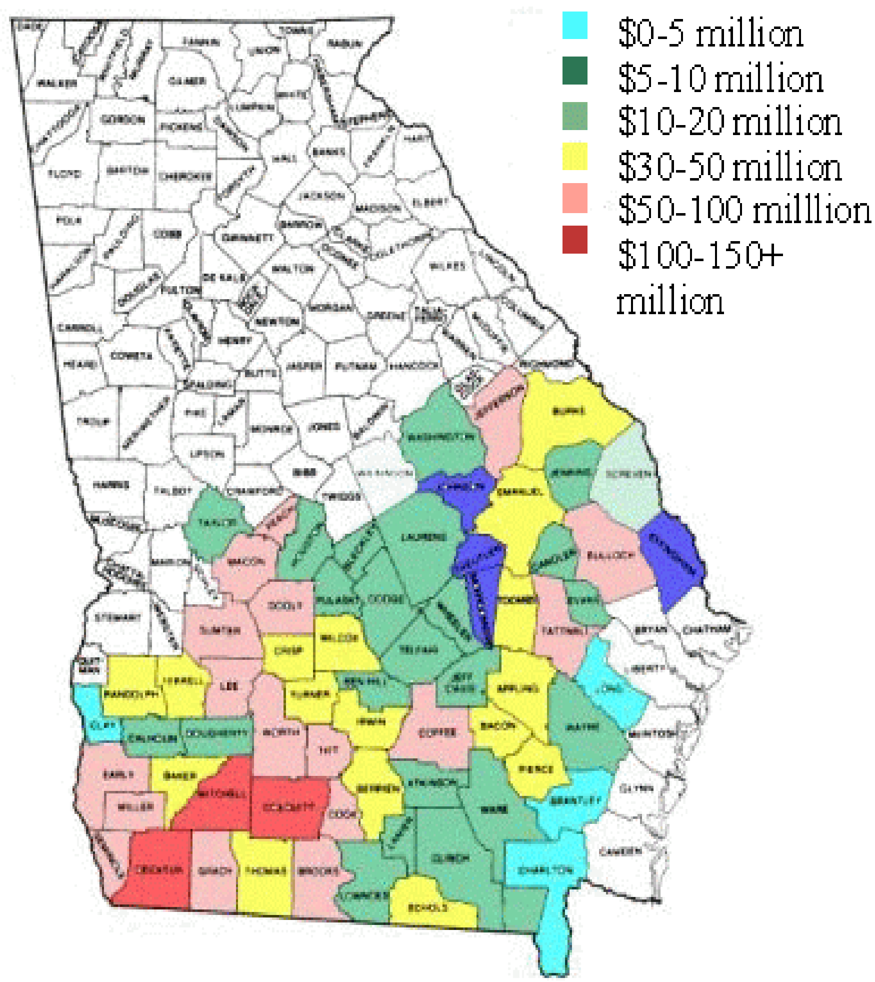

Figure 3: County Surveyed and Gross Row Crop Sales

The counties included in the survey vary widely in size, population of farms, and gross agricultural sales. Because of these factors it was determined the two best measures of competition would be to obtain the nearest competitor in road distance and to obtain the number of competitors within a 15-mile Euclidean distance. To achieve this information firms were mapped using Microsoft Map Quest. The addresses of firms were obtained in the original RUP list from the Georgia Department of Agriculture.

The next step in the data collection process was to collect empirical data from various sources. The number of commercial farms, or farms with $200,000 or more in sales, in each county was obtained through the USDA's 1997 Census of Agriculture, Table 6: Farms, Land in Farms, and Value of Land and Buildings, and Land Use: 1997 and 1992. The final variable was the gross agricultural row crop sales as defined earlier in each of the counties in the survey region. This information was interpolated from data in 2001 Farm Gate publication by the Center for Agribusiness and Economic Development.

The survey attempted to obtain prices for the following pesticides listed below. All the chemicals are widely used pesticides, herbicides, and fungicides used on numerous and various crops throughout the South Georgia area.

