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Economic comparison of alternatives to sulfamethazine drug use in pork production

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CHAPTER 1. INTRODUCTION

Changes in food safety technologies offer the opportunity for improved food quality, foods with reduced potential for microbial or chemical hazards, and increased efficiency in food production and commodity processing. These improvements come from techniques which achieve greater control over production and processing procedures and the capability to make new innovations available for cost effective industry adoption. The primary goal of technology assessment is to provide information for decision making for public policy, allocation of research effort, and investment on the potential for food safety technology innovation and adoption. Potential economic and social impacts and related resource adjustment problems from commercialization of food safety innovations need to be identified.

Through proper use strategies, both product (input) users and the food consumer can benefit. In the analysis public health issues too must be considered. In recent years the continued usage of antibiotics in animals at sub-therapeutic levels has been the center of controversy on two fronts, one involving residues in food supplies and the other, bacterial resistance.

Discovery of antibiotics has been one of the greatest achievements with therapeutic applications both in human and veterinary medicine. Over 100 million kilograms of these drugs are being used worldwide annually. There are obvious impacts of

great proportions on human and animal health, agriculture, ecology, environment and public health.

The use of antibiotics has become an integral part of modern day medicine. There are implicit as well as explicit economic factors and considerations involved in the use of antibiotics. Antibiotic production and antibiotic use in animal feed has provided demonstrable economic benefits. Moreover, the level of use and availability of antibiotics for use in animal production has economic implications for consumers, producers as well as the meat industry. These issues need to be analyzed. The use of antibiotics helps prevent and control spread of diseases in animals, promotes feed efficiency, and weight gain. Feed costs on average constitute about 60 percent of the costs of livestock production, depending on production system and type of livestock. Factors such as feed efficiency impact industry efficiency and profit. Embedded in antibiotic usage in animal feed are economic benefits which result from lower average production costs per animal, lower average feed consumed per animal, and reduced days to market, etc. Such benefits have enabled producers to enjoy improved production efficiencies. Moreover, these benefits can be and are usually passed on to consumers in the form of cheaper and more readily available meat and meat products.

Some groups and individuals have observed that a ban or further restriction on the use of antibiotics in livestock production, at subtherapeutic levels, will likely transform into slower animal weight gain, more diseases and associated increase in treatment expenses, higher feed expense per animal, and higher mortality rates etc. for the industry. This would transform into higher costs for producers and thus, higher consumer prices for meat products. The quantity of meat produced would

decline leading to market price increases. Although, in view of the complex market systems that exist, it is difficult to predict exactly what deleterious or positive effects a ban on drug usage would entail, it is possible to evaluate expected relative shifts.

Some have argued that use of antimicrobial drugs has improved the life of both the animals and humans by controlling infectious diseases and promoting good health. Evidence suggests microbial diseases were a serious problem as far back as in the ancient civilizations of Egypt and Greece [1]. Successful use of organic agents, for which evidence exists, dates back to 1633 with the use of Cinchona bark extract used for the treatment of malaria. It was later demonstrated that quinine was the active principle ingredient in cinchona bark.

The ability to maintain or stimulate animal growth can be identified with the expanding animal industries. The advancement of hygiene in the control of disease unknowingly created nutritional problems that were first recognized in pigs taken from pasture to feedlots where debris, excreta, worms and living organisms were no longer recycled. By the 1920s the need for protein in the pigs diet was recognized, as an important feed input in the pig industry.

An antibacterial agent with significant clinical potential was first developed in 1932 by a group of scientists in Germany. They located and described a sulfonamide that was effective in treatment of certain bacterial diseases. Since that discovery, different forms of sulfonamides have been synthesized. However, not all have been approved for usage. Some of the sulfonamides have been found to be therapeutically effective and of low toxicity and thus, approved for use in human and animal medicine.

Discovery and use of sulfonamide has been an achievement leading to improved human and animal health and livestock production. It is used for treatment in human

illnesses. Additionally, it has been shown to be effective in fighting animal diseases as well. In livestock production, it is used for therapeutic as well as sub-therapeutic purposes. Sub-therapeutic use of drugs in veterinary treatment for disease prevention, growth promotion and feed efficiency constitutes about 40 to 60 percent of the value of antibiotics and drugs marketed.

Modern day antimicrobial drug usage as viewed by Dr. J.P Utz, is said to have begun as early as mid 1930s with the introduction of sulfonamides. Despite all the advances in antimicrobial drug research, even today, some sulfonamides are first choice drugs for treatment of uncomplicated urinary infections etc. Sulfonamides have also greatly contributed to the control of rheumatic fever.

The antibiotic era began in the mid 1940s with the rediscovery of the activity of penicillin G and its use in severe human diseases. Soon after streptomycin was isolated from a culture in the laboratory of Waksman at Rutgers. This antibiotic was clinically very effective against gram negative organisms, as studied by Herell and Nichols. This was followed up with the discovery of aureomycin, the first of tetracyclines, in 1948 by Duggar et al. It was found to be active against gram-positive, gram-negative bacteria, rickettsiae and plueropnuemonia-like organisms. The discovery of terramycin in 1950, followed the discovery of aureomycin . It is now argued that frequent or higher dosages of antibiotics are understood to make resistant strains more prevalent in a patient originally infected with sensitive strains [1].

The use of antimicrobial drugs at subtherapeutic levels in livestock rations worldwide is enormous. In United States, nearly 100 percent of chicken and turkeys, 90 percent of swine and veal calves, and 60 percent of beef cattle receive rations containing antimicrobials during some part of their growth stage. Approximately 70 percent

of beef consumed in the U.S. comes from cattle that received such feed supplementation at some stage of the production process and for veal, pork, chicken, and turkey the figure stands above 90 percent. In 1951, of 0.4 million kg antibiotics used in U.S, excluding sulfonamides and nitrofurans, 28 percent or 0.1 million kg were used to feed livestock subtherapeutic. By 1978, total use rose 30-fold to 11.7 million kg, of which 48 percent was fed to 111 million beef cattle, 100 million swine , 4.5 billion broiler chicken, and 120.2 million turkeys in the nation [2].

Within the category of food producing animals, principal benefactors have been the swine producers. Highly beneficial, economical and effective results have been observed with the sub-therapeutic use of antibiotics on swine producing farms [2].

Within the family of sulfonamides, it is principally sulfamethazine and sulfathiazole which are used at subtherapeutic levels in rations or water provided for feed livestock. This is especially true for swine producing farms.

The beneficial modes of action in response to the use of antibiotics is still not fully understood. However, studies have shown, although not adequately elucidated, there is evidence for:

1. direct growth promotion
2. a metabolic effect
3. a nutrient sparing effect
4. a disease control effect

Sulfonamides and other antibiotics are primarily used as feed additives in animal production to increase feed efficiency, weight gain and prevent disease.

Use of antibiotics in feed rations modifies metabolic reactions in that the antibiotics directly affect the rate or pattern of metabolic processes in the host animal. There is however, little evidence if any, at this time that this mechanism is of major importance in the beneficial effects obtained in subtherapeutic use of antimicrobial drugs.

Antimicrobial drugs have nutrient sparing effects which stimulate development of intestinal bacterial flora. Antimicrobial drugs synthesize essential vitamins by depressing micro-organisms in intestinal floras which compete with the host animal for essential nutrients by increasing availability of nutrients and or increasing nutrient absorption from the digestive tract. Livestock continuously fed rations containing antimicrobial drugs have a thinner, more absorptive intestinal wall structure.

Disease prevention is the most beneficial of subtherapeutic feeding of antibiotics in food producing animals. Repeated studies show greater response to drugs in animals in poor or contaminated environmental conditions [24].

In swine the greatest effects of subtherapeutic feeding of antimicrobial drugs has been during periods of stress from weaning to about 75 pounds weight range. On average, weaned pigs show 25 percent increase in weight gain and a 9 percent improvement in feed efficiency with the use of antibiotics. Beneficial results have also been observed in finishing pigs under conditions of low sanitation and high stress [1].

Over the years, level usage of antibiotics has largely varied between 100-400 gm/ton feed. Declining costs of antibiotics has dictated this increasing use of drugs at such high levels. Economic considerations have contributed to this increasing trend in the use of these drugs. The relative costs of drugs has been on a decline compared to the benefits derived.

To remove these drugs from the market or to ban these drugs from usage in rations fed to food producing animals would impact on meat availability and prices. Retail prices could be much higher than current levels.

In 1949, when the effect of antibiotics on growth of animals was found by Jukes et al., there was a tremendous surge of interest in this subject and all over U.S. animal health scientists tested chlortetracycline, penicillin, and other antibiotics in chickens and pig production [28].

As production and the use of antibiotics increased, its price declined causing it to become more economically feasible to increase the levels of antibiotics added to a ton of feed [28]. Higher levels of chlortetracycline (100-200 gm/ton of feed) were shown to provide control of enteritis in swine, a major source of economic costs or losses to swine producers and the industry in general.

With the use of antibiotics came the issue of residues in food animal products. A tolerance level for residues in edible tissues for each antibiotic approved for use in livestock production has been established (Kiser). This level has been judged to be safe for human consumption and has been identified as tolerance. This tolerance level is based on the results of very extensive tests for toxicity and carcinogenicity. For sulfamethazine this tolerance level in swine tissues has been established at 0.1 μg/g (microgram per gram weight). This is the same level for sulfathiazole. These levels would be as exhibited in uncooked, edible tissues. Withdrawal time periods are established such that at the time of slaughter there is no violation of these tolerance levels established by the Food and Drug Administration (FDA).

Withdrawal time for feed containing sulfamethazine is 15 days prior to slaughter, while for sulfathiazole it is 7 days. A withdrawal time is the time from the last

availability of a medicated feed to an animal until its slaughter. This time is based on tissue residue studies in which animals are dosed with the highest permitted level of drug in the feed for the longest time period permitted. Animals are killed at time of withdrawal of drug feed and at suitable intervals thereafter until the residue of drugs in tissues falls below the limit of detectability [28].

Continuous antibiotic usage at subtherapeutic levels in livestock is believed to cause and transmit resistance both in humans and animals. The use of sulfamethazine in pork production has often been the center of such discussions. The purpose of this study will be to examine a small segment of this issue, the occurrence of sulfamethazine residues in pork, and to identify alternatives and the economic impacts to sulfa use in pork production.

After defining the problem and stating the objectives of this study, the literature will be examined in terms of benefits and concerns about antibiotic use in general. A brief summary of the issues confronting the usage of sulfamethazine in swine will then be presented followed by identification of some alternatives to sulfamethazine use in pork production. Finally, probable producer and consumer impacts of substituting these available alternatives for sulfamethazine will be presented. This will be followed by some conclusions and recommendations.

1.1 Statement of problem

Concern on the use of antibiotics in animals with special reference to the use of sulfamethazine and it's use in pork production has centered around the controversy of drug resistance and tissue residue violations. The use of sulfamethazine in swine production has also brought to the forefront issues of environmental and feed cross

contamination. In view of these controversies surrounding the use of sulfamethazine use in pork production, there has been continued pressure to further limit the use of sulfa drugs in pork production. While the discussion continues there is a need to evaluate the producer, industry and consumer impacts from possible limitations to sulfa use. This study seeks to address these issues and identify economic impacts.

Once an antimicrobial has been given to an animal, the compound is excreted from the tissues over a period of time. Any remnants of an antimicrobial or its metabolites found in the tissues at time of slaughter, over and above established FDA limits, is referred to as violative residue.

The use of sulfamethazine in swine has shown some excellent results in terms of performance. The Hay's report summarized these effects of use of sulfamethazine and measured the response of 20,000 plus pigs during the starter stage. It showed an improved average daily gain of 23.1 percent over control groups and an improved feed efficiency of 8.6 percent over the control groups. These results showed that sulfamethazine was a very effective compound for use in the livestock production.

However, sulfa residues have remained of concern for several reasons:

1. Sulfas are excreted from the tissues more slowly than some of the other antimicrobials.

2. There is emerging evidence that sulfa residues are not broken down during the cooking process as are many other antimicrobial residues (Fischer et al., 1990).

3. It has been discovered that as little as 2 ppm of sulfamethazine in the feed fed during last 15 days prior to slaughter can cause violative residues in the tissue (Ashworth et al., 1986).

4. There is some evidence that sulfamethazine may be carcinogen (Cordle, 1989).

Sulfamethazine in swine production is essentially used in the treatment and prevention of Bordetella rhinitis caused by *Bordetella bronchiseptica*. When used as a feed additive it helps in maintaining and promoting feed efficiency and average daily gain even under circumstances of diseases such as pnuemonia, *Salmonella cholerasuis*, atrophic rhinitis and other swine diseases.

The use of sulfamethazine is permitted only in combination with certain antibiotics. In swine, sulfamethazine may be used at 100g/ton feed with 100g/ton feed chlortetracycline and 50g/ton feed penicillin. Also sulfamethazine at 100g/ton may be used with tylosin 100g/ton feed for maintaining weight gains and feed efficiency in the presence of atrophic rhinitis and lowering the incidence of *Bordetella bronchiseptica* infection. The use of this combination is the same as 100g/ton chlortetracycline as feed additive except that it is more effective than chlortetracycline alone in promoting growth and improving feed efficiency, maintainance of weight gains in the presence of atrophis rhinitis, and treatment of bacterial swine enteritis. Sulfathiazole is also permitted as a feed additive at 100g/ton level in swine production only as a combination drug with chlortetracycline 100g/ton and penicillin 50g/ton.

It is argued that resistant bacteria can develop through excessive usage or higher dosage forms of antibiotics in patients with sensitive bacteria strains. Persistent usage of antibiotics has been argued to trigger resistance in the patients microflora thus, posing increased risk to patients.

If the main deleterious effects of antibiotic use is the emergence of resistant populations, it is important to discuss how such populations arise. Use of antibacterial agents selects resistant populations where resistant bacteria are already present in

the population. Thus, it can be argued that it is not really the use of antibiotics that causes resistant bacteria but that it may lead to the condition that expand the population of resistant bacteria.

Antimicrobial drugs are selecting an ever widening range of resistant bacteria which seem to be arising by gene transfer. That number of resistant bacteria seems to be increasing at the moment is probably a reflection of the increased usage of antibiotics. It may be expected that incidence and types of resistant bacteria will continue to increase, more so if the human race continues to use antibiotics as widely as at present [1]. Antibiotic resistant bacteria move among animals and people through various routes, including the handling and ingestion of contaminated meats and other foods or feed through direct contact. This has been the primary objection with pork containing sulfamethazine residues. The tolerance level for sulfamethazine in pork has been established at $0.1\mu/\text{g}$. Levels of sulfamethazine in pork in violation of the established limits poses a potential threat of resistance.

This analysis is an extension of Berger's study in an attempt to identify and evaluate the producer, industry and consumer impacts from potential limitations to use of sulfamethazine in pork production in response to residue violations witnessed in the pork industry.

Berger concentrated on an economic assessment of reducing sulfa residues in pork supplies. Her master's thesis took two approaches. The first being the evaluation of potential testing procedures and respective market locations for identification of sulfa residues and the second being an economic analysis of industry-level impacts from a complete removal of sulfa availability for use in swine production.

1.2 Objectives of study

An oversimplifying assumption in Berger's study was that alternatives to sulfa in swine production were ignored. It evaluated a total ban on sulfamethazine use in pork production as it compares to the current situation for sulfamethazine use. While perfect substitutes do not exist, there are alternatives which would lessen industry impacts than would be the situation where no alternatives exist. Thus, this study expands the evaluation to analyze the potential substitution for sulfamethazine.

The study objectives are to :

1. Further identify products which are viable substitutes for sulfamethazine. This would involve identification of expected production adjustments for the respective alternatives.

2. Provide an economic evaluation of the producer and industry impacts from the use of the respective alternatives.

The purpose of this thesis is to identify these alternatives to sulfamethazine use in pork production and conduct an economic assessment at both the industry and producer level. Potential impacts on pork production, production costs, and consumer demand will be analyzed for selected alternatives.

CHAPTER 2. LITERATURE SURVEY

2.1 General overview

Subtherapeutic use of compounds has played an important role in animal husbandry by assisting in the control or elimination of disease, and the improvement of growth and efficiency of feed conversion. Livestock producers, industry, veterinary, and regulatory personnel share responsibility to ensure that food products are free from metabolites, residues, and other chemicals to which the livestock and poultry may be exposed. The predominant concerns are the potential adverse effects on human health. Data demonstrate that the feeding of subtherapuetic antimicrobials to livestock and poultry increases the prevelance of R+ enteric organisms. Some of these organisms may be pathogenic for humans [20].

Over the last 50 years, the progress made in identification, development, and marketing of antimicrobial agents can only be described as remarkable and a great credit to academia, industry, research, and government which have made lasting contributions to this achievement. Sales of animal feed additives totaled more than 1.1 billion dollars in 1983, 270 million of which were antibacterials. Approximately one-half of the 35 million pounds of antibiotics manufactured in U.S. were provided to animals.

The beneficial effects of antibiotic feeding such as growth promotion were dis-

covered by accident. In the 1940s vitamin B-12, a dietary component obtained from fermentation products of the micro-organism, *Streptomyces aureofaciens*, was being studied. Researchers found that feeding of crude fermented material containing *Streptomyces aureofaciens* produced growth in chicks beyond that expected from the vitamin B-12 factor. This was later substantiated to be a result of the chlortetracycline present in the fermentation products [20].

Soon after their discovery and use in human medicine, antibiotics became available for use in veterinary medicine. Before the end of WW II, infusions of penicillin in saline were used to treat mastitis in lactating dairy animals. It was the introduction of antibiotics into animal feeds during the early 1950s that ushered in a new era in livestock management and meat production. Chlortetracycline was the first to be used in animal feed in 1950, and it continues to occupy a large share of feed antibiotic market. Although used at lower concentrations earlier, reductions in manufacturing costs in the 1950s allowed economic uses in feed at higher concentrations. At these new levels tetracyclines were found to play a significant role in control of livestock diseases. It was in the 1960s that scientists first became aware of plasmid-mediated resistance and found that clinical bacterial isolates resistant to several gram-negative antimicrobial products could transfer the genetic information encoding these resistances to other bacteria. In recent years this has become the central focus point on antibiotic use in animal feed and human health risks. It was postulated that use of certain antibiotics in animals could generate resistance plasmids in the enteric flora of livestock, and that this genetic material might eventually encode antibiotic resistance in human pathogens. It was argued that the continuous use of antibiotics in animal feed could eventually lead to a loss of antibiotic efficacy in human medicine [21].

Assessments of public health claims on feed antibiotics have been carried out by many a experts. The first studies in England had concluded that no alternation in the use of antibiotics was warranted. The Swann committee of enquiry, set up after the outbreak of salmonella in calves in mid-1960s, submitted a report in 1969 recommending that feed antimicrobials used for animals be regulated according to category of use [21]. Products that were used for growth promotion and feed efficiency could be continued to be used at producers discretion, however, antimicrobials with claims for disease prophylaxis or therapy would be used under the order of veterinarian only. This procedure continues to be used in England even today.

Various U.S. expert committees have also submitted their reports on the antibiotic controversy. In late 1987, the FDA joined hands with National Academy of Sciences (NAS) to develop a risk assessment model for the feed antibiotic controversy. The model was to use data on salmonella deaths in humans. In 1989, the report cautioned that the model presented could not yield hard and highly useful figures because the data that were used as inputs were in many cases sketchy and unreliable. The committee recognized that salmonella was used only because it was traceable, and that far less than 1 percent of the antibiotics used in U.S. are directed against infection by salmonella. To state otherwise, the committee was unable to find direct evidence that established existence of a definite human health hazard in the use of subtherpeutic concentrations of penicillin and tetracyclines in animal feeds [21].

Research attempts have also been made to study the effects of a significant decline or elimination in the use of feed antibiotics in livestock. The university of Kentucky conducted one such study. A herd provided with chlortetracycline at levels

of 50 to 100 g/909 kg in feed since 1972, was used for the purpose of study and compared with another group raised since 1972 without exposure to either subtherapeutic or therapeutic treatment. Coliforms from both groups were observed over the years and prevalence of antibiotic resistance was determined. The results indicated that the pigs not fed any antibiotics showed a gradual decline of antibiotic resistance [21]. They also showed a concomitant decline in performance as measured by litter size, litter weight, conception rate, increased incidence of joint problems, and etc. When given a single dose of therapy, these pigs showed a rapid increase in resistance at levels compared to the group fed antibiotics. Such an experiment is of importance because it determines that a significant reduction in current uses of these antibiotics would not quickly restore antibiotic sensitivity to the enteric flora of pigs and that any potential long-term reduction in resistance would probably be prevented by occasional therapeutic uses [21].

Recent trends in antibiotic resistance in human clinical isolates is not increasing as originally feared. Atkinson and Lorian have reported results of a large data base of information on resistance to 16 commonly used antibacterials. They concluded that the antibiotic resistance to most antibiotics was not showing an increasing trend.

In his article in Food-Animal practice, 1993, Dr. Payne discusses ways to maximize antibiotic efficacy and prevent drug residues on dairies. He suggests that in choosing appropriate treatment, antibiotic susceptibility testing is a good way to start before deciding on the antibiotic treatment. The cornerstone of modern antibiotic sensitivity is the determination of an isolates minimum inhibitory concentration (MIC). The development of resistance can lead to profound differences in the MIC's of different isolates of same pathogen species. Though antibiotic testing is useful as

an initial guide in selection of treatment, it is not to be followed blindly. It is also true that such a reliance may divert attention away from more important issue of disease prophylaxis.

Extralabel use of drugs is unavoidable in the course of food-animal practice, as is also recognized by the FDA. Such extra-label use however, is guided by criteria established by the FDA such as in a situation of client/veterinary/patient relationship where no effective labeled alternatives exist, where significantly extended withdrawal times are assigned and no illegal residues occur. A veterinarian needs to select an effective treatment, while at the same time try to minimize costs of the producer. For example treatment of a 300 pound calf with ceftiofur costs $2.70 a day as compared with $0.27 when treated with oxytetracycline. In such a situation oxytetracycline would be a better choice for dairy where pathogen have not developed a resistance to oxytetracycline. If the owner and veterinarian want to reap maximum benefit from treatment, then employees must be carefully instructed in each phase of procedure. The animal restraint facilities should facilitate treatments to be performed efficiently. Another practice of vital importance can be the training of dairy employees to recognize the pnuemonic calves etc. Also treatment personnel should be carefully trained in proper administration of the respective treatments. Maintaining records of treatment will offer control in treatment and help realize safe tissue levels. Morbidity and mortality at the herd level can often times help determine efficacy levels of therapy. Finally, guidelines should be established for dairy employees to assist them in determining when the treatment should be discontinued, withdrawal time observed, and the animal culled. Although, Dr.Paynes paper concentrates on the dairy industry, all other livestock and poultry raising producers have much to learn from this article.

S.C. Henry and D. W. Upson in their paper entitled "Therapeutics", have listed some of the therapeutic responsibilities and decisions. These are to satisfy many parties to whom veterinarians and livestock producers are responsible:

Animal: The goal is to provide a specific, targeted, efficacious therapy that is delivered in a humane manner.

Producer/Owner of livestock: The producer expects a practical, applicable, therapy that is cost effective and does not pose undue risk to the personnel administering the medication.

Government regulators: The government requires adherence to state, federal, and international constraints on medication of animals intended for human food, including responsibility for documentation of therapy.

Pharmacuetical manufacturers : manufacturers expect application of products within their established envelope of safety and in a manner allowing efficacy at demonstrated potency.

Consuming public: responsibility for therapeutic decisions is expected of livestock producers and veterinarians.

In a symposium in 1969, James L. Goddard, expressed his view that veterinarians are working on faith rather than hard facts and data of veterinary medicine. He felt the urgent need for veterinarians to work more with hard data and present concrete results in connection to the various issues that had come up with the use of antibiotics in animal feeds.

According to Virgil Hays, antibiotic feed supplements have been used extensively the world over for over 50 years now. The wide acceptance of these antibiotics has been based on their benefits of increasing growth rate, improving feed efficiency, and decreasing mortality and morbidity from clinical or subclinical infection. Although different in their chemical compositions and bacterial spectrum, antibiotics effective in improving performance of animals have one thing in common, their ability to suppress or inhibit growth.

In a comprehensive summary of effects of antibiotics on beef cattle, Burroughs et al. had noted that animals fed diets that resulted in less rapid and efficient gains showed a greater percentage response to antibiotics. To cite an example of such an antibiotic would be chlortetracycline.

Numerous studies have indicated that the major benefit of subtherapeutic feeding of antibiotics is their suppression or control of subclinical diseases. Research shows the response of antibiotics to be less when fed provided a cleaned and disinfected pen. This was a result obtained by Speer et al. in his study on pigs. Although in theory it might appear correct that antibiotics are a substitute for poor environmental conditions, in practice it is reasonable to suggest that all are needed, wise use of antibiotic complements good husbandry and sanitation.

Long term use of antibiotics in animal feeds has elicited concern about potential harmful effects due to development of resistant strains of organisms or allergic reactions in consumers of meat, milk, eggs from animals continuously fed antibiotics. Dr. Hays expressed a view that this controversy has lasted for so long now, that there is a need for veterinarians to change their rational thinking leading to adequate evaluation of potential harmful effects as contrasted with proven health and economic

benefits .

Hays indicated that practical use levels are not necessarily levels sufficient to elicit maximum response. The rate of increase in growth response decreases , however, as level of antibiotic use increases. Thus, level of dosage is a compromise based on cost-benefit analysis.

Some have argued that antibiotics have lost their efficiency in treating animal illnesses. This has been explained as "organisms are developing resistance". This claim, however, is not widely supported. Experiments such as those conducted by Peo summarized long term effects of antibiotic feeding to swine a Nebraska study and concluded, that after more than 10 years of extensive use of antibiotics, a response was still observed.

Use of antibiotics leads to certain benefits in animal growth and improves the feed efficiency of the animal. Subtherapeutic treatment with antibiotics leads to thinner intestinal walls. Thinner intestinal walls are more efficient in absorbing nutrients than intestinal walls of conventional animal which undergoes thickening as reaction to bacterial toxins or to some other damaging effect of microflora. This study was done by Gordon in chicks [5]. As per C.K. Whitehair and B.S. Pomeroy, antibiotics at low levels inhibit growth of undesirable micro-organisms in intestinal tract. The improved growth rate is a manifestation of increased feed consumption and better absorption of nutrients. At high levels these antibiotics are used in treatment of systemic infection with limited impairment of digestive system.

Use of antibiotics has helped make substantial savings in other costs of production by speeding growth process and by reducing death losses. According to Dr. H.R.Bird the biological bases for these economic effects are:

1. Antibiotics prevent bacterial destruction of feed protein in the gut

2. They inhibit toxin-producing organisms.

3. They prevent thickening of gut wall and permit better absorption.

4. They prevent bacterial destruction of vitamins and favor certain bacterial species which synthesize vitamins.

Experience with use of antibiotics in treatment of livestock and poultry diseases appears to emphasize [48]:

1. Feed may be used as the vehicle for antibiotic administration

2. When diseases are properly diagnosed the proper dosage of antibiotics is effective treatment for specific infectious diseases of poultry and livestock.

3. Infection and nutrition are inter-related

4. Disease prevention practice must be used in conjunction with antibiotic therapy to decrease poultry and livestock diseases more effectively

Each drug in animal feeds is subjected to considerable study before it is proposed for use. There is however, a practical limit to the amount of testing that can be conducted before a drug is introduced. True and full evaluation of relative safety comes only finally, when the drug is widely distributed and used under all sorts of conditions.

2.2 Issues in antibiotic use

There are concerns over drug residues in animal tissues. Withdrawal times have been established by the Food and drug Administration (FDA), in order to avoid tissue residues. Monthly statistical samples of tissue collected at packing plants are tested for residues of antimicrobial drugs among other residues measured by Food Safety and Inspection Service (FSIS).

The residue avoidance program has been effective in eliminating antibiotics from animal products among major meat animals. Antibiotic residues in carcasses decreased between 1978 and 1986 by 84 percent in swine, 75 percent in adult cattle, 66 percent in veal calves, 79 percent in poultry. An attempt to reduce sulfa residues during the same period did not meet with as much success. There was a 53 percent decline in swine residues, i.e., from 9.7 percent to 4.6 percent and poultry sulfa residues declined from 3.1 percent to 1.6 percent, i.e., a decline of 48 percent [1].

Failure to follow withdrawal times, use of unapproved levels, use of soluble powder, and contaminated water lines have in large been responsible for sulfa drugs.

Hypersensitivity reactions have been principally concerned with penicillin and less with other drugs including sulfonamides. Sulfonamide residues in pork have been of concern in food mainly due to prevalence of residues and toxicity of drugs. Hypersensitive reactions in sensitized human patients includes blood and kidney damage.

The FDA has responsibility for regulating all animal drugs as safe and efficacious for their intended uses and for freedom from residues hazardous to human health when such drugs are used as approved. The responsibility for enforcing these regulations lies with the FDA. United States Department of Agriculture (USDA) has the responsibility for licensing all veterinary biologicals for animal use and through

FSIS national residue program for nationwide monitoring of meat and eggs for drugs and chemical residues, as well as for inspection of all animals and poultry slaughtered in federally approved packing plants.

Livestock animals and poultry, except at certain small poultry slaughter operations, which are butchered for commercial sales are at least sample inspected by government inspectors under veterinary supervision [2]. In 1986 antibiotic residues were reported in 1.2 percent of the animals and 0.5 percent of the poultry. Sulfa residues were found in 2.5 percent of the animals tested and 1.6 percent of the poultry tested.

Subtherapeutic levels vary with different antibiotics, but are usually between 30 and 300 milligram per ton of feed. These levels have increased overtime mainly because the compound costs have fallen in relation to observed benefits. Nearly 80 percent of the Broiler chicken and turkeys, 75 percent swine, 60 percent feedlot cattle and 75 percent dairy calves marketed or raised in U.S. have been fed antimicrobial compounds during some period of growth [2].

2.3 Total antibiotic production

Impact of antimicrobials on farm animals requires reliable data on the total amounts of penicillin and the tetracyclines used annually in animals and medical use in humans. The data indicates that the percentage of total antibiotic production directed to animal feed and other uses increased from 16 percent in 1951 to 38 percent in 1959. In 1960s the average was 40 percent of total antibiotic production. This figure increased to 42-48 percent for the 1970s. It is also estimated that 36 percent of entire antibiotic production for 1983 consisted of antibiotics directed to feed additive

and other uses [26].

Penicillins and tetracyclines together made up 42 percent of the total 1983 antibiotic production. Of the other 58 percent, only a few were approved for use as feed additives. The FDA, through use of 1979 data from International trade committee (ITC) has estimated that approximately 55-60 percent of the penicillin and tetracycline was used for subtherapeutic use in food animals.

A summary analysis of antibacterials for livestock and poultry feeds, 1980-85, studied by the Institute of Medicine indicated little variation in this period in total feed use of antibacterials: 9.7 to 11.7 million pounds a year. Tetracyclines accounted for 57 percent of this production in 1980 and 49 percent in 1984 and 1985. Penicillin accounted for only 5-8 percent of this volume.

According to the U.S. Department of Agriculture, approximately 86.5 million pigs with an average weight of 110 kg were marketed in 1985 [26]. Using the survey estimate figure of 6.6 g of tetracycline per pig, the committee derived total amount of tetracyclines used in the rearing of swine for 1985, to equal a figure of 0.57 million kg of tetracycline (i.e. 86.5 million pigs multiplied by 6.6 g tetracycline per pig). If all swine feed were to be medicated with tetracycline, the total would be 1.7 million kgs.

It is understood that the use of antibiotics in animal production has led to the reduction in the incidence of several zoonotic diseases [2]. This decrease is indirectly attributed to better control of these diseases in animal population through vaccines and antibiotic use. However, there is need to more firmly establish the positive role of antibiotic use in animal production and decrease in zoonotic diseases. *Leptospira interrogans ponoma* was referred to as the "swine herds disease" in humans. While

vaccines did help control leptopira bacterium, the use of antibiotics cannot be ruled out since it is very sensitive to several antibiotics [2]. *Eryipelothrix rhusiopathiae* an occupational disease associated with packing plant workers, not unheard of in the early time period of mid 1930s is now a rarity. It is believed that antibiotic usage has, especially in hog production, aided in the reduction of incidence of erysipelas [2].

2.4 Sulfonamides

Sulfonamides have for long been accepted for human and veterinary treatment. Its beneficial effects as a growth promotant and effectiveness in controlling systemic diseases in animal production has been widely acknowledged in the literature. The drugs are a wide spectrum antibacterial, effective against both gram positive and negative bacteria and well absorbed systemically. These drugs have enjoyed wide use and were also recommended for treatment of urinary tract infections, pnuemoccocal infections, gonococcal infection, rheumatic fever, cholera etc.

In recent years, however, there has been a reduction in the use of individual sulfonamides for the therapy of human diseases as a result of increased bacterial resistance to drugs and the development of more effective antimicrobial agents [4].

During the early 1940s sulfonamides found extensive use for treatment affecting pet and food-producing animals. Calf pneumonia, calf diahrrea, infectious entiritis in swine were some of the commonly treated diseases. The use of sulfonamides, although greatly reduced, has persisted in veterinary medicine mainly because they are easily administrated in feed and water, are economical and have proven to be effective for treatment of various livestock diseases. The 1950s initiated a new era

with commercial feed production of sulfamethazine and sulfathiazole in combination with other antibiotics. In swine, these combination products, as feed additives, were extremely efficient in increasing feed efficiency and improving rate of weight gain. In swine, these combinations have particularly been effective under situations of atrophic rhinitis. Currently, besides being used as a feed additive in animal production, sulfonamides are also used in treatment of respiratory diseases and infections in swine and cattle. Use of these combination drugs in swine led to the realization of two major benefits namely, an increased antibacterial spectrum and decreased rate of development of bacterial drug resistance.

Sulfonamides can be administered easily via oral, intravenous, intramuscular, intraperitoneal, and intrauterine routes. Cattle and swine producers administer sulfa drugs orally by means of feed additive or by mixing with water. Sulfa drugs in swine production are used to promote growth, improve feed efficiency and reduce incidence of disease.

It is estimated that in human use, at least 5 percent of the persons receiving sulfa treatment will experience some untoward reaction. Vascular lesions, drug fever and lesions of skin are some of the common expressions of sulfa hypersensitivity. Crystullaria, hematuria and blockage of renal tubules disturbances are urinary tract disturbances which may result from sulfa use in humans.

In animals toxicity occurs most frequently following rapid or excessive intravenous administration of drugs and is often referred to as "drug shock". Renal damage due to crystallization of sulfonamides is not uncommon. These, essentially in pigs, are a result of inappropriate husbandry practices. Most sulfonamides are excreted primarily in the urine. Feces, milk, and sweat are excretory routes of lesser

importance.

The Food and Drug Administration has set a tolerance level of 0.10 micrograms sulfonamide per gram of edible animal tissue. The FSIS monitors animal tissue for sulfonamide residues and tissue levels. Chromotographic techniques, sulfa-on-site, and E-Z test are more prevalent methods of estimating tolerance levels in swine tissue at farm levels. Sulfonamide concentrations above the tolerance limit are termed residues. Meat products in violation of these tolerance limits are subject to condemnation by FSIS. In 1978, 10 percent of swine carcasses were deemed condemned for exceeding tolerance levels. These were attributed to failure of following withdrawal periods. Later, however, causes were found to be wholesale contamination of animal feeds with sulfonamides, recycling of drugs from animal wastes, and failure to prescribe to withdrawal periods. The occurrence of sulfa residues observed in recent year or two are estimated to be below the 1 percent residue incidence permitted by the FDA (Teddi Wolff, 1994, private communication). Better and appropriate management techniques, improved awareness, stringent measures by FDA, and granular sulfamethazine have helped reduce these violative levels in swine.