Temik®

Temik® is a restricted use pesticide for the control of insects, mites and nematodes. Aventis CS is the manufacturer of this product, which has a generic, or common, name of Aldicarb. Temik® is used on peanuts, cotton, soybeans, and tobacco[9] at planting to control a variety of pests in the surveyed region.

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[9] Temik® is not labeled for tobacco use in Georgia. However, it is widely used on the crop according to many retailers.

Round-Up® UltraMax

Round-Up® UltraMax is a popular herbicide that is used on a variety of crops in the survey area. The generic name is Glyphosphate, and has many competitors. The introduction of genetically modified crops, such as Round-Up ready cotton has greatly increased the demand of this product. Round-Up® Ultramax is a product of the Monsanto, and in sold in three different ways: 2.5-gallon containers, 30 gallon drums, and in bulk. The survey included price questions for the 2.5-gallon containers and in bulk.

Glyfos® X-TRA

Glyfos® X-TRA is a popular generic herbicide, Glyphosphate, that is direct competition with Round-Up® Ultramax. It is used on the same crops and sold in the same forms: 2.5-gallon containers, 30-gallon drums, and bulk. Price was collected on 2.5-gallon containers and in bulk.

Prowl® 3.3 EC

Prowl® 3.3 EC is a herbicide used on cotton, fruit & nut crops, peanuts, soybeans, and a variety of vegetable crops. The generic name is pendimethalin, and it is manufactured by the BASF Company. Prowl® 3.3 EC is sold in 2.5-gallon containers.

Trilin®

Trilin® is a selective herbicide for the pre-emergence of annual grasses and broadleaf weeds. Trilin® is used on a variety of crops including vegetables, soybeans, cotton, and peanuts. Trilin® is a product of the Griffin Corporation and is sold in 2.5-gallon containers.

Trifluralin HF

Trifluralin HF is a product of the UAP company and is a basically the same product as Trilin®. Again, the chemical is used on the same crops as Trilin® and is sold in 2.5-gallon containers.

Orthene® 75 S

Orthene® 75 S is a water-soluble insecticide powder manufactured by the Valent Corporation. Orhtene 75 S is composed of 75% of the active ingredient, Acephate. Orhtene 75 S is used on many crops in the survey region including vegetables, cotton, tobacco, and peanuts.

Orthene® 90 S

Orthene® 90 S is a stronger version of Orthene® 75 S, and is made up of 90% Acephate. Both Orthene® 75 S and 90 S are sold by the pound in a variety of packing. The surveyed packing was a 10-lb water-soluble bag.

Bravo® 720

Bravo® 720 is an agricultural fungicide used mainly on vegetable and peanut crops in the surveyed region. The generic name is Chlorothalonil. Bravo® 720 is a product of ISK Biosciences Corporation and is sold in 2.5-gallon containers.

Chlorothalonil

Chlorothalonil is a generic name for Bravo 720 and is manufactured by a variety of chemical companies. It is also sold in 2.5-gallon containers and is used on the same crops as Bravo® 720.

Listed below, in table 1, are the number of responses, number of county observations, maximum chemical price, minimum chemical price, and the average chemical price. As the chart reveals Temik® was the most widely observed chemical with 64 observations and Prowl® with 63 observations was the second most widely observed chemical. This may be because of the flexibility of these two chemicals to be applied to numerous crops. The least observed chemical was Chorothalonil. Chlorothalonil is a generic substitute for Bravo® 720. The low number of observations may be a sign ISK Biosciences, the maker of Bravo® the main manufacturer of Chlorothalonil, to successfully market its product over the generic Chlorothalonil brands.