In recent years use of sulfa drugs, with special reference to its use in swine production, has been an issue of controversy regarding the issue of resistance. Long term use of antibiotics has shown to favor development of bacteria that are not susceptible to antibiotic at that dosage level. Research has also shown that antibiotic resistance can be transmitted between some bacterial species and strains by plasmids (small pieces of genetic material termed R-factors). The transmission of R-factors causes a further risk that resistant, but non-harmful bacteria, could transfer the genetic material necessary for resistance to other, disease causing bacteria. Such bacteria, or

an altered bacteria could then cause outbreak of disease in human population that would be difficult to control due to resistance to antibiotics.

The use of sulfa drugs in swine production has also brought to the forefront the issue of environmental contamination and cross-feed contamination.

Many producers, have as a result chosen to substitute sulfamethazine in pork production with sulfathiazole, a drug with very short biological half-life. The rapid elimination of the drugs increases the level in the feeds necessary to cause violative residues. With the use of sulfathiazole, violative residues are uncommon [1].

2.5 Effects of a ban on subtherapeutic antibiotics in animal production

The effects of banning or reducing the use of antibiotics in animal feed for subtherapeutic disease treatment can be better understood when evaluated by industry segment such as:

1. Livestock producers
2. Consumers
3. Veterinarian

2.5.1 Livestock producers

Livestock producers are among the principal benefactors of antibiotics use in animal production. Antibiotics are routinely used as supplements to increase feed efficiency, improve weight gain, and reduce mortality rates. These benefits save hog producers an estimated two billion dollars in annual production costs [47].

Performance improvements from the subtherapeutic use of antibiotics has led to an increase in it's use from 2 million pounds in 1962 to 5.1 million pounds in 1987 in the U.S. Approximately 45 percent of antibiotics used annually in the United states serve as supplementation in animal feed [47]. A ban on subtherapeutic drugs would lead to allied affects on the agribusiness industry. Feed tonnage would be reduced by a ban because of fewer hogs on feed. Animal health suppliers would lose profitability but might be encouraged to invest more heavily into a new product development. Veterinarians would lose a vital and conventional health management tool. A smaller number of lighter hogs would be available to pork packers. Without antibiotics, the cost of gain would increase, resulting in shorter feeding periods and lighter hogs. The animal producing industry would have to explore changes in production, technology, and marketing in the face of a ban or further restrictions on antibiotic usage in food generating animals [47].

Research done by Wade and Barkley on "The economic effects of a ban on subtherapeutic antibiotics in swine production" compared welfare levels for producers as well as consumers after the ban. The mean retail price of $2.18 per pound of pork and retail quantity of 3305.5 million pounds of pork resulted in estimated consumer surplus before a ban of 4615.5 million dollars and producer surplus equal to 5193.5 million dollars. Under certain assumptions of a 4 percent decline in pork supply and a 5 percent increase in demand for pork plus the assumption of constant price elasticity of supply and constant price flexibility of demand, Wade and Barkley concluded that market shifts would lead to a new equilibrium price of $2.25 per pound and a postban equilibrium quantity of 3211 million pounds of pork. The ban was expected to result in increases of $6.19 million in consumer surplus and 6.97 million dollars in producer

surplus. It was estimated that each consuming household would benefit by an average of $0.09 per quarter if a ban were legislated, whereas producers would gain $29 each (1987 dollars). A sensitivity analysis was conducted to make the results more reliable. The sensitivity analysis concluded surplus levels for both pork producers and consumers would not change drastically in response to a ban of antibiotics. Consumers were expected to benefit from a ban if their response to the ban is large. These gains in surplus are mitigated by increases in production costs and, hence, shifts in supply.

It was concluded that hog farmers could maintain preban output levels by either feeding the same number of animals for a longer period of time or feeding a greater number of hogs for the same amount of time. Output levels would definitely reduce if hog numbers and feeding time were held at pre-ban levels after the ban. such responses would lead to increase in swine production costs, quantity supplied would be reduced at every given price of pork. In the long run some swine producers would find it convenient to move out of the swine production market.

2.5.2 Consumers

According to Wade and Barkley, the demand for pork is conditioned by consumer perceptions and knowledge of the attributes of the product. In other words food safety is an important determinant in demand for food products. In their study Wade and Barkley referred to a survey conducted by the Good Housekeeping Institute in 1985, which found that primary food concern of over 40 percent of women respondents was food safety. Also a 1985 study of 390 Kansas residents indicated that 71 percent would pay more for safer meat. A similar study in 1990 had concluded that 88 percent

of the 360 respondents were willing to pay at least 5 percent more for residue-free beef, and that 79 percent of these people had reduced their beef consumption with only 14 percent of it being price related.

Given that consumer demand will likely increase following a ban on use of antibiotics in swine production, if legislated, the reaction of consumers to a potential ban is not known with certainty and thus, must be projected. Wade and Barkley conclude that consumer welfare would probably increase because of elimination of a perceived health risk, which would offset the increased production costs associated with swine.

2.5.3 Veterinarians

Antibiotics have been an effective tool in a veterinarians pandora's box for the treatment of bacterial diseases in animals. They have led to a better client-veterinarian relationship and also improved relations between the animal farmer and the veterinarian. As effective means of treating various illnesses, antibiotics have offered veterinarians and farmers some control in the production process of food producing animals and processed meat. A ban on the use of antibiotics would be a big loss to the veterinarians since it would entail suspension of effective mode of treatment until new research on better and more efficient means of treatment is found. Thus, the farmers may observe huge economic losses until a time period when an effective treatment is found. At present no guarantees can be offered that any alternative mode of treating animal illnesses will be as economically feasible as antibiotics are.

2.6 Population of livestock and poultry

Knowing the populations of livestock and poultry helps estimate the penicillin and tetracycline used to medicate them. Food animal population in U.S. is extremely large, much more than twenty times the human population [26]. In 1971 and 1985, as an example, the total U.S. food animal population was 3,522 and 5,122 million head respectively. The number of head of livestock (exclusive of poultry) for the same 2 years was 237 and 206 million. While poultry production increased, the production of red meat in the intervening 14 years declined somewhat. A relationship between amount of red meat to white meat food is important in considering the magnitude of human exposure to meat or poultry products contaminated with pathogenic bacteria of farm- animal origin. This magnitude can be understood by inspection of per-capita consumption figures for meat and poultry in this country. The consumption of red meat per capita ranged between 168 pounds in 1971 to a low of 153.2 pounds in 1985. In the same period, the amount of poultry consumed increased from 49 to 69.7 pounds.

2.7 Economics of drug use

As per estimates provided by Beran, the cost of adding antimicrobial drugs to livestock rations represents about 3.75 percent of the total ration costs. The increase in daily rate of gain for swine have ranged between 9.7 percent and 17.7 percent, with feed efficiency increases from 3.3 percent to 7.6 percent in reported experiments. With the improved feed efficiency levels, return on investment appears to be about two dollars for each dollar invested, or about 3.5 billion dollars a year for the U.S.

Beran indicates that in context of the present agricultural economy, an effect of a ban of subtherapeutic use will impact more heavily on livestock producers than consumers [2].

In an industry-level economic conceptual model, Buhr, Kliebenstein, Walker and Johnson estimated the effects of improved animal health. Livestock disease reduces production efficiency leading to producer, industry-level, and societal economic losses. Most animal health analysis have focussed at producer level. However, consumers can experience economic losses or decreases in welfare through higher food prices.

In order to measure economic impact of animal diseases, it is important to study its effects on animal productivity. This is not always an easy task because [7]:

1. the effects are not always pronounced and obvious
2. they are influenced by other factors such as overall management, environment etc.
3. they have a temporal dimension which adds to complexity of evaluating their impacts over time
4. the effects often manifest themselves in an integrated complex with other diseases.

Quantitative measures of disease impacts can be categorized under traditional production-oriented data and non-traditional indicators of disease presence. Traditional data include factors as mortality rates and average daily gain. Non-traditional indicators include factors as mortality rates and average daily gain and also factors such as labor requirements, feed costs, veterinary costs may be included. Veterinary

services will increase with the level of disease, and thus can serve as indicator to a disease. Other factors help as indicators on a similar basis. Feed costs may increase from necessity to feed medicated rations to control subclinical diseases.

Numerous studies have indicated that pneumonia and rhinitis, even at subclinical levels, can cause significant decreases in average daily gain and feed efficiency. Decreasing animal production efficiency leads to a decrease in economic efficiency.

Research by Christian Boessen, James Kliebenstein, Ross cowart, Kevin Moore and Clark Burbee on determination of swine pneumonia and rhinitis, and impacts on production costs through slaughter checks concluded the increased costs per hog due to pneumonia for batch production at a weighted average of $1.09 annually. The annual decline in the average daily gain due to pneumonia was estimated to be 2.83 percent. For rhinitis, the annual weighted average increase in cost per hog was estimated at $0.95. In some cases, the expenses incurred in disease prevention and/or control can be considerable. Without information on disease levels in the herd, producers can incur unnecessary expenses. Knowledge of a disease level can enable producers to improve disease management and possibly reduce levels of medication. Use of slaughter checks, a method of monitoring levels of subclinical diseases by examining the internal tissues and organs of an animal as it moves through slaughter plants, offers the potential result of healthier animals with lower levels of medication.

The most evidence linking human disease to multi-resistant bacteria of farm origin has been found in salmonellae. Most data linking incidence and associated morbidity and mortality of salmonella infection in farmers, slaughterhouse workers, and their families is not available. Comparison of case reports on farmers who used subtherapeutic antibiotics as feed additives in animals with those on farmers who did

Table 2.1: Frequency & percent deaths due to salmonellosis (1968 - 1985)

Age	Number of deaths	Percent per year of age
Under 1 day	1	0.1
1 - 6 days	8	0.6
7 - 27 days	30	2.1
28 - 364 days	165	11.6
1 - 4 years	42	3.0
5 - 9 years	12	0.8
10 - 14 years	11	0.8
15 - 24 years	14	1.0
25 - 34 years	30	2.1
35 - 44 years	42	3.0
45 - 54 years	104	7.3
55 - 64 years	176	12.4
65 - 74 years	314	22.1
75 - 84 years	296	20.8
85 + years	174	12.2
Unknown	2	0.1
All ages	1421	100.0

Source: Institute of Medicine, 1989

not might be particularly of interest. The only data available is in the form of case reports or descriptions of small number of outbreaks in farmers and their families and not slaughterhouses.

The National center for Health Statistics has estimated the frequency and death due to salmonellosis by age for the years 1968-85. Table 2.1 lists this data. The age group between 65-74 years represents the maximum deaths both in absolute numbers and in percent. The lowest figures are for the age group "under 1 day".

The number of salmonellosis incidence is suspected to be 10-100 times larger than that reported to CDC (Center for Disease Control). This is mainly because many patients with salmonellosis do not seek medical attention since in most cases

Table 2.2: Resistance of salmonella to antimicrobials

Rate of resistance of Salmonellae to:	Low Estimate	Mid-Range Estimate	High Estimate
At least one antimicrobial	16%	24%	31%
At least penicillin/ampicillin or tetracycline	10%	15%	20%

Source: Institute of Medicine, 1989

salmonellosis is believed to be a simple case of diahrrea. The proportion of salmonella isolates from humans with resistance to at least one antimicrobial was 16 percent in the 1979-80 CDC survey and 24 percent in 1984-85 survey. The rate of occurrence of antibiotic resistance of salmonellae is shown in the Table 2.2 . The committee on human health risk assessment of using subtherapeutic antibiotics in animal feeds used a risk model and concluded that major consequences of feeding antimicrobial agents to animals or humans are likely to be:

1. a tendency to increase the prevalence of drug-resistant strains

2. an effect on both the pathogen and the fecal flora that might alter their usual interaction

The committee also constructed and used a risk model to estimate and plot annual number of deaths that result from subtherapeutic use of antibiotics in animal feed. Some of these results are presented in Figures 2.1 through 2.3.

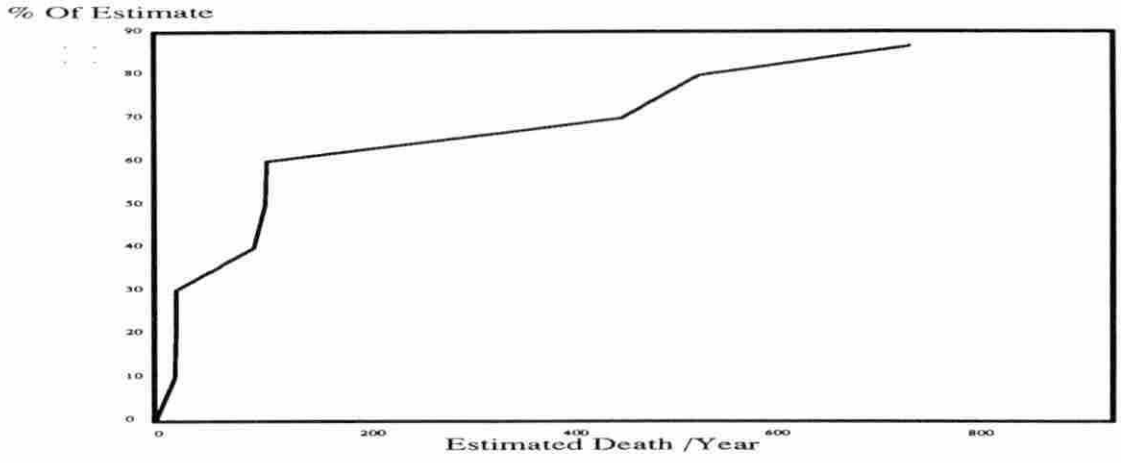

Figure 2.1: Estimates of annual numbers of deaths from subtherapeutic uses of any antibiotic for both prophylaxis and growth promotion

Source: Institute Of Medicine, 1989

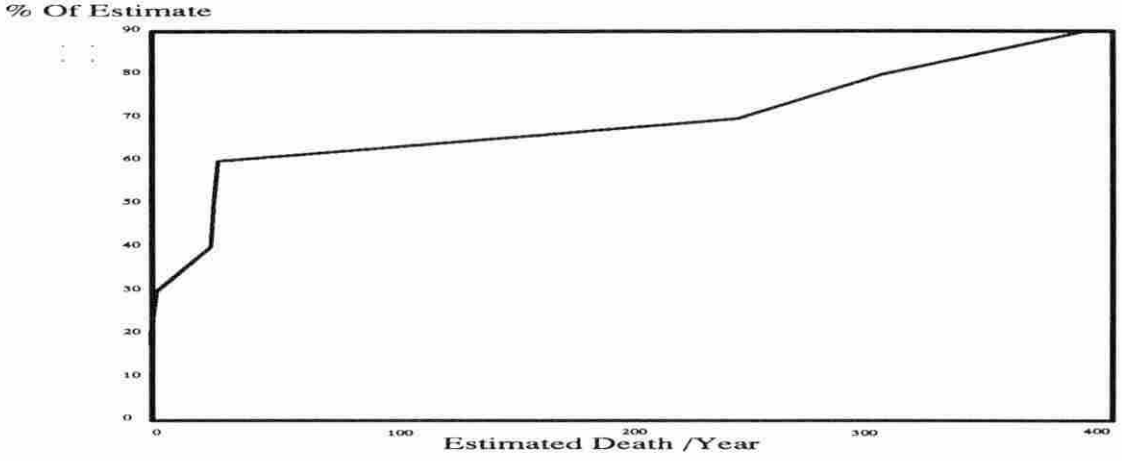

Figure 2.2: Estimates of annual numbers of deaths from subtherapeutic uses of any antibiotic for growth promotion only

Source: Institute Of Medicine, 1989

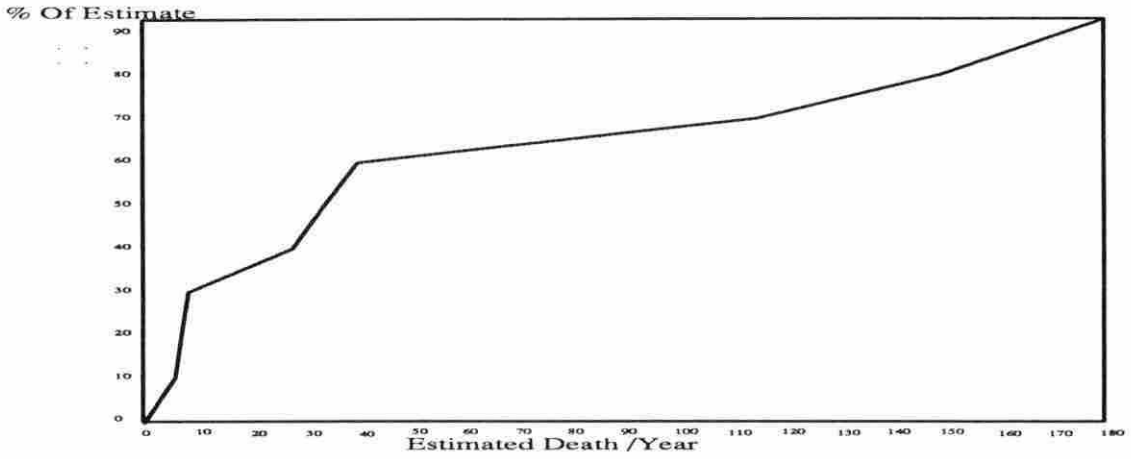

Figure 2.3: Estimates of annual numbers of deaths arising because of higher death rate and increased difficulty of disease treatment attributable to subtherapeutic uses of any antibiotic for both prophylaxis and growth promotion