Table 1: Chemical Price Response Summary

Chemical	*Count*	*County*[11]	*Max ($)*	*Min ($)*	*Mean ($)*	*STD($)*
Temik®	64	36	3.49	2.95	3.09	0.11
Round-Up®(2.5)	57	32	55	33.35	45.64	4.08
Round-Up®(bulk)	48	29	46.90	37.40	40.11	2.12
Glyfos® X-TRA (2.5)	44	30	42	19	27.95	5.98
Glyfos® X-TRA(bulk)	32	24	35.25	18.5	23.39	4.31
Prowl® 3.3 EC	63	36	34	13	18.84	2.72
Orthene®75S	40	29	17	7.5	10.39	1.51
Orhtene®90S	53	34	12	7.5	9.29	0.76
Bravo® 720	42	29	55	35	39.50	3.72
Chlorothalonil	29	23	32	55	37.75	4.35
Trilin®	27	19	21	10.65	15.96	2.23
Trifluralin HF	52	32	22.5	8.95	15.29	2.06

[10] Refers to total number of observation
[11] Refers to total number of counties in which observations were obtained

The Model

The Economics of Imperfect Competition by Greenhut, Norman, and Hung (1987) develops a general model of basic spatial competition. This section shows how these authors' develops their model. The basic assumptions for their model are as follows:

1. Each producer is located at a point on an unbounded line market.
2. All producers produce a homogenous product
3. Producers are local monopolists. When firms are in competition, there is no market overlap; consumers buy from the firm offering the lowest price.
4. Consumers are continuously distributed over the market at uniform density D.
5. Individual demand functions are identical for all consumers and have negative slopes in the relevant domain.
6. The freight rate is linearly proportional to distance and quantity transported.

The general functional form gives individual demand:

$$q(r) = f(p(r)) \quad (f' < 0)$$

And the price under the under the f.o.b. mill pricing policy:

$$p(r) = m + tr$$

The full price (the delivered price) to a buyer located r distance units from the seller is made up of the mill price, *m*, plus the freight cost, *tr*, where *t* is a constant freight rate and *r* is the number of distance units from the seller to buyer.

With an understanding of the importance of spatial competitors and demand shifting factors, the following model was built:

$$\log(P_{ij}) = B_i + B_2(logDC_j) + B_3(logNC15_j) + B_4(logSF_k)$$
$$+ B_5(logNF_{200}) + B_6(\log NF_k) + \varepsilon_{ij}$$

Where: i = chemical, j = store, and k = county

P_{ij} = price of chemical *i* and firm *j*

B_i = intercept of chemical *i*

DC_j = distance to the closet competitor

$NC15_j$ = number of competitors within 15 mile radius

SF_k = Gross sales of row and forage crop production, fruit & nut production, vegetable production, ornamental horticulture production, forestry production

$NF200_k$ = Number of farm with over $200,000 in sales

NF_k = Number of total farms

ε_{ij} = Error term

CHAPTER 5

EMPIRICAL RESULTS AND CONCLUSION

In this chapter the econometric techniques used for estimating the parameters of model in the preceding chapter are reviewed. Econometrics is basically the application of statistical and mathematical methods to the analysis of economic data with the purpose of supporting or refuting economic theory. The theory being tested in this study is the spatial and demand shifting factors that affect the prices of agricultural chemical at the retail level. An econometric analysis was done to determine the importance of each variable on price. The model is shown again below.

$$\log(P_{ij}) = B_i + B_2(logDC_j) + B_3(logNC15_j) + B_4(logSF_k) + B_5(logNF_{200}) + B_6(\log NF_k) + \varepsilon_{ij}$$

Where: i = chemical, j = store, and k = county

P_{ij} = price of chemical *i* and firm *j*

B_i = intercept of chemical *i*

DC_j = distance to the closet competitor

$NC15_j$ = number of competitors within 15 mile radius

SF_k = Gross sales of row and forage crop production, fruit & nut production, vegetable production, ornamental horticulture production, forestry production

$NF200_k$ = Number of farm with over \$200,000 in sales

NF_k = Number of total farms

ε_{ij} = Error term

The parameters of the model were estimated first using OLS, or Ordinary Least Squares. OLS is probably the most popular estimator among researchers doing empirical work (Kennedy, 1998). Once the OLS parameters were estimated, the model was tested for heteroscedasticity. Heteroscedasticity arises in cross-sectional data where the dependant variable and the explanatory power of the model tend to vary across observations. This was confirmed by calculating the error variances of different observations in the data set (Shown in Appendix B). Heteroscedasticity was determined to follow the pattern: $\mathrm{Var}(\varepsilon_{ij})$[12] $= \sigma_i^2$, where σ_i^2 is the chemical-specific variance assumed constant for all observations on each chemical. Once the chemical-specific variances were estimated using the OLS residuals, General Least Squared was used to estimate the model parameters. GLS is more efficient than OLS when errors are heterscedastic.