Source: Institute Of Medicine, 1989

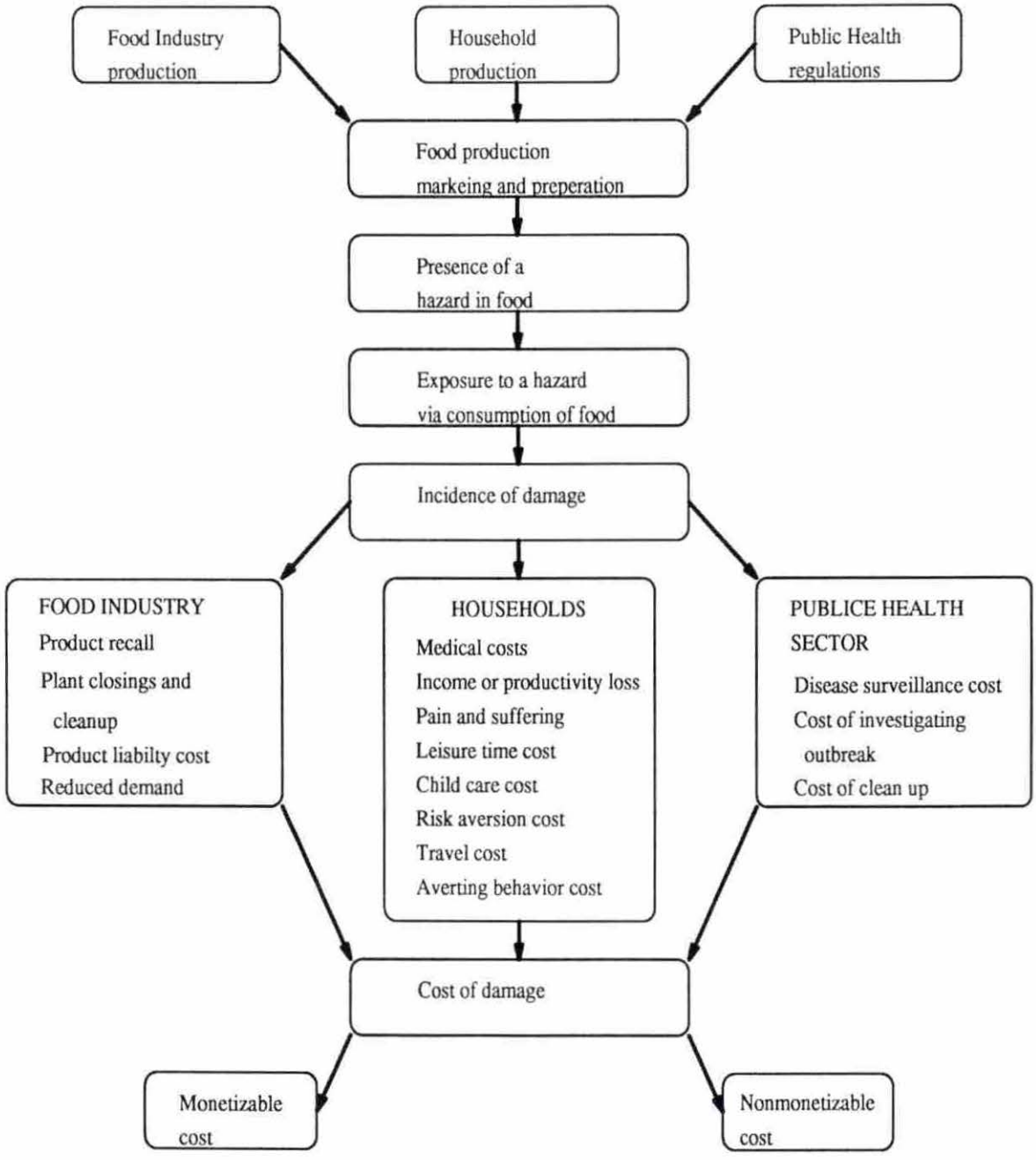

Figure 2.4: Costs from exposure to foodborne diseases

Source: Tanya Roberts, Poultry Science, 1988

The economic costs of human illnesses caused by Salmonella and Listeria have been used to extrapolate costs to other bacterial caused human illness costs of hundreds of million of dollars annually. Research estimated these human illness costs to be approximately $100 million or more [41]. Estimates could be enhanced by including factors other than medical costs and productivity losses as has been done by economists Curtin, Harrington, Krupnick, and Spofford who estimated value of non-work time directly and by Fisher, Chestnut et al. who used willingness-to-pay estimates of the value of a statistical life saved.

Compensation for pain and suffering and other psychic losses has been granted in courts. However, if pain and suffering expenses were also to be added to estimates, death and illness estimates would increase by over half a million dollars for each category. The costs incurred from exposure to foodborne diseases is graphed in Figure 2.4 [41].

Foodborne diseases rank seventh in importance in terms of disability days, eleventh for number of deaths, and fourteenth in economic costs to society of the seventeen disease categories, as stated by Mushkin. In light of such evidence it becomes imperative that we estimate human illness costs of food borne bacteria.

In using salmonella and listeria to extrapolate the economic costs of food borne diseases, they also represent diversity in foodborne diseases. Salmonellosis is typically of a mild severity, while lesteriosis cases usually require hospitalization. Cost estimates include medical and productivity losses excluding psychic costs as pain and suffering and leisure lost. Medical costs are the expenditures for physician, hospital, and related services plus drugs. Productivity losses are comprised of time loss from work evaluated at wage rate in case of listeriosis or at individual's wage reported in

a survey.

Four severity groups were identified under cases of salmonellosis and listeriosis. These being deaths, hospitalized cases, physician visits and mild cases [41]. The medical and productivity losses under each category of illness was estimated for 1987 data. The average costs per case of salmonellosis were estimated to be $372,000 in an event of death, $4,350 for hospitalized cases, $680 in an event of physicians visit and finally $221 for mild cases. Estimated cost per case over the four severity levels given outbreak data averaged $700.

In an event of lesteriosis, fetal/newborn cases resulting death were estimated to have an average cost of $1,100,000 per case. the costs for survivors was estimated at $71,000. Adult deaths averaged $281,000 and for those who survived the estimated average was $17,000. In situation of maternal illnesses the costs were estimated as $7,100 on average. The average cost, for all three populations, per lesteriosis averaged $135,000.

Extrapolating these cost figures to all other foodborne bacterial diseases, estimated medical and productivity costs for the year 1987 stood at a total of $4.8 billion [41].

Research by Berger evaluated the concern for use of sulfonamides in pork production in view of the frequency with which residues occur. There was an attempt to identify the point in the pork product chain that would be the most cost effective and efficient to intervene to reduce the incidence of sulfa residues. The FAPRI pork model was chosen to asses the changes in pork production, consumption, farm level prices and retail prices. The two main scenarios that were examined were:

1. A supply only shift resulting from a total ban of sulfamethazine in pork pro-

duction, assuming no substitutes exist to sulfa use.

2. A demand only shift resulting from a 5 percent increase in consumer demand, arising from a perceived improvement in the wholesomeness of pork products.

Alternatives discussed were:

1. A ban on sulfamethazine use implemented by the FDA
2. Increased testing by FSIS
3. Implementation of testing programs by pork processors, both pre- and post -slaughter.
4. Implementation of a "bill back" law that would allow processors to trace and charge sellers for animals that are violative.
5. Implementation of a selected supplier program by processors.
6. Implementation of output testing programs at the producer level.
7. Implementation of input testing programs at the producer level.
8. Implementation of a combination of input/output testing programs at the producer level.

A ban of sulfa use in pork production, by the FDA, would result in higher pork prices and reduced supplies. Producers would receive higher prices than before, however it was found to be hard to estimate if these higher prices were sufficient to compensate for the higher production costs. Also some pork producers would be driven out of the market due to increased production costs. Pork production

following these restrictions showed a decline by 1.43 percent under the base scenario at the end of ten years. Farm prices showed an increase of 4.96 percent over the base by the end of tenth year of pork production without the use of sulfamethazine. For the same analysis, pork retail prices increased 2.74 percent while pork consumption declined 1.38 percent over what it was projected to be without the ban.

An increase in demand by 1 percent in response to safer meat supplies indicated a decline of 1.16 percent in pork production at the end of ten years, while a 5 percent change in demand indicated almost negligible effects in pork production by end of tenth year. Farm prices increased 5.21 percent in response to an assumed 1 percent change in demand, while the change observed with a 5 percent change was a 6.20 percent increase. Pork consumption showed a decline of 1.10 percent in response to 1 percent change at the end of the tenth year and was negligible for a 5 percent change. Finally, the retail prices increased 3.53 percent for a period ten years into future with a ban on sulfa use for a 1 percent change in demand. For a 5 percent change this figure stood at 6.67 percent.

Increased testing by FSIS would also lead to increased retail prices and farm prices but could also lead to increased pork supply . In this scenario, tax dollars will have to be used in instituting this practice into the pork production chain.

Implementing either pre- or post-slaughter testing will lead to higher prices due to increased production as well as macro effects. Pork producers would be facing lower prices, although it was not clear if this was sufficient to offset the increase in prices resulting from macro effects.

The bill back proposal was estimated to have negligible effects on pork supply and demand. Also a careful analysis brought to question as to how to identify viola-

tors, and the relationship between producer and processor, if such a proposal gained acceptance.

The selected supplier program showed to lead to decreased pork supplies and higher prices at both farm and retail level where a majority of the cost was to be borne by producers.

The impact of the final three strategies depends on the producer participation. If a sufficient number of producers were to participate, consumers may perceive meat to be safer and demand more. As a result there would a decreased pork supply and increased pork farm and retail prices.

Berger's analysis revealed that the optimal solution is to institute a program of combination testing and management safeguard at producer level. It may be necessary to combine such a program with increased penalties from regulatory agencies or controls. This combination of strategies appears most efficient in control over residue violations at point of origin with least cost to any given group [3].

Substituting sulfamethazine with other drugs as alternatives in pork production is expected to have/create an economic impact. In the following chapters an attempt to identify these alternatives to sulfamethazine and conduct an economic comparison to study the economic effects is carried out.

CHAPTER 3. SULFA RESIDUES: A MANAGEMENT ISSUE

The use of sulfamethazine has brought two main questions to the forefront in the usage of antibiotics in food generating animals. The emergence of the residue issue with the use sulfamethazine as a feed additive in pig production has lead to the realization of potential problems associated with the use of antibiotics in food producing animals. The questions raised have been that of environmental contamination and feed cross contamination on hog and other animal raising farms.

Sulfamethazine has been linked with the environmental contamination of farms since sulfa is a compound that remains present in the environment and active for a long period of time. Contamination of water and the movement of sulfa contaminated water between pens poses a potential threat of environmental contamination and residue violations. Additionally, since sulfa granules tend to stick to grinder/mixer walls, there is a possibility of feed cross contamination. Issues such as this have led to the question of "Management techniques" in antibiotic and drug use on food producing animal farms. This chapter deals with the use of sulfamethazine and the management issues which have been developed to reduce the chance of residues.

Efficacy, applicability and economy (costs) are primary concerns of swine producers and veterinarians when treating respiratory diseases. The goal of acute respiratory disease treatment is to rapidly attain therapeutic levels of appropriate an-

timicrobials in the blood supply and affected tissues. The choice depends on drug sensitivity. Adding medication to water or feed is a popular method because it saves time and labor in addition to achieving rapid blood coverage. However, pigs with acute respiratory illness have severely curtailed feed and water consumption, resulting in sub-optimal levels of compounds in blood and tissue. Atrophic rhinitis is caused by *Bordetella brochiseptica*. Sulfamethazine, a sulfonamide, is a highly effective compound in the treatment of atrophic rhinitis.

When continuous low levels of antibiotics and sulfonamides are added to diets of pigs in affected herds, they help pigs maintain weight gain, minimize disease and the negative effects of the disease on growth rate and feed efficiency.

Preventive medication schemes are aimed at primary pathogens that cause chronic respiratory diseases. A sow/gilt passes atrophic rhinitis to offspring through respiratory aerosol exchange.

The greatest cost of swine pneumonia is due to increased feeding periods and development of "low-value" or "no-value" animals (CYANAMID, 1994). This has by and large resulted in the use of sulfamethazine as the feed and water additive in pigs to contain the respiratory problem because of good absorption and it's ability to remain in the body for extended periods of time. Thus, for the little water and feed the pigs may consume, sulfamethazine remains in the body for a longer period and is quite efficient in combating respiratory problem. No other drug shares this property of sulfamethazine leaving less effective alternatives which may add to the pork production costs if replaced. Moreover, expensive, long acting forms of antibiotics may increase the per pig medication cost and extend withdrawal times thus delaying marketing after removal of the product from the production process.

Thus, there are trade-offs with the use of sulfamethazine in pork production. While sulfamethazine can be continued to be used as before and benefits of its broad spectrum drug activity be realized, there are perceived risks of residue violation. Sulfamethazine residues have largely been the result of inappropriate management practices rather than by the use of sulfamethazine itself. The following present some of the inappropriate management practices followed by pork producing farmers which have caused or led to residue problems in pig meat.

1. Crowding: a large number of pigs in a confinement pen
2. Poor cleaning and washing of pig facilities
3. Not maintaining written records of medication
4. Use of powdered sulfamethazine
5. Following of "extra-label" and "off-label" practices

These management practices largely refer not to pig handling techniques but to facility management or environment management.

To effectively use sulfamethazine and gain best results, good management practices need to be followed. This may mean improved techniques for some producers. Studies indicate that crowding of pigs in confinement systems may lead to stress in pigs. Under stress, animals tend to loose their appetite for food and water. This makes water and feed medication less effective as a mode of treatment. Moreover, the animal becomes more susceptible to diseases. To cite an example would be where *Salmonella choleraesuis* organisms tend to become active under pressure or stress.

Poor appetite for feed and water supplemented by increased susceptibility to diseases influences the average daily weight gain and feed efficiency of the animal. It is also true that for the more congested herds, disease spread among the herd can quickly reach epidemic situations. For some producers poor environmental conditions have been offset to some degree through the the increased use of antibiotics and drugs in general. Eventhough antibiotics are more effective in poor environmental conditions, this is not the best practice to follow [1]. Regular cleaning of pens is a better management practice in reducing the chances of residue violations. It is important to clean the pens 4-5 days after the withdrawal of sulfamethazine. Additionally, medicated pigs should be moved to a new pen once the medicated feed has been withdrawn.

What is needed at many of the farms is to minimize water and manure movement between pens on the farm. Water and manure movement can cause recycling of excreted sulfamethazine. Winter periods tend to be a little less of a threat mainly because water and manure tend to freeze . However, severely low temperatures do not deactivate sulfamethazine, instead as the water and manure thaws, risk of residue violations reappear.

Sulfamethazine powder has the electrostatic property of getting charged and as a result if used in the feed grinder/mixer to prepare medicated feed, it tends to stick to the walls of the grinder. This may be a potential hazard especially if non-medicated feed mix was to be prepared using the same mixer/grinder. The non-medicated feed will tend to get contaminated by sulfamethazine thus recycling sulfamethazine back into swine's body. Better facilities needed to clean the mixer/grinder need to be maintained. One such way is to use a flush feed of 500 lbs to eliminate all the possible

sulfamethazine from the grinder [26]. Also, the use of granular form of sulfamethazine would be a much better since it does not have the property of getting charged as does powdered sulfamethazine.

It is wise to use at least 100-300 lbs of cracked corn or an amount equal to 5 percent of mixer capacity as feed flush in order to reduce sulfamethazine level in the mixer below a level sufficient enough to cause residue violations, as part of better management practices. It is also essential that farmers maintain dosage and medication records for easy reference and convenience. This will in part help reduce the incidence of residue violation.

Combining medications or using "off-label" is currently under review by the FDA. Combining drugs or using higher-than-labeled dosages can lead to reduced effectiveness, increase withdrawal time, and/or change the safety profile of the drugs in the animal. It is illegal for non-veterinarians to compound medications or use them in an off-label manner unless a veterinary-client-patient relationship is in place and the veterinarian has directed the producer to do so.

In summary, many residue violations faced in livestock production are a result of inappropriate management practices. It is estimated that no more than 25-30 percent of hog farmers are using sulfamethazine as a feed additive even though it offers economic benefits in terms of better feed efficiency and average daily weight gain (Dr. Teddi Wolff, 1994, private communication). Most farmers are giving up some of the economic benefits to stay away from the perceived danger of residue violation.

It has been suggested by many scientists that sulfamethazine may be substituted by sulfathiazole, especially since it belongs to the same family of sulfonamides and

thus, has the same pharmacological properties. Moreover, residue violations have not been shown to occur with the use of sulfathiazole since it is rapidly excreted from the pig's body. But this is also precisely the reason why we need approximately twice as much sulfathiazole as sulfamethazine to obtain results close to that obtained with the use of sulfamethazine(CYANAMID, 1994). Thus, to maintain therapeutic blood levels in swine, it is necessary that sulfathiazole be administered six times a day at approximately twice the recommended dosage for sulfamethazine. Also unlike sulfamethazine, sulfathiazole cannot be used as a water additive.

Thus, despite the fact that both sulfathiazole and sulfamethazine belong to the same class of broad spectrum sulfa drugs, they differ in their properties of absorption, excretion and solubility. Studies have concluded sulfamethazine to be a far more superior product in terms of effectiveness in combating swine diseases when compared to sulfathiazole.

Sulfamethazine in feed at sub-therapeutic level complements the treatment of many diseases. One of them is acute respiratory problems in swine, which pose extremely high economic costs in terms of treatment expenses, longer duration of stay in the pen,and slower achievement of market weight.

An effective and an efficient use of sulfamethazine is the use of sulfamethazine medicated feed during the starter or grower phase (i.e. upto 75 lbs of production). Beyond this weight level, sulfamethazine can be withdrawn in favor of aureomycin or terramycin. This will help farmers realize efficient and effective use of sulfamethazine, since it is an established fact that pigs respond the best to antibiotics and drugs during their initial growth stage. Younger pigs are more susceptible to disease and stress than older pigs because their immune system is still developing. As pigs grow

older, they develop greater immunological protection and are better able to cope with disease causing organisms in their environment.