Next the R-squared was determined. The R-squared is basically a measure of how much variation of the dependant variable is explained by the independent variables. That is, a R-squared of .97 implies that the estimated model explained 97% of the variation in the dependant variable.

After finding the R-squared, the condition number was determined. The condition number is a measure of how highly variables are correlated in cross-sectional data. Multicollinearity arises for several reasons. For example, independent variables may share a common trend, or data may not have been collected from a wide enough source. The condition number for the model data matrix is 387.27, so multicollinearity is not a problem.

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[12] i = chemical and j = firm

Spatial autocorrelation is a problem for regression models when the error terms show a spatial pattern in which areas close together are more similar than areas that are far apart. The Moran's I test (Moran, 1950) is the most popular form of spatial autocorrelation testing because of its straightforward approach and ease of calculation (Anselin and Kelejian, 1997). The Moran's I test uses the residuals from the OLS estimation to test for spatial autocorrelation, and is defined as:

$$I = \frac{G_i G_j W_{ij} Z_i Z_j / G_i G_j W_{ij}}{G_i Z_i^2 / n}$$

Where $Z_i = y_i - \hat{y}$, $Z_j = y_i - \hat{y}$, $W_{ij} = 1$, if the firms i and j are neighbors[13], otherwise 0, and n is the number of observations. Because the data is spatial, two chemicals were tested with Moran's I test for spatial autocorrelation: Temik® and RoundUp® UltraMax (2.5 gallon). Only these two chemicals where chosen to test for spatial autocorrelation because these were two of the most popular chemicals and most retailers which provided prices for other chemicals provided prices for these two.

Table 2: Results of the Moran's I test

	Temik®	*RoundUp® UltraMax*
Moran I	-0.0929	-.054897
Z-score	-1.2498	-0.52512

The results of the Moran's I test reveal that spatial autocorrelation does not exist. If spatial autocorrelation existed the Moran I's would be greater than one. The Z-scores of the two tests reveals that the null of no spatial autocorrelation will be rejected at the

[13] A neighbor defined as a one that borders a county or is in the same county.

significance of 5% since the Z-scores are less than 1.96. Therefore, the GLS model is free of spatial autocorrelation.

The Results

Table 3, below, show the coefficient, standard error and the p-value for the variables as described by the GLS model. The intercepts, standard errors, and the p-values for individual chemicals are located in Appendix C.

Table 3: Results of Empirical Study

Variable	*Coefficient*	*Standard Error*	*P-value*
CLOSEST	0.0031	0.0026	.2268
15MILES	-0.0009	0.0023	.7036
FARMS	0.0822	0.0160	<.0001
BIGFARMS	-0.0798	0.0172	<.0001
AGSALES	-0.0289	0.0073	.0001

R-Squared of log(p): .9786 **Condition Number 387.2728**

Discussion of empirical results

The CLOSEST variable in the table above measured the effect on the price of the closest competitor to a participating firm. The estimated coefficient is not significant at a 10% level. The coefficients are elasticities due to the log-log model form, so this coefficient can be interpreted to means that for a one percent increase in mileage distance between competitors in the area studied there is .0031% increase in the price of the chemical bundle surveyed in the study. An increase in price would be expected under the Hotelling-Smithies conjecture of spatial competition, but not under the Löschian conjecture. However, the price change is very minimal. If one were to purchase one unit of every chemical at the average retail price the total expenditure would be $255.95. With the estimated parameter in the model, the price would only change $0.0079. Needless to say, this variable does not have a major economic impact on price.

The 15MILES variable is the number of competitors a participating firm has within a 15-mile Euclidean distance of the firm. With a p-value of 0.7036 this variable is not significant. However, the sign is negative which does fall into line with the Hotelling-Smithies conjecture of increased competition decreases prices. The insignificance of this variable could be interpreted as implying that as long as a firm has at least one competitor within 15-miles retail prices are kept in check. That is, the number of competitors after one competitor has little affect on the price of the chemical bundle.

The FARMS variable measures the number of total farms at the county level. This variable is a demand-shifting variable that is a measure of demand within a specific county. Under the Hotelling-Smithies theory of spatial competition it would be expected that the more farms within a county the higher the price for the chemicals within that county. This variable is significant with a 5% significant level, and had a coefficient of .0822. Since the sign of the coefficient is positive it means the more farms within a county the higher price will be price for the chemicals in the survey. This is in line with classical economic theory and the Hotelling-Smithies theory of spatial competition.

The BIGFARMS variable is a measure of the number of commercial farms in a specific county. This variable is significant at the 5% level and has a coefficient of -.0798. The negative sign implies that the higher number of commercial farms the lower the price of the chemicals. The survey requested the retail price paid by the average farmer. If the average farmer were a large farmer who purchases large amounts of chemicals then it would make sense for the number of commercial farms to lower price due to volume discounts. Also, commercial farmers are probably more willing to travel to purchase chemicals. Smaller farmers, who purchase fewer chemicals, are more likely to pay a higher price and stay in the market area of the local retail supplier. A large market could allow retailers to take advantage of economies of scale that tend to lower costs per unit of pesticides. The economies of scale for a large market are related to overhead costs and inventory holdings. Overhead costs can include: warehousing, administrative, and inventory holding costs. Inventory holding costs are the cost associated with holding the chemicals while waiting for sell. A large market should have higher inventory turnover and should reduce the holding costs. A smaller market, less commercial farmers, could have not the same economies of scale that a large market enjoys. However, it is important to note the lack of economic significance related to this variable, along with the rest of the variables. The economic significance is marginal at best.

The last variable included in the model is AGSALES. This variable is the gross amount of agricultural row crop sales within a county. This variable is significant at a 5% significance level and has coefficient of -.0289. This demand-shifting variable has a negative coefficient and is in line with the Hotelling-Smithies conjecture on spatial competition. The Hotelling-Smithies theory states as population increases in the long-run prices will fall. On the other hand, the Löschian theory states as the population increase prices will increase as well. In the model, AGSALES is measured in millions. This means that a $4,018,806 increase in the defined crops sales in the average county will result in $.0289 decrease in the price of the chemical bundle, not an economically significant impact at all.

It is important to remember that only the agricultural chemical manufacturing industry has consolidated, the agricultural chemical retailers have not. The six chemical manufacturers' products are sold in the various retail outlets. It can be argued that it is in the best interest of the manufacturers that the local retail outlets not enter into competitive price wars. This is because if local outlets engaged in price wars there could be pressure on the manufacturers to lower the wholesale price charged.

Conclusion

Farmers need pesticide inputs to produce crops in South Georgia, the United States, and the rest of the world in order to produce high yield and high quality crops. In the United States alone, there are approximately 600 species of insects, 1800 species of plants, numerous species of fungi and nematodes that are all serious threats to destroy crops (Klassen and Schwartz, 1985). These pests have to be controlled. Research has been done to study on how to best control these pests and to determine the best pesticides to apply to individual crops in order to secure crop protection. However, little research has been conducted on the price farmers' pay for these vital chemical inputs. This research studied the price paid by farmers at the local level by examining spatial competition (supply shifters) and county-level data (demand shifters).

The pesticide industry has shifted into an oligopoly market structure. Only six major firms produce chemicals worldwide. These six firms had sales of $22.70 billon for the year 2000. With such a large industry and relative few firms there is debate whether the move into the oligopoly structure is positive or negative for consumers. On one hand, it is argued that the number of reduced firms has made the industry more cost efficient by having better economies of scale. On the other hand, the industry consolidation has allowed the companies to have more control over price at every juncture from manufacturing to retail.