A point made by some is that the declining use of sulfamethazine has coincided with an increasing incidence of "*Salmonella choleraesuis*". According to results obtained from a study conducted by CYANAMID and also Dr. Kent Shwartz of Iowa state University, a decline in the use of sulfamethazine between 1981-90 has coincided with a increase in incidence of *Salmonella cholerasuis*. The National Animal Health Monitoring services has estimated the cost of Salmonellosis in Iowa alone to be 27 million dollars annually. Salmonella is estimated to be the most costly problem facing hog producers today [44].

Salmonella cholerasuis can cause intestinal inflammation and respiratory problems. Pneumonia is very often cited as a result. *Salmonella choleraesuis* invades the blood stream and spreads throughout the tissues and lungs. The efficiency and use of sulfamethazine appears more evident in such a case since sulfamethazine effectively invades the bloodstream and rapidly spreads throughout the tissues and organs. Besides it is very well absorbed systemically. Sulfamethazine penetrates well into the lungs and provides an effective treatment. Drugs such as lincomix and carbadox etc. are very poorly absorbed and thus inefficient and uneconomical for treating systemic diseases.

Salmonella cholerasuis is estimated to have cost about 100 million dollars in the US during the period 1992-93 [44]. It is the most frequently found pathogen in growing and finishing pigs. It is estimated that 60-70 percent of the pig population today is infected with this pathogen. Stressful circumstances trigger the organism to develop and spread very rapidly. It is suspected that in many cases *Salmonella cholerasuis*

goes unnoticed and untreated because of it's subtle character, thus, causing even larger economic losses.

In an experimental study of the effectiveness of AUREO SP-250, a feed additive containing sulfamethazine, in the treatment of *Salmonella cholerasuis*, conducted by CYANAMID, pigs were broadly categorized under treatment group 1, i.e., the control group not fed AUREO SP-250 and group 2, i.e., the group receiving AUREO SP-250. The results were in favor of using AUREO-SP 250. Mortality rates due to *Salmonella choleraesuis* were observed to have declined by 83 percent for the group using AUREO SP-250 when compared to the control group. Group 2 observed 67 percent fewer scour days and 49 percent fewer septecemia days than group 1. The feed conversion rate for group 2 observed a 29 percent improvement over the control group. Also group 2 observed a 62 percent increase in average daily weight gain over the control group.

Recent studies have also shown a decline in the percentage of sulfamethazine residue violations. A residue violation of 0.61 percent has been observed to exist currently, which is much lower than the acceptable rate of 1 percent laid out by FDA (Dr. Teddi Wolff, 1994, private communication). This has been largely responsible due to the extensive education programs and better management practices. A rapid decline in the usage of the drug may be partly responsible for this low figure. Increasing use of screening tests which make detection easy have also helped reduce residue violations, since any residue violations implies economic costs to the producer.

CHAPTER 4. IDENTIFYING THE VIABLE ALTERNATIVES TO SULFAMETHAZINE IN PORK PRODUCTION

Sulfonamides have become an effective compound for use in the pork production. They are easily administered in feed and water, are economical to use and have proven to be effective for treatment of livestock diseases. Additionally, they promote and improve feed efficiency and average daily weight gain in herds. They are effective in treatment of atrophic rhinitis. Sulfamethazine or Sulfathiazole is also used for treatment of respiratory infections. Sulfamethazine and sulfathiazole being sulfonamides are broad spectrum compounds which are readily absorbed into and, slowly eliminated from the body.

However, recently the use of sulfamethazine in pork production has elicited concern and been associated by some individuals with development of bacterial resistance through gene transfer. The associated costs for both the producer and consumer affected by the resistance problem have been estimated to be high. Additionally there are associated economic costs of residue violation to the producer [3]. The use of sulfathiazole, however, as a feed additive in swine feed has not been plagued with accusations and controversy of bacterial resistance.

This chapter, analyzes in detail the various possible alternatives which could be used to replace sulfamethazine in swine production. Each will be evaluated as an

alternative to sulfamethazine in pork production.

Sulfamethazine has the property of being slowly excreted from the body of the animal. This is precisely the reason it is as effective as it is in it's use and in attaining effective therapeutic levels. However, this is also the reason why many of the residue violations occur with the use of sulfamethazine. Use of sulfamethazine has been suggested by some as a compound which can contaminate the animals environment. Sulfamethazine is used mainly as a feed additive in the form of Aureo SP-250 which contains 100 g/ton feed each of sulfamethazine and chlortetracycline, and 50g/ton feed of penicillin. Tylan 40-Sulfa G is also a feed additive containing sulfamethazine whose active ingredients are 40 g/lb of product of tylosin and 40 g/lb of product of sulfamethazine. Sulfamethazine helps maintain weight gains and feed efficiency in the presence of atrophic rhinitis.

The recommended dosage level for Tylan 40-sulfa G is 100 g/ton tylosin and 100 g/ton feed of sulfamethazine. At similar dosage levels, it helps in lowering incidence and severity of *Bordetella bronchiseptica* rhinitis, and the control of swine pneumonia caused by bacteria pathogens. It must be thoroughly mixed in feed before use, is not meant for use in finishing feed and has a withdrawal period of 15 days prior to slaughter. At the onset the criteria for selection of the possible alternatives needs to be established. This implies understanding the properties of sulfamethazine.

Sulfamethazine is an effective drug which helps combat both systemic and enteric diseases. Swine diseases can be broadly categorized as systemic and enteric. Enteric diseases primarily involve the gastrointestinal tract (gut). Systemic diseases involve blood, tissues and organs. Symptoms of systemic disease may involve coughing, respiratory disease, difficulty in walking etc. Indications for an enteric disease include

animal diahrrea (scours). Salmonella is of special interest in that it begins as an enteric disease but rapidly progresses to be a systemic disease.

Feed additives and water solubles can also be classified as being either systemic or enteric in action. Since all feed additives are administered orally they have some enteric activity. Systemic activity, however, requires that medication be absorbed through the wall of the gut and be carried to effected tissues and organs via the bloodstream. For effective disease prevention and or control , it is necessary that a drug be first absorbed and then attain effective concentrations at site of action.

Effective use of feed additive and water soluble compounds and their selection requires that the therapeutic goal be first identified and then it be determined whether the purpose of medication is to prevent/control or treat an enteric or systemic disease. This will guide in our selection of the appropriate enteric or systemic medication. An understanding of comparative blood and lung concentration level of the compound can further guide our selection. It is also useful to know the sensitivity of the organism. An understanding of comparative sensitivities may also help in the determination of the appropriate medication. Withdrawal times should be noted and followed to avoid residues. Lastly, it is important that before a choice be made on the compound for using as a feed additive, that it be cost effective and provide a positive return on investment.

In searching for an alternative , it thus becomes important to identify the properties of the compounds such that they come the closest in serving the purpose of replacing sulfamethazine. This implies that the alternative compounds be well absorbed both systemically and enterically. Slow excretion from the body would provide an added advantage. The remaining part of this chapter evaluates the properties of

the other drugs which may be considered as alternatives to sulfamethazine use in swine production.

CSP 250/Aureozol: The active ingredients of CSP 250/Aureozol are 100g/ton feed of chlortetracycline, 100 g/ton feed of sulfathiazole and 50 g/ton feed of Penicillin.

The main difference between Aureo SP-250 and CSP-250/Aureozol is the substitution of sulfamethazine with sulfathiazole in CSP-250. Broadly speaking since both sulfamethazine and sulfathiazole belong to the same family of sulfonamides, sulfathiazole is expected to be atleast as effective as sulfamethazine. However, since sulfathiazole is excreted more rapidly from the host body, CSP 250/Aureozol is not as effective as Aureo SP-250. Thus, eventhough sulfathiazole is broad spectrum and as well absorbed systemically as sulfamethazine, it is not a perfect alternative to sulfamethazine. Currently, CSP-250/Aureozol is used for reducing cervical abscesses and in the treatment of swine entiritis. Sulfathiazole helps maintain weight gain in presence of atrophic rhinitis besides promoting feed efficiency and average daily weight gains. CSP 250/Aureozol is beneficial in the treatment of swine raised in confinement.

The withdrawal period for sulfathiazole is 7 days and no issues of residue violation have emerged with it's use. To achieve desired performance, animals should consume indicated rations in minimum amounts.

Prestarter: for a body weight of 20 lbs, minimum daily feed intake is to be 1.0 lb. For starters weighing 50 lbs, minimum daily feed intake is 1.5 lb. For grower with weight level of 80 lbs, the feed intake is 2 lbs and for finisher weighing 150

lbs, the minimum feed intake is 3 lbs.

Denagard: the active ingredient is tiamulin at 10 g/lb of product. It is used in the control of swine dysentery and its usage level is 35 g/ton feed. A withdrawal period of 2 days needs to be followed. Denagard is also used as a growth promotant in starter grower feeds at a level of 10 g/ton of feed with no withdrawal period prior to slaughter. However, Denagard is not for use as an undiluted feed premix and in swine weighing greater than 250 lbs. Alternatively, with the emergence of toxicity, it's use needs to be discontinued.

Mecadox: The active ingredients are carbadox at a level of 10 g/lb of product. It is used for controlling swine dysentery/bacterial swine entiritis.

It's use promotes feed efficiency and rate of weight gain.

Mecadox can be used up to levels of 2.5 g/lb product in swine supplements used for producing complete feeds containing not less than 15 percent crude protein. 5 lbs/ton of complete feed is used for the treatment of swine dysentery/entiritis. Mecadox also promotes feed efficiency and aids in the improvement of average daily gain.

Mecadox is not meant for use in swine weighing greater than 75 lbs. and in feeds containing less than 15 percent crude protein. The withdrawal period is 70 days prior to slaughter.

Mecadox has proven effective in controlling scours and promoting improved growth. There are however, cost prohibitions with the use of mecadox, it is extremely expensive to purchase. In terms of absorption mecadox is not well

absorbed systemically, i.e., it does not penetrate effectively into the blood tissues and lungs.

Experiments with more than 7000 pigs have shown mecadox to be a superior drug in the control of scours and highly effective in enhancing growth in comparison with some of the other drugs [17].

Neo-Terra 20/20: Active ingredients are terramycin (oxytetracycline) 20 g/lb product and neomycin sulfate at 20 g/lb product. It is used in swine (baby/growing-finishing) for preventing and treating bacterial entiritis, baby pig diahrrea, salmonellosis, vibrionic and bloody dysentery. The recommended dosage level for prevention is 50 g terramycin/ton feed and 35 g/ton feed of neomycin. At treatment levels the recommended dosage is terramycin 100 g/ton feed and 70 g/ton feed for neomycin.

Neo-terra aids in weight gain and feed consumption in presence of atrophic rhinitis. Also, it aids in the treatment of bacterial entiritis. Neo-terra is used in dry feeds only and follows a 5 day withdrawal time prior to slaughter.

Terramycin is a broad spectrum drug, effective against diseases caused by susceptible gram positive and gram negative bacteria.

Neomycin on the other hand is effective in treatment of scours and gram negative bacteria including *E. Coli* and salmonella.

Neo-terra 50/50: Active ingredients are neomycin sulfate and terramycin at 50 g/lb product each. It is used as prevention and treatment of bacterial entiritis/baby pig diahrrea, vibrionic dysentery and salmonellosis. It aids in maintainence of weight gains and feed consumption in presence of atrophic rhinitis.

It may be used as a dry feed only and a 5 day withdrawal period prior to slaughter needs to be observed.

Aureomycin: contains chlortetracycline only. A dosage of 10-50 g/ton feed is used to promote growth and improve feed efficiency. At levels of 50-100 g/ton feed it prevents scours/swine entiritis and helps maintain weight gains in presence of atrophic rhinitis and reduces cervical abscesses. This dosage level is also sufficient to prevent bacterial entiritis during stress. At a level of 100-200 g/ton feed, chlortetracycline is used as a treatment of scour while a level of 200 g/ton feed simply helps reduce spread of leptospirosis. A dosage of 400 g/ton feed may be used in the starter phase as the sole medication for no more than 14 days. There is no withdrawal period for aureomycin.

Lincomix 50: Lincomycin at 50 g/lb of product is the active ingredient. It helps in controlling swine dysentery and reducing severity of swine mycoplasmal pneumonia. Lincomix also promotes rate of weight gain in growing-finishing swine.

Recommended dosage is at 100 g/ton of complete feed as ration for 3 weeks in treating swine dysentery. In a situation of swine dysentery where there is a history of dysentery but the symptoms have not yet appeared, a dosage level of 40 g/ton as the sole ration is effective while at 20 g/ton of complete feed as sole ration it promotes weight gain from weaning to market weight.

At a level of 100 g/ton feed until symptoms of swine dysentery disappear and then follow it up with 40 g/ton of feed is an effective means of treating swine dysentery.

Use of lincomycin feed is followed by diahrrea/swelling of arms within the first

two days. This is usually self correcting. Lincomix is not for use in swine weighing greater than 250 lbs. A withdrawal period of 6 days prior to slaughter needs to be observed.

It is extremely important that the feed additive be thoroughly mixed before use. Cleanout procedures are important to avoid cross-contamination of feed.

Strep-Pen: 75 g/lb of product of streptomycin and 25 g/lb of product procaine penicillin constitutes this combination which is used as a growth promotant and to increase feed efficiency at a level of 7.5 g/ 1.5 ton feed. At levels of 37.5 g/ 7.5 ton feed, it aids in prevention of bacterial entiritis and at levels of 75 g/ 15 ton feed it treats swine entiritis.

Tylan 40: This drug contains 40 g/lb of product of Tylosin. It helps maintain weight gains and feed efficiency in the presence of atrophic rhinitis. Increased rate of weight gain and feed efficiency is achieved by the use of this drug. The drug is also used in the prevention of, treatment and control of swine dysentery. It is essential that the drug be mixed in feed before use.

Most alternatives listed here have a withdrawal time period established by guidelines prescribed by the FDA. It is important that these withdrawal periods be observed by users to keep violative residues at a minimum. This is true for all drugs listed with withdrawal periods and not only sulfamethazine.

Absorption and excretion differences cause some systemic feed additives or water solubles to provide greater and higher concentration and absorption in the blood and lung tissue thus providing better respiratory disease prevention and control.

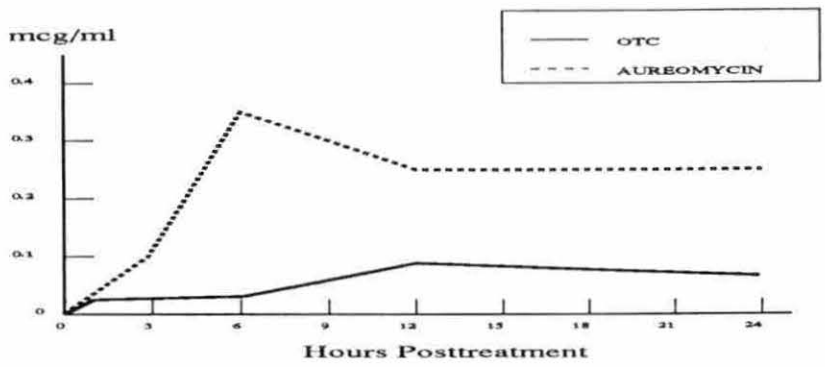

Figure 4.1: Aureomycin and terramycin levels in swine plasma

Source: CYANAMID

An attempt to understand systemic absorption between aureomycin and terramycin revealed aureomycin concentrations in plasma and lung tissues to be much higher than terramycin (oxytetracycline) when fed in drinking water or as a feed additive. This can be seen in Figures 4.1 and 4.2. This level remained far beyond two days post-treatment.

A study measuring aureomycin and terramycin levels in swine blood and lung tissues until seven days post-treatment, Figures 4.3 and 4.4, also indicate higher levels of aureomycin at all times. In comparing aureomycin with terramycin thus, it became clear that there is a better systemic absorption and concentration in blood with aureomycin. A similar analysis between sulfamethazine and sulfathiazole for blood and lung levels indicated a higher sulfamethazine concentration as is indicated in Figure 4.5 and Figure 4.6.

A study of "Comparative Efficacy of Sulfathiazole and Sulfamethazine in feed for *Bordetella bronchiseptica* infection in Swine" by Kopland, Gale, Maddock, Graces

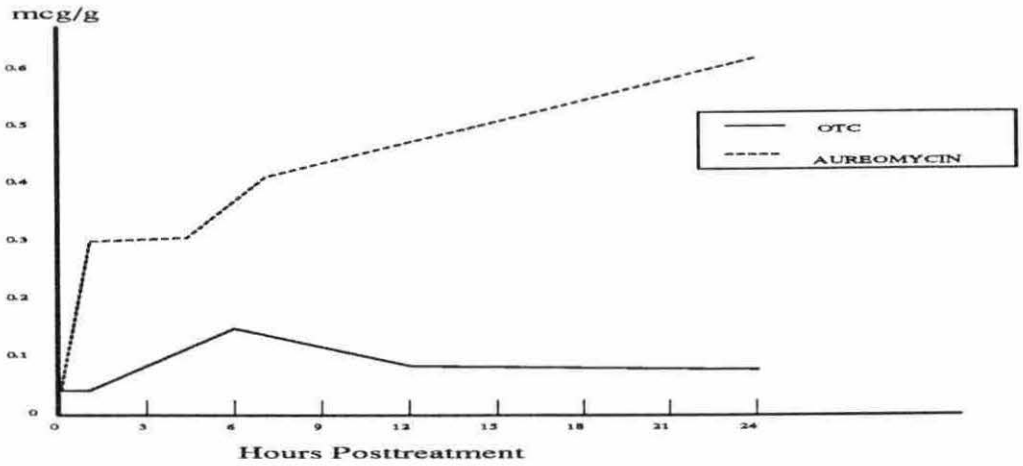

Figure 4.2: Aureomycin and terramycin levels in lung tissue

Source: CYANAMID

and Simpkins concluded that *Bordetella bronchiseptica* isolation rate decreased faster in sulfamethazine group than in the sulfathiazole group. By day 42, sulfamethazine-medicated pigs were negative for *Bordetella bronchiseptica*, whereas 8-17 percent of sulfathiazole medicated pigs were positive between day 42-56 (Figure 4.7). Turbinate spacing averaged 11 percent less in sulfamethazine than in sulfathiazole treated group (CYANAMID, 1994).

In an experiment carried out by CYANAMID which studied the comparative efficiency of Aureomycin and Aureo SP-250 in prestarter and starter diets of weaned pigs, the average daily gain of pigs under Aureo SP-250 increased 24 percent compared to the control group, 4 percent faster than group fed aureomycin at 400 g/ton for the first 14 days and 200 g/ton for the next 28 days and 10 percent faster than experimental group fed 200 g/ton of aureomycin (Figures 4.8 and 4.9). The feed/gain in Figure 4.10 shows an increase of 10 percent with Aureo SP 250 and there was also a 27 percent improvement in total pounds of pork produced.

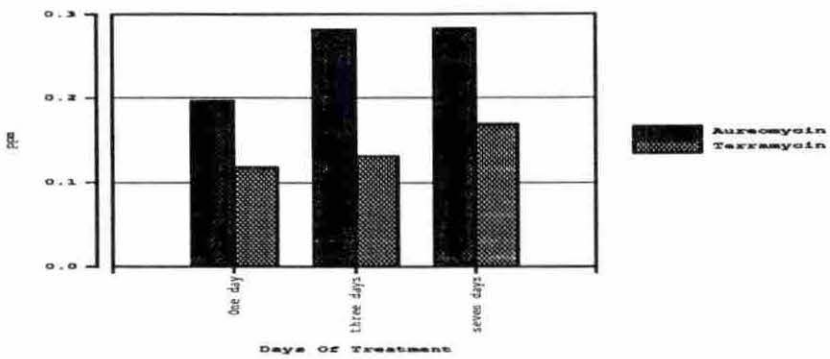

Figure 4.3: Aureomycin and terramycin levels in swine blood

Source: CYANAMID

Upon comparison, it can be concluded that sulfamethazine is a superior drug when compared over any other drug such as aureomycin, terramycin and sulfathiazole when looking at rate of gain and feed efficiency. Since a primary use of sulfamethazine is in treating respiratory ailments which requires rapid systemic absorption and concentration, we can eliminate all possible alternative compounds except aureomycin, sulfathiazole and terramycin as alternatives to sulfamethazine. (Figure 4.11).

Thus, in analyzing the possible alternatives to sulfamethazine it is encoded that none of the alternatives really serve as a perfect substitute. Most alternatives discussed at the beginning of the chapter appear to serve the purpose of promoting growth and feed efficiency as well as maintaining them under conditions of atrophic rhinitis. It should be noted that although growth promoting functions are well performed by alternatives, they are not as efficient as sulfamethazine. However, an important use of sulfamethazine, is its use in treating and preventing respiratory ailments which requires the drug to be well absorbed systemically. Fewer compounds

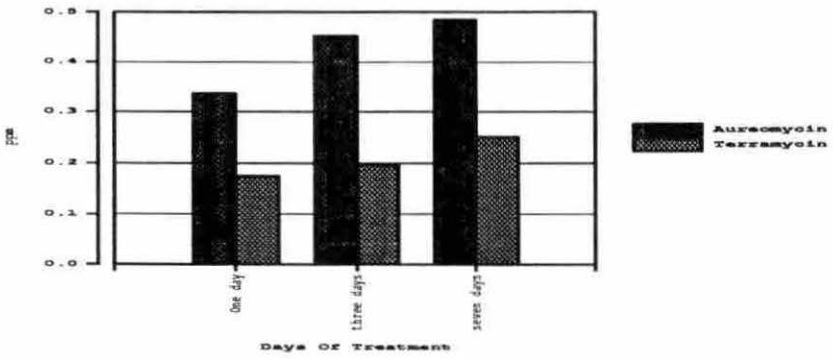

Figure 4.4: Aureomycin and terramycin levels in swine lung tissues
Source: CYANAMID

serve as alternative in this function.

In concluding briefly, alternatives exist for the growth promoting function of sulfamethazine in swine. These include:

1. Sulfathiazole (CSP 250/Aureozol),
2. Neomycin-Oxytetracycline combination (Neo-Terra),
3. Carbadox (Mecadox),
4. Lincomycin (Lincomix),
5. Chlortetracycline (Aureomycin),
6. Tylosin (Tylan),
7. Tiamulin (Denagard), and
8. Strep-pen combination

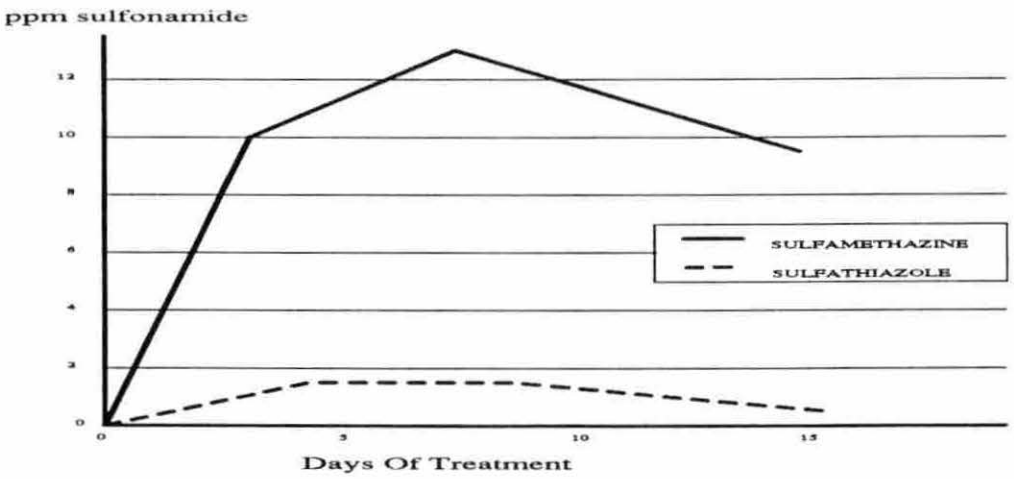

Figure 4.5: Comparative sulfa concentrations, Blood levels, ppm

Source: CYANAMID

However, our analysis also indicates that theoretically except for chlortetracycline, sulfathiazole and oxytetracyline none of the other drugs are well absorbed systemically eventhough they are well absorbed enterically. This would severely restrict our selection of alternatives since an important property of Sulfamethazine is that it is well absorbed systemically. The alternatives need to meet this condition as well.

Thus, it is concluded that the alternatives for analysis are:

1. Chlortetracycline,

2. Oxytetracycline, and

3. Sulfathiazole

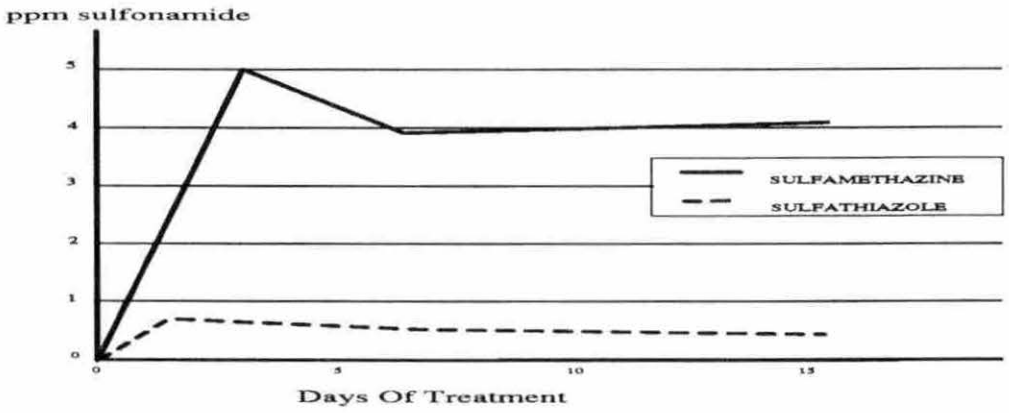

Figure 4.6: Comparative sulfa concentrations, Lung levels, ppm

Source: CYANAMID

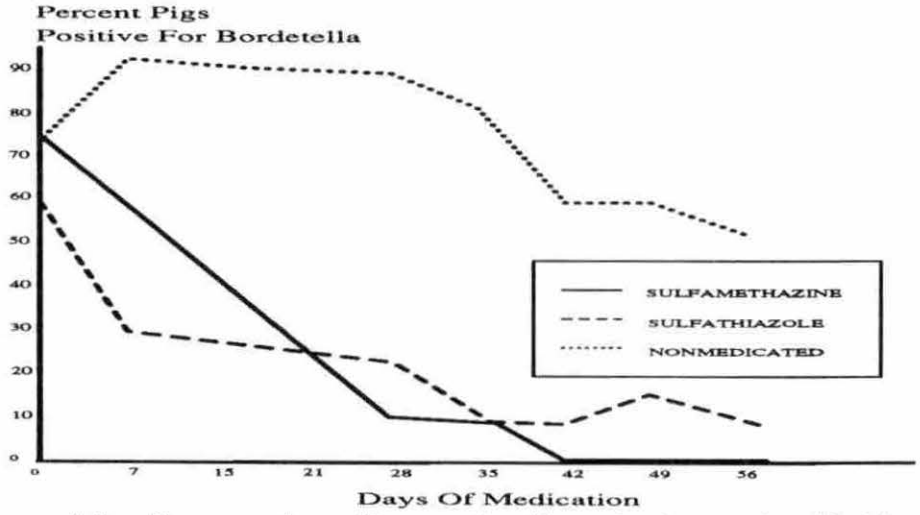

Figure 4.7: Comparative efficacy of sulfamethazine and sulfathiazole in treating Bordetella bronchiseptica

Source: CYANAMID

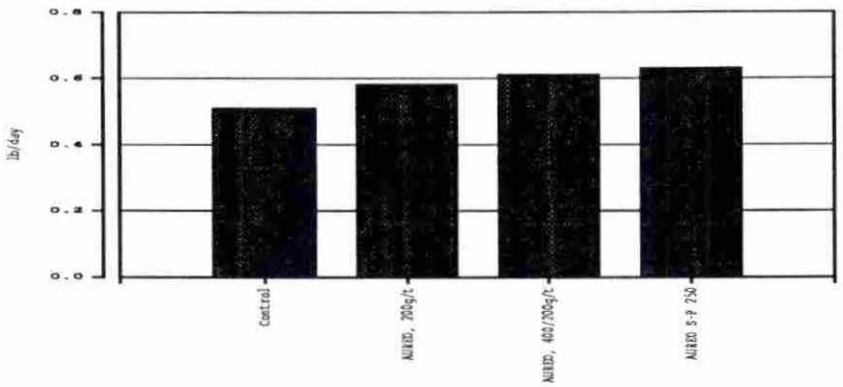

Figure 4.8: Average daily gain of starter pig

Source: CYANAMID

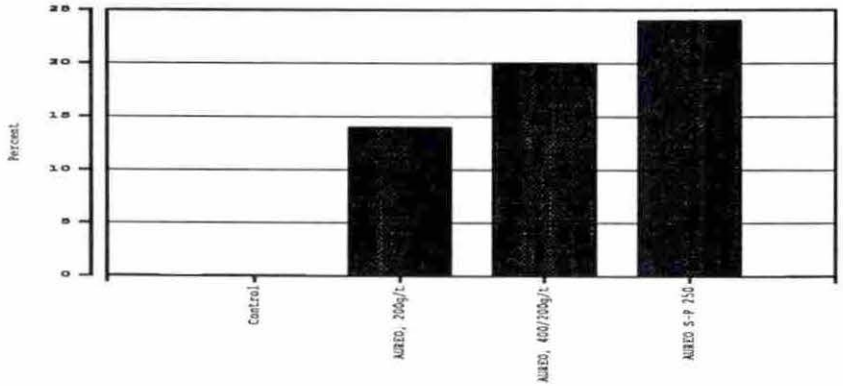

Figure 4.9: Average daily gain of starter pig (percent)

Source: CYANAMID

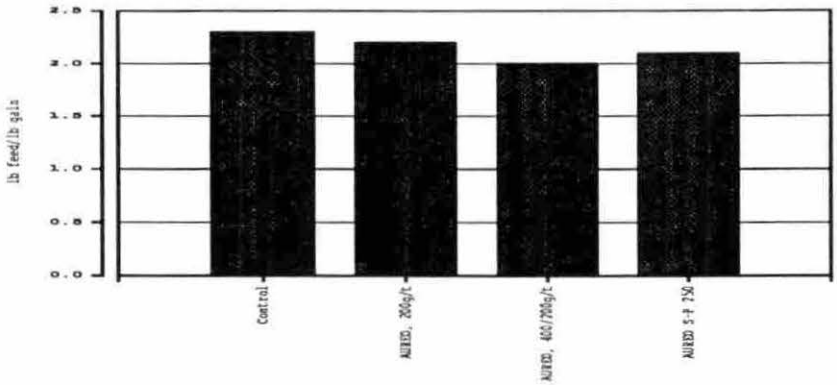

Figure 4.10: Feed/Gain of starter pigs

Source: CYANAMID

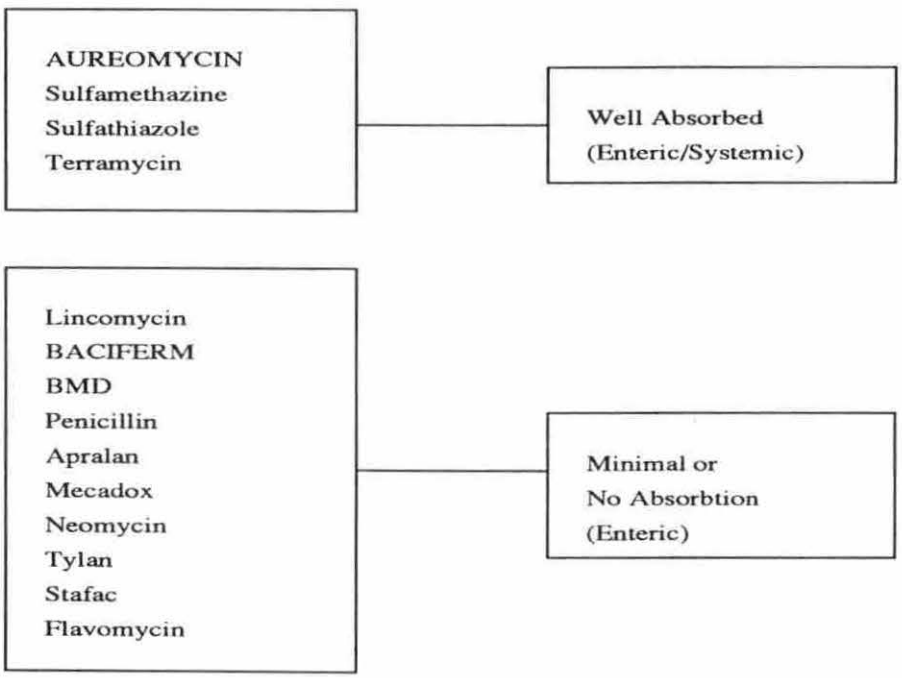

Figure 4.11: Comparative absorption chart for swine feed additives

Source: Veterinary Pharmacology and Therapeutics

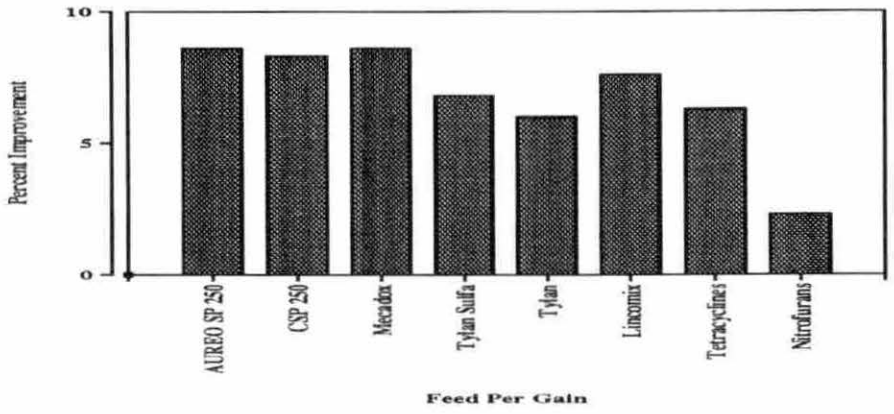

Figure 4.12: Response of pigs to antibiotics during the starter stage (Hays Report)

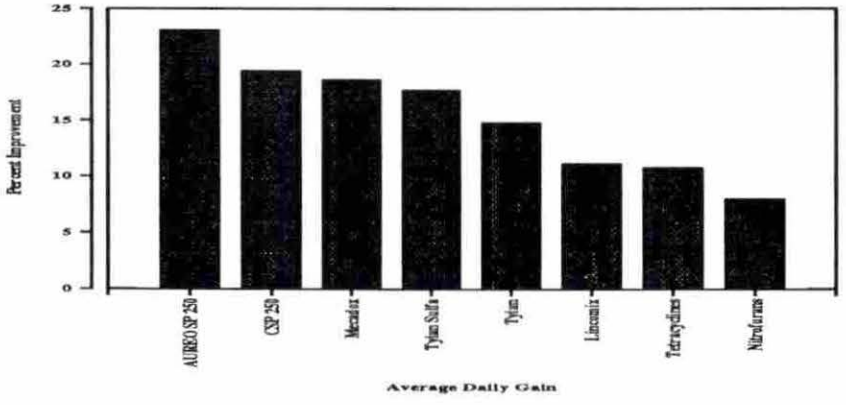

Figure 4.13: Response of pigs to antibiotics during the starter stage (Hays Report)

Although not as well absorbed systemically tylosin and lincomycin are being used as alternatives to sulfamethazine in the treatment of atrophic rhinitis, because of their observed effectiveness in treating and preventing the disease. Thus, this report will incorporate tylosin and lincomycin also as alternatives to use of sulfamethazine in pork production for purposes of economic comparison.