As mentioned earlier, theory indicates that a firm may price discriminate provided (1) the firm controls the means in which its overall market is separated into a number of distinct submarkets and (2) elasticity varies between sub markets. The most natural way to separate markets is through spatial criteria. Farms, households, and businesses exist, purchase, and consume in a spatial environment. Spatial economic research was first started in the early 1920's with Hotelling describing the disutility of traveling as a factor of purchasing.

Further spatial economic research has described three conjectural variations considered in the analysis of spatial economic theory: Löschian, Hotelling-Smithies, and Greenhut-Ohta competition. The Hotelling-Smithies and Greenhut-Ohta conjectures assume that increased competition will lead to lower prices as more firms enter the market and price also falls as population (consumers) increase. Contrastingly, the Löschian conjecture assumes as competition increases prices increases, and when population (consumers) increases price also increases.

The results of the research imply that chemicals prices at the local retail level in Georgia are a mixture of the assumptions of the Hotelling-Smithies pricing conjecture and the Löschian conjecture. The two spatial variables in the survey are split into the closest competitor and the number of competitors within a 15-mile radius of firm. The closest competitor marginal increases price as competition moves further away, which is in line with the Hotelling-Smithies conjecture. The number of competitors is also in line with the Hotelling-Smithies conjecture because it reveals as the number of firms within a market area increases the price does fall. However, the insignificance of this variable may reveal that the number of competitors is not as important as having at least one competitor. This may reveal that may than one firm has generally little affect on price.

The demand-shifting variables show different results for two different measures of population. The number of farms in a county has a positive affect on price. That is, more farms in the county actually increases price. The Loschian assumptions state as population increases the prices also increases. This is in line with classical theory that believes that more competition the higher the price. On the other hand, a greater number of commercial farms within a county leads to a lower price for the chemical bundle. The lower price in an area with larger commercial farms may be a result of bulk discounts and more competition with large farmers more willing to travel to purchase chemicals. The gross agricultural sales of row crops with a county reveals that an increase in sales does provide a reduced price of the chemical bundle. This may be a result of economies of scales resulting from the higher volume.

The results of the survey reinforce the research of McEwan and Deen (1997) who state that local retail suppliers of agricultural chemical inputs have little control over the price of the chemicals sold in their firm. The results of this research suggest that the variables included in the model only provide a marginal affect on price. From an economic perspective, this research finds no significant impact or spatial competition (or lack thereof) on agricultural chemical prices.

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APPENDIX A

COMPETITION IN THE GEORGIA AGRICULTURAL CHEMICAL RETAIL

INDUSTRY SURVEY

Dear Agricultural Chemical Retailer:

The Department of Agricultural and Applied Economics at the University of Georgia is conducting a survey entitled, "Competition in the Georgia Agricultural Retail Chemical Industry." This survey is part of a study to research chemical pricing patterns in the state. It is our hope that you will take the time to fill out the simple survey on the second page.

The survey is completely voluntary, but your participation would be greatly appreciated. If you choose to complete the survey, **your responses would be completely confidential**. All identity information will be destroyed once the survey has been completed. This will be no later than November 1, 2002.

Once you have completed the survey, please fax it to Agricultural and Applied Economics at (706) 542-0739.

Thank you for your consideration. If you have questions about the **survey,** please contact Lee Hall at (706) 542-0855 or rhall@agecon.uga.edu. Or you may contact Dr. Jeff Dorfman at (706) 542-0754 or jdorfman@agecon.uga.edu.

If you have any questions regarding your **rights,** please call or write: Chris A. Joseph, Ph.D., Human Subjects Office, University of Georgia, 606A Boyd Graduate Studies Research Center, Athens, GA 30602-7411; telephone (706) 542-6514; e-mail: irb@uga.edu.

Sincerely,

Lee Hall
Graduate Research Assistant
Agriculture and Applied Economics

The survey consists of 11 chemicals. Please provide the average retail price paid by the farmer of each chemical. If your firm does not sell a chemical, just leave that line blank. Your individual responses **will not** made public at any point.