The Hays report measured the response of pigs to antibiotics during the starter stage on more than 20,000 pigs and estimated average responses. The results of this analysis are graphed in Figures 4.12 and 4.13. The report concluded that the response of pigs during the starter stage was maximum in response to Aureo SP 250 both in terms of feed efficiency as well as average daily gain.

CHAPTER 5. FAPRI PORK MODEL

This study uses the Food and Agricultural Policy Research Institute (FAPRI) annual econometric model of the U.S. livestock sector. The model aids in comprehensively synthesizing data and causal relationships. The model can be used for analyzing changes in policy, technology, structure and forecasting. This model is used as part of the project to analyze and quantify the effect of a ban on sulfamethazine in pork production, while at the same time, allowing similar products to be used as alternatives. Attached as Appendix to the study can be found a concise summary of the model equations and the variable names.

5.1 Model documentation

The U.S hog industry has undergone dramatic structural changes as the trend for fewer producers continues with increased enterprise size. Technology-intensive production practices and techniques, efficient use of inputs and improved disease control measures have enabled producers to attain more production per sow, more production per unit housing, and lower feed costs [27].

The use of antibiotics, technology and capital intensive confinement systems has along with management changes enabled year round production of hogs and lessened the seasonal component that historically existed in hog production. Supplements used

in pork production, such as antibiotics, have also aided in these shifts. However, even with more captial intensiveness pork production remains regionally concentrated. Seventy percent of the production is concentrated in the corn belt states. There has been some significant growth in production in the southeast, especially in North Carolina, but their production is still small relative to the overall corn belt states. Production is dominated by the farrow-to-finish operations, with producers retaining control over the entire production phase from breeding to birth to slaughter [27].

However, even as these changes have occurred in hog production, the biological nature of growth process has remained unchanged even when litter rate, feed efficiency, and the time of weaning have changed.

5.2 Model overview

Economic and other complex relationships between variables are built into the FAPRI pork model by means of regression equations. The model merits some explanation which would better enable us to understand these relationships and the results obtained. Figures 5.1 and 5.2 present an overview of how the supply and demand interact in the FAPRI model at both the farm and retail level.

The supply estimates recognize that current supply is conditioned on past breeding decisions. The size of the breeding herd determines the industry's production capacity. The stages of production fall sequentially from the determination of the breeding herd size.

Producers usually expand the breeding herds by retaining gilts and/or sows from slaughter in response to investment decisions which entail higher pork production. This investment decision is reflected by the number of hogs entering the breeding

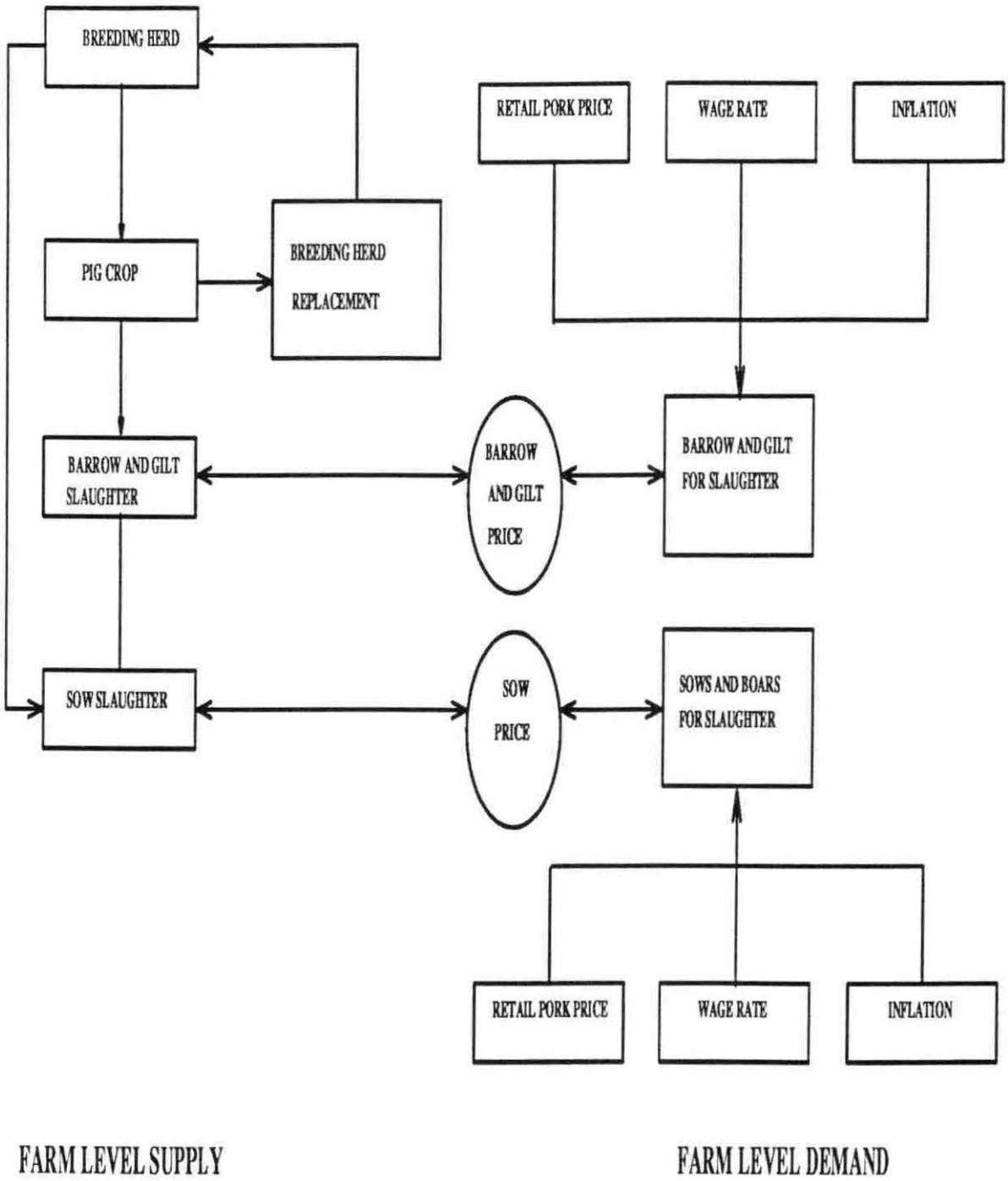

Figure 5.1: Farm level

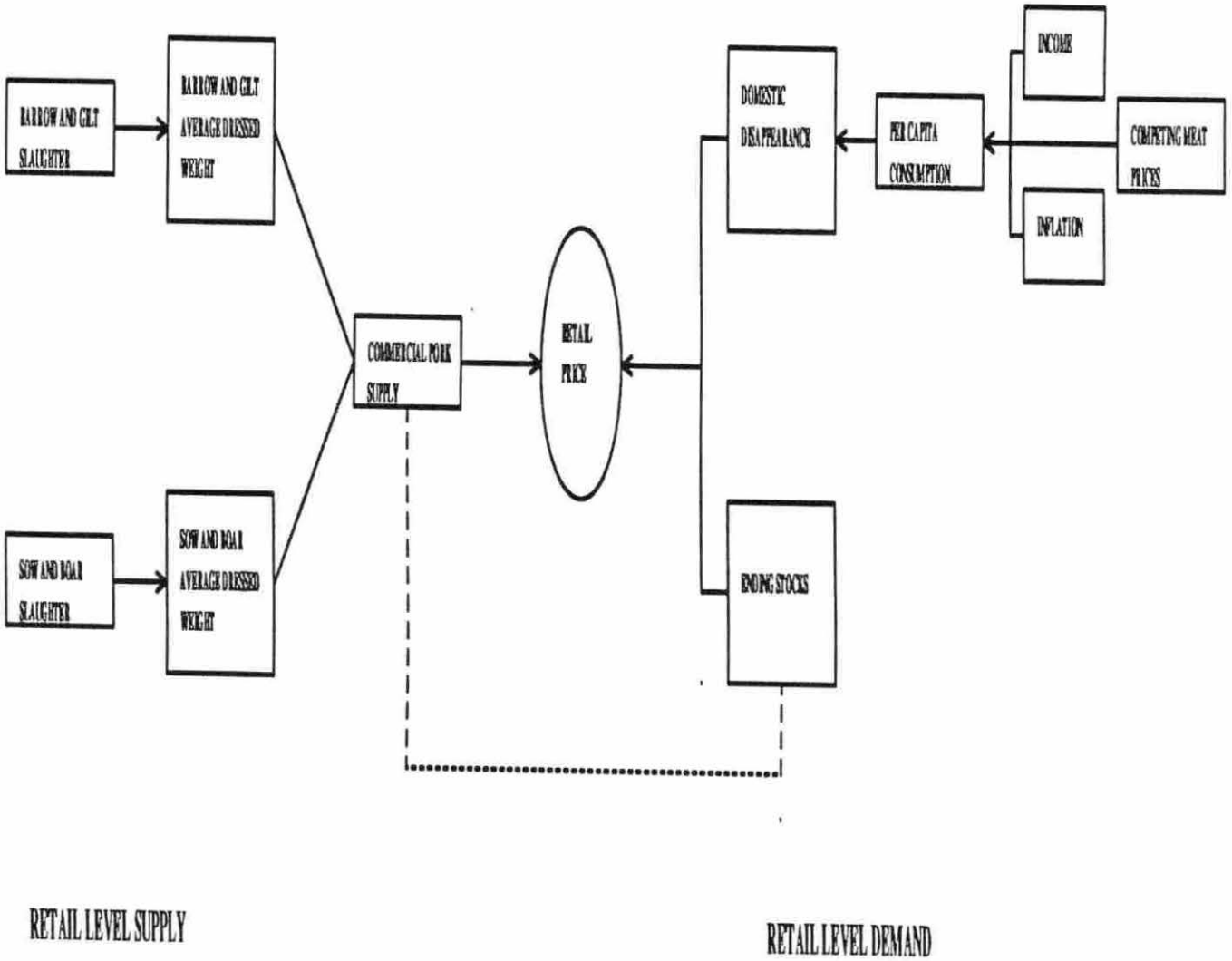

Figure 5.2: Retail level

herd and the number of sows retained in the breeding herd. During expansion, sows may be retained in the breeding herd even with reduced productivity. A higher rate of sow slaughter indicates disinvestment decisions by producers. The net difference between sow additions and sow slaughter reflects the changes in the breeding herd.

The size of the breeding herd determines the size of the pig crop. The pig crop is either finished and slaughtered or retained for breeding purposes. Barrow and gilt slaughter is determined by the size of the pig crop. Sow slaughter, is determined by the size of the breeding herd and the incentives to invest or disinvest.

Total pork production is determined by sum total number of sows and boars slaughtered as well as the total number of barrows and gilts slaughtered, which includes hogs imported for slaughter.

The lag structure in the supply block is governed by the biological timetable in sequential phases of the production process. These biological relationships inherent in pork production are incorporated in the behavioral equations, placing the restraints on supply response. The supply response is governed by time lags in breeding, gestation, birth, finishing and slaughter. Also the supply response is a function of producer investment decisions. This need to identify and incorporate the biological restrictions in pork supply were first identified and incorporated by Johnson and MacAulay in a quarterly beef model, 1982 [27].

The pork demand block represents consumer behavior and response. Pork is compared with other meats such as chicken and beef in formulating the decision to consume.

The equilibrium of retail supply and retail demand determine retail price for pork. Since supply cannot respond immediately to increases in price due to the

Table 5.1: U.S. pork supply and utilization

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Hogs on Farms						(Million Head)					
Market Hogs(Dec.1)	51.0	49.8	50.4	50.7	51.5	51	49.9	50.2	51.9	51.8	51.4
Breeding Hogs(Dec.1)	7.3	7.03	7.07	7.26	7.33	6.87	6.63	6.98	7.04	6.81	6.60
Total Hog Slaughter	94.9	93.0	91.2	93.9	96.6	95.5	93.1	95.2	97.6	95.6	95.0
						(Million Pounds)					
Supply	18,267	18,200	17,613	18,173	18,697	18,655	18,234	18545	18,945	18,571	18,401
Beginning Stocks	388	385	375	354	380	400	380	367	391	408	381
Imports	645	720	700	687	688	730	743	668	541	529	526
Production	17,234	17,095	16,538	17,131	17,649	17,525	17,111	17,509	18,014	17,634	17,495
Disappearance	17,882	17,825	17,259	17,793	18,297	18,275	17,867	18,154	18,537	18,191	18,024
Domestic Use	17,475	17,413	16,859	17,381	17,865	17,905	17,510	17,722	17,978	17,620	17,450
Exports	407	412	400	412	432	370	357	432	559	571	574
Ending Stocks	385	375	354	380	400	380	367	391	408	381	377
Per Capita Consumption						(Pounds)					
Carcass Weight	68.4	67.4	64.6	66.0	67.1	66.7	64.6	64.8	65.2	63.3	62.2
Retail Weight	53.1	52.3	50.1	51.2	52.1	51.7	50.1	50.3	50.5	49.1	48.2
Change	5.4%	-1.5%	-4.2%	2.1%	1.8%	-0.7%	-3.1%	0.3%	0.6%	-2.8%	-1.8%
Prices											
230-250 lb											
Iowa Southern Minnesota						(Dollars Per Hundredweight)					
Barrows and Gilts	43.03	46.07	48.53	45.83	42.11	45.79	49.83	47.06	44.05	46.82	50.19
Change	-13.4%	7.1%	5.3%	-5.6%	-8.1%	8.8%	8.8%	-5.6%	-6.4%	6.3%	7.2%
6 Market Sows	34.00	37.07	35.46	32.55	33.85	35.55	34.17	31.77	33.21	34.76	
Change	-18.3%	9.0%	0.5%	-4.8%	-8.2%	4.0%	5.0%	-3.9%	-7.0%	4.5%	4.7%
						(Dollars Pounds)					
Pork Retail	1.98	1.98	2.00	1.96	1.89	1.95	2.02	1.99	1.94	2.04	2.13
Change	-6.6%	-0.2%	1.2%	-1.7%	-3.8%	3.3%	3.4%	-1.6%	-2.6%	5.2%	4.6%
Net Returns						(Dollars Per Hundredweight)					
Farrow - Finish	1.28	3.73	4.48	3.36	-0.62	2.33	6.15	2.42	-1.21	0.68	2.70

biological lags in the production process, prices respond more to changes in demand in the very short run.

Included is the baseline results obtained from the model. This is given in Table 5.1. Results from this table are used as baseline levels for purpose of our study in the next chapter.

5.3 Farm level equations

The pork model is broken down into the farm level supply and demand and retail level supply and demand. At the farm level, two behavioral equation capture the demand for sows and the demand for barrows and gilts. Supply and demand

at the farm level is quoted live animals while at the retail level supply and demand refers in terms of the processed product.

5.3.1 Farm level supply

The supply of hogs and pigs are determined by the following relationships at the farm level:

1. Cost of production equations
2. Number of breeding hogs on the farm
3. Number of market hogs on the farm
4. Pig crop
5. Sow and boar slaughter
6. Barrow and Gilt slaughter

The cost equations determine investment and disinvestment decisions of producers. Net returns on pork are an indication about the health of the pork industry. Based on figures obtained for net returns, the producers decide to invest or disinvest in the pork market. The cost equations are estimated as:

1. Pork, Cost of production, Slaughter hog receipts

$$\begin{aligned} \text{CPPKSLHG} = \quad & -1.28 \\ & + 0.957 * \text{PKBAGPM} \end{aligned}$$

2. Pork, Cost of production, Cull sow receipts

CPPKCLSW = 10.91
+ 0.066*PKSOWPM
- 1.377*PKPIGLIT
- 0.469*D801234

3. Pork, Cost of production, cash expense for grain

CPPKGRAN = - 1.678
+ 4.042*CRPFRM(-1)
+ 2.978*CRPFRM

4. Pork, Cost of production, Cash expense for protein supplements

CPPKSUPP = 3.529
+ 0.042*SMP44D(-1)
+ 1.713*D734

5. Pork, Cost of production, Cash expense for veterinary and medicine

CPPKVET = 0.067
+ 0.005*PPIW
+ 0.058*D756

6. Pork, Cost of production, Cash expense for livestock hauling

CPPKHAUL = 0.024
+ 0.001*PPICFULW
+ 0.032*SHIFT86

7. Pork, Cost of production, Cash expense for marketing

$$\begin{aligned} \text{CPPMARK} = \quad & 0.067 \\ & + 0.002*\text{PPIW} \\ & + 0.001*\text{PKBAGPM} \\ & + 0.044*\text{DUM78} \end{aligned}$$

8. Pork, Cost of Production, Cash expense for bedding

$$\begin{aligned} \text{CPPKBED} = \quad & - 0.005 \\ & + 0.001*\text{PPIW} \\ & + 0.039*\text{DUM81} \end{aligned}$$

9. Pork, Cost of production, Cash expense for fuel, lube, and electricity

$$\begin{aligned} \text{CPPKFLE} = \quad & 0.166 \\ & + 0.018*\text{PPICFULW} \\ & + 0.327*\text{SHIFT86} \end{aligned}$$

10. Pork, Cost of production, Cash expense for repairs

$$\begin{aligned} \text{CPPKREP} = \quad & 0.193 \\ & + 0.020*\text{PPICMETW} \\ & - 0.166*\text{DUM88} \end{aligned}$$

11. Pork, Cost of production, Cash expense for hired labor

CPPKLABR = - 0.212
+ 0.166*ZWRHP20W
+ 0.091*D845

12. Pork, Cost of production, Cash expense for manure credit

CPPKMANU = - 0.058
- 0.0008*PPICHMW
- 0.0006*PPICPETW

13. Pork, Cost of production, Cash expense for general farm overhead

CPPKGFO = - 0.279
+ 0.025*PPIW
+ 1.504*D867
+ 0.508*SHIFT88

14. Pork, Cost of production, Cash expenses for insurance and taxes

CPPKTAX = 0.225
+ 0.0004*FIVLAND
+ 0.002*ZTXCBSPW
+ 0.115*DUM85

15. Pork, Cost of production, Cash expense for interest

CPPKINT = 0.738

+ 0.011*(CPPKEXP*ZINTAAA)

+ 2.417*DUM82

+ 2.407*DUM86

16. Pork, Cost of production, Cash expense for capital replacement

CPPKCAPR = 1.937

+ 0.037*PPIW

- 1.623*DUM74

+ 1.136*DUM79

The number of breeding hogs on the farm is an identity equal to 99 percent of the number of breeding hogs on the farm in the previous year plus gilts added to the breeding herd less the sows slaughtered. This identity is given by the following equation in the model:

PKHOGNBR = 0.99*PKHOGNBR(-1) + PKGLTADD - PKSOWKS

Where, PKGLTADD is a behavioral equation which provides gilts added which is representative of the investment decisions of producers. This equation is identified in the model as:

Hogs, Number of breeding hogs added to herd

PKHOGNBR - PKHOGNBR(-1) = - 3132.28

+ 1522.06*((CPPKSLHG)/(CPPKGRAN + CPPKSUPP))

+ 821.22*((CPPKSLHG(-1))/(CPPKGRAN(-1)

+ CPPKSUPP(-1)) - 43.23*TREND

+ 534.44*D778 - 779.04*D867

The number of breeding hogs added to the herd is a relationship defined by costs of pork production, both grain and protein supplements cash expenses and the slaughter hog receipts. These costs of production are ordinary least squares estimates given as linear linkages to price changes.