Temik 15G$____________________/lb.

RoundUp Ultramax (2 x 2.5gal.) $__________________/gal.

RoundUp Ultramax (bulk) $______________________/gal.

Glyfos X-TRA (2 x 2.5 gal.) $________________________/gal.

Glyfos X-TRA (bulk) $ ________________________/gal.

Prowl 3.3 EC (2 x 2.5gal.) $____________________/gal.

Trilin (2 x 2.5gal) $____________________/gal.

Trifluranlin* (2 x 2.5gal) $_______________/gal.

Orthene 75S (4 x 10/lbs.) $______________/lb.

Orthene 90S (2 x 20/lbs.) $______________/lb.

Bravo 720 Weather Stik (2 x 2.5 gal) _____________/gal.

Chlorothalonil* (2 x 2.5 gal) $_________________/gal.

* Please specify manufacturer

Please fax to: Lee Hall
Agricultural and Applied Economics, UGA
706.542.0739

APPENDIX B

CHEMICAL SPECIFIC VARIANCES

Chemical	*Chemical Specific Variances*
Temik®	0.0015
RoundUp® UltraMax(2.5 gal)	0.0078
RoundUp® UltraMax (bulk)	0.0032
Glyfos® Plus(2.5 gal)	0.0420
Glyfos Plus (bulk)	0.0269
Prowl®	0.0149
Trilin®	0.0195
Trifluralin®	0.0346
Orthene® 75S	0.0149
Orthene® 90S	0.0056
Bravo® 720	0.0067
Chlorothalonil	0.0108

Appendix C

TABLE OF INTERCEPTS, STANDARD ERRORS, AND P-VALUES FOR THE TWELVE CHEMICALS

Chemical	*Intercepts*	*Standard Error*	*p-value*
Temik®	1.1641	0.0403	<.0001
RoundUp® UltraMax(2.5)	3.8512	0.0418	<.0001
RoundUp® Ultramax (bulk)	3.7243	0.0411	<.0001
Glyfos® X-tra(2.5)	3.3448	0.0523	<.0001
Glyfos X-tra(bulk)	3.1741	0.0496	<.0001
Prowl®	2.9622	0.0427	<.0001
Trilin®	2.7998	0.0483	<.0001
Trifluralin®	2.7807	0.0474	<.0001
Orthene® 75S	2.3690	0.0446	<.0001
Orhtene® 90S	2.2589	0.0415	<.0001
Bravo® 720	3.7113	0.0420	<.0001
Chlorothalonil	3.6592	0.0435	<.0001

APPENDIX D

OLS REGRESSION RESULTS

Chemical	*Intercepts*	*Standard Error*	*p-value*
Temik®	1.1995	0.0662	<.0001
RoundUp® UltraMax(2.5)	3.8860	0.0667	<.0001
RoundUp® Ultramax (bulk)	3.7590	0.0672	<.0001
Glyfos® X-tra(2.5)	3.3804	0.0667	<.0001
Glyfos X-tra(bulk)	3.2109	0.0686	<.0001
Prowl®	2.9972	0.0661	<.0001
Trilin®	2.8353	0.0687	<.0001
Trifluralin®	2.8166	0.0665	<.0001
Orthene® 75S	2.4045	0.0676	<.0001
Orhtene® 90S	2.2932	0.0669	<.0001
Bravo® 720	3.7474	0.0672	<.0001
Chlorothalonil	3.6940	0.0668	<.0001

-CONTINUED ON NEXT PAGE-

APPENDIX D (CONITUED)

OLS REGRESSION RESULTS

Variable	*Coefficient*	*Standard Error*	*P-value*
CLOSEST	0.0031	0.0043	.4665
15MILES	0.0013	0.0038	.7347
FARMS	0.1357	0.0261	<.0001
BIGFARMS	-0.1376	0.0282	<.0001
AGSALES	-0.0441	0.0119	.0002

R-Squared of log(p): .9789 Condition Number 379.3327