Wage rates and inflation are both determined exogenous to our model.

5.3.2 Farm level demand

The farm level demand on the other hand is defined by:

1. Sow slaughter demand

2. Barrow and gilt Slaughter demand

The sow slaughter demand is a derived demand determined by:

1. Sow price: this equation is expressed in units of number of animals and is given by log of sow slaughter adjusted or deflated by the producer price index for all items in United States.

   7-market sow price / PPI, All items, U.S

$$\begin{aligned} \text{LOG(PKSOWPM/PPIW)} = {} & 3.677 \\ & - 0.305\text{*LOG(PKSOWKS + PKBORKS)} \\ & + 1.269\text{*LOG(PKRETP/PPIW)} \\ & - 1.308\text{*LOG(ZWRHP20W/PPIW)} \\ & - 0.233\text{*SHIFT88} \\ & + 0.217\text{*D723} \end{aligned}$$

2. Retail pork price

3. Wage rates: these are determined exogenous to the model

4. Inflation : it is determined exogenous to the model

The barrow and gilt slaughter demand is a derived demand too. This is determined by

1. Barrow and Gilt price: this is given by log of 7-market barrow and gilt price adjusted or deflated for producer price index for all items in United States.

   7-market Barrow and gilt price / PPI, All items, U.S

$$\begin{aligned} \text{LOG(PKBAGPM/PPIW)} = 8.427 \\ &- 0.453*\text{LOG(PKBAGKSD + PKBAGKSI)} \\ &+ 1.396*\text{LOG(PKRETP/PPIW)} \\ &- 0.664*\text{LOG(ZWRHP20W/PPIW)} \\ &- 0.130*\text{SHIFT88} \\ &- 0.138*\text{D667} \end{aligned}$$

2. Wage rates: these are determined exogenous to the model

3. Inflation : it is determined exogenous to the model

5.4 Retail level equations

In the following section we look at the retail level components of both demand and supply.

5.4.1 Retail level supply

The retail level supply is determined by the following set of equations:

1. Sow and boar slaughter

2. Barrow and Gilt slaughtered

3. Trend

At the retail level, the number of animals slaughtered is converted into pounds of pork via the total pork production equation defined as:

$$\begin{aligned} PKPROD = \quad & 594.207 \\ & + 0.330*(PKSOWKS + PKBORKS) \\ & + 0.147*(PKBAGKSD + PKBAGKSI) \\ & + 0.0005*(TREND*(PKBAGKSD + PKBAGKSI)) \end{aligned}$$

In some models the conversion of the number of animals slaughtered into pounds of pork is made with an identity allowing the carcass yield to vary through time. However, in this version of FAPRI pork model, pork is converted from live animals to pounds of pork via a behavior response equation. The pork production equation is estimated as a function of the number of barrows and gilt slaughtered, sows and boars slaughtered, and a time trend. This time trend is a variable reflecting the movement towards leaner barrow and gilt carcasses with less waste and higher dressing percentages.

The sow slaughter equation identified as PKSOWKS and the barrow and gilt slaughtered equation identified as PKBAGKSD are mentioned elsewhere earlier in the

chapter. The number of imported boar and gilts slaughtered, given by PKBAGKSI, is exogenous to our model. Boar slaughter identified as PKBORKS is given as follows:

Hogs, Boar slaughter

PKBORKS = - 993.74383
+ 0.115*PKHOGNBR(-1)
+ 0.084*(PKSOWKS - PKGLTADD)
+ 332.462*LOG(TREND)
+ 219.829*DUM66

The other behavioral equation which defines the identity is given by sows slaughtered. This equation is representative of disinvestment decisions taken by producers in response to market changes. An increasing number of sows slaughtered indicates disinvestment decisions taken by producers which may be in response to higher costs of swine raising etc. This equation is given by:

Hogs, Sow slaughter

PKSOWKS = 4268.35
+ 0.304*PKHOGNBR(-1)
- 1138.88*((CPPKSLHG + CPPKCLSW)/(CPPKGRAN
+ CPPKSUPP + CPPKPAST + CPPKVET + CPPKHAUL
+ CPPKMARK + CPPKBED + CPPKFLE
+ CPPKREP + CPPKLABR + CPPKMANU))
- 720.659*SHIFT75
+ 756.027*DUM66
- 938.293*DUM73

- 610.353*DUM76

The number of market hogs on the farm is defined as an identity which equals market hogs on the farms in previous year less market hog death loss, less barrow and gilt domestic and imported slaughter, plus the pig crop. This is given in the model by:

$$\begin{aligned} \text{PKHOGFRM} = \; & (1\text{-PKPIGD})*(\text{PKHOGFRM}(-1)) \\ & + \text{PKPIGCRP} - \text{PKBAGKSD} - \text{PKBAGKSI} \end{aligned}$$

The behavioral equations supporting this identity include barrow and gilt domestic slaughter:

$$\begin{aligned} \text{PKBAGKSD} = \; & - 15754.13 \\ & + 0.502*\text{PKPIGCRP} \\ & + 0.943*\text{PKHOGFRM}(-1) \\ & + 6116.49*\text{SHIFT83} \\ & - 4578.51*\text{DUM73} \\ & + 3614.79*\text{DUM76} \end{aligned}$$

The coefficient on barrow and gilt slaughter suggests that 50 percent of the pig crop on farm is slaughtered to obtain total barrow and gilt slaughtered. Ninety four percent of the market hogs on farm are taken in for slaughter from previous year. A higher pig crop indicates a higher availability of pigs for slaughter and market sale.

The pig crop equation, an identity, and the imported hogs slaughtered, determined exogenously, are behavioral equations explaining the number of market hogs on the farm.

The pig crop, PKPIGCRP, is an identity equal to the number of sows farrowed times the number of pigs per litter. The number of sows farrowed is a behavioral equation defined as follows and is identified by PKSOWFAR. Pigs per litter is identified exogenous to the model.

PKPIGCRP = PKSOWFAR*PKPIGLIT

Where,

PKSOWFAR = 986.17
+ 0.911*PKHOGNBR(-1)
+ 0.015*(TREND*PKHOGNBR(-1))
+ 0.836*PKGLTADD
- 0.383*PKSOWKS
- 987.67*DUM78
- 941.728*DUM75
+ 946.856*D701

The sows farrowed is a function of the trend, and the gilts added to the breeding herd which is a positive function reflecting that an increase in it's number will lead to an increase in the sows farrowed. The sows farrowed is also expressed as a negative function of the sow slaughter reflecting that lesser number of sows will be farrowed with a larger number of them being farrowed. There is also a positive linear relationship of sows farrowed with the number of breeding hogs on farm both for the present period and those on farm in the last period.

Thus, sows farrowed is a function of number of breeding hogs on the farm (PKHOGNBR), an identity and gilts added (PKGLATDD) and sow slaughtered (PKSOWKS), two behavioral equations and finally the trend. The equations rep-

resenting gilts added and sow slaughtered are mentioned elsewhere earlier in the chapter.

5.4.2 Retail level demand

At this level the demand component is captured by two equations, the per capita consumption and ending stocks. Per capita consumption is influenced by exogenous factors as income, inflation, relative prices of other meats, population above 75 years of age and finally, retail price of pork. Price determination is assumed to occur at the retail level. The retail price is linked to the farm price. Civilian disappearance is determined from the market closing identity. This identity is given by

PKCDIS = PKSUPP - PKEXPT - PKSTK

Where,

PKSUPP = Total pork supply

PKSTK = Total ending stocks

PKEXPT = Pork exports

Log linear form of equations is used to express demand equations such as Pork consumer demand given by LOG(PKPCCW) and on the farm level demand by LOG(PKSOWPM/PPIW), the 7 market sow price and LOG(PKBAGPM/PPIW). The last two equations are also adjusted or deflated by the producer price index for all items in United States. The pork consumer demand equation is given by the log of per capita pork consumption and is written as

LOG(PKPCCW) = 0.335

- 0.861*LOG(PKRETP/PCIUW)

+ 0.360*LOG(BFRETP/PCIUW)

+ 0.008*LOG(CKRETP/PCIUW)

+ 0.145*LOG((ZCENFABW/POPTOTW)/PCIUW)

- 0.907*(POP75PW/POPTOTW)

- 0.047*D845

The retail price of beef and chicken are reflected as conditioning variables in pork demand equation. Per capita food expenditure, and consumer price index for food, proxy for all competing food products is also included. A variation in the taste of the earlier generations is reflected by the US population for people aged above seventy five years. This is expected to be a negative relation mainly because people of earlier generations represented by people above the age of seventy five years tend to demand lesser of pork.

In the short run, the axioms of consumer behavior do not hold mainly due to the reason that there is a lag in the consumers reaction to price and income changes. In the long run however, these axioms hold. The model, as given in the appendix, expresses these equations with the anticipated signs.

Marketing cost index includes both meat packers wage rate and a measure of fuel and utilities cost. The fuel and utility index reflects changes in general overhead costs. In certain cases, the equations have been deflated by producer price index. Packers bid up farm prices in response to higher by-product prices.

The ending stocks is also a retail demand component. It is a function of retail price of pork today less lag pork retail price, adjusted for producer price index, and total pork production. The equation is given as follows:

$$
\begin{aligned}
PKSTK = \quad & - 167.125 \\
& - 14768.61*(PKRETP - PKRETP(-1))/PPIW \\
& + 0.030*PKPROD \\
& + 52.639*SHIFT78 \\
& + 139.517*DUM73 \\
& + 127.501*DUM75
\end{aligned}
$$

The retail price of pork has a negative effect on ending stocks mainly because as price increases, packers are less willing to hold excessive stocks. Total commercial production and beginning stocks, which is previous years ending stocks, have a positive influence on ending stocks because as total available supply increases, given existing demand, ending supply will invariably increase.

The retail demand is defined by equations for civilian disappearance (PKCDIS), and per capita pork consumption (PKPCCW/PPKCCR).

Market clearing equation equates pork supply and demand. From this identity total pork civilian disappearance is obtained. Exogenous supply and demand components include on farm pork production, exports, and imports.

Table 5.2: Definition of mnemonics used in FAPRI pork model

Abbreviation	Definition
PKBAGPM	Hogs, Barrow and Gilt, Seven market price
CPPKCLSW	Pork, Cost of production, Cull sow receipts
CPPKSLHG	Pork, Cost of production, slaughter hog receipts
PKSOWPM	Hogs, Sow seven market price
PKPIGLIT	Hogs, Pigs per litter
CPPKGRAN	Pork, Cost of production, Cash expense for grain
CRPFRM	Corn season average farm price
CPPKSUPP	Pork, Cost of production, Cash expense for protein supplements
SMP44D	Soybean Meal price, Decatur 44% protein
CPPKVET	Cost of production, Cash expense for veterinary and Medicine
CPPKHAUL	Pork, Cost of production, Cash expense for livestock hauling
PPIW	Producer price index, All items, US
PPICFULW	Producer price index, Industrial commodity, Fuel and related
CPPKMARK	Pork, Cost of production, cash expense for marketing
CPPKBED	Pork, Cost of production, Cash expense for bedding
CPPKFLE	Pork, Cost of Production, Cash expense for fuel, lube and Electricity
CPPKREP	Pork, Cost of produiction, Cash expense for repairs
PPICMETW	Producer price index, Industry commodity, metals and products
CPPKLABR	Pork, cost of production, Cash expense for hired labor
ZWRHP20W	Average hour earnings, Food and kind products
CPPKMANU	Pork, Cost of production, cash expense for manure credit
PPICHMW	Producer price index, chemicals and allied products
CPPKGFO	Cost of production, Cash expense for general farm overhead
CPPKTAX	Pork, Cost of production, Cash expense for insurance and taxes
CPPKINT	Pork, Cost of production, Cash expense for interest
CPPKCAPR	Pork, Cost of production, Cash expense for capital replacement
PKHOGNBR	Number of breeding hogs added to the herd
PKPROD	Pork, Total production
PKSOWKS	Hogs, Sow slaughter
PKBORKS	Hogs, Boar slaughter

Table 5.2 (Continued)

Abbreviation	Definition
PKBAGSKD	Hogs, Barrow and gilt domestic slaughter
PKBAGKSI	Hogs, barrow and gilt imported slaughter
PKGLTADD	Hogs, Gilts added to breeding herd
PKPIGCRP	Hogs, Pigs crop
PKRETP	Pork retail price
BFRETP	Beef retail price
CKRETP	Chicken retail price
PCIUW	Consumer retail price
POPTOW	Total population, Including armed forces overseas
POP75W	Population - U.S. - Age 75+
ZCENFABW	Personal consumption exp., Food and beverage
PKSTK	Pork ending stocks U.S.

CHAPTER 6. DISCUSSION

In the previous chapters the purpose of this thesis has been outlined, the alternatives to sulfamethazine in pork production listed, and the techniques for analysis have been discussed. In the following chapter the analysis and the final results will be presented along with observations and comments. Assumptions inherent to the analysis will be outlined and conclusions presented. An attempt to evaluate which of the suggested strategies appears to be most effective in achieving a stable long term supply of a safer residue free pork product is also presented.

In an earlier chapter, the persistent pressure on the FDA to further restrict the use of sulfamethazine in pork production for reasons as residue violations and transfer of antibiotic resistance through meat was discussed. Comments and particular reference was made to sulfamethazine residue violations in pork. There has been pressure on the swine industry to lessen the use of sulfamethazine due to perceived economic costs which result from sanctions imposed upon the producers by the FDA in response to detection of sulfa residues in pork which are in violation of FDA standards. Earlier in the thesis possible alternatives to sulfamethazine use in pork production were discussed, these may be broadly categorized as follows:

1. Ban sulfamethazine and continue pork production in the absence of any alternatives

2. Use of tetracycline - chlortetracycline and oxytetracycline, as a substitute for sulfamethazine

3. Use of tylosin as a substitute for sulfamethazine

4. Use of lincomycin as a substitute for sulfamethazine

5. Use of sulfathiazole as a substitute for sulfamethazine

Use of any of these alternatives will entail cost increases for the farmer primarily because of the potential for elevated animal disease levels, and slower and less efficient animal growth. Implementing any of these alternatives would also imply changes in swine production management practices. Cost increases will vary with the alternative strategy of pork production. However,the potential for reduced sulfamethazine residues can improve the quality and wholesomeness of the food supply thus impacting consumer demand by increasing consumer confidence. Another potential benefit, not discussed in this study but common to all proposed strategies is the possibility of reducing costs associated with economic sanctions imposed against producers for violation of residue levels in swine carcasses.

6.1 Supply shocks

A ban on the use of sulfamethazine, assuming no substitutes are available, will cause the swine producer to face reduction in feed efficiency. The feed efficiency for a ban is projected to decline by 8.6 percent [23]. Thus, there will be an associated increase in feed costs and protein supplements needed to raise swine. Average and marginal costs will increase with a ban on sulfamethazine use. Mortality rates are

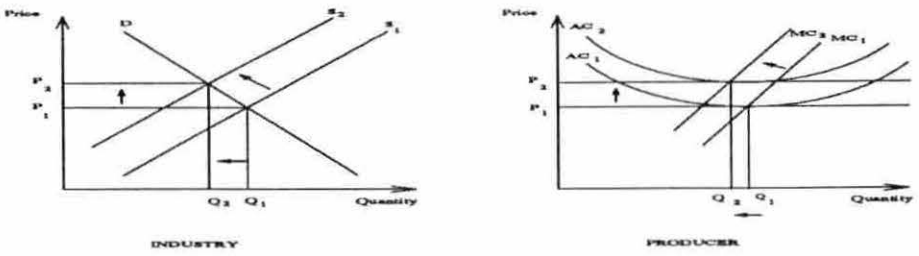

Figure 6.1: Effects of increased production costs on the individual pork producer and the pork industry

expected to increase by 5-6 percent. This shock will however, be softened when the alternatives are considered.

The market for all agricultural products is competitive and the demand for such products has been shown to be inelastic. This holds true for pork. A ban on sulfamethazine with no alternative substitutes will cause the industry pork supply to decrease (S_1 to S_2), and producer production costs to increase as seen in Figure 6.1. The total cost for the producer increases due to reduced production efficiency, causing an upward shift in the marginal cost (MC_1 to MC_2) and average cost (AC_1 to AC_2). In a competitive market, equilibrium level of pork production for the producer can be found at the intersection of marginal cost and average cost equal to price. In the example, equilibrium quantity declines from Q_1 to Q_2. Prices increase from P_1 to P_2. Shifts in the marginal cost curve of individual farmers will cause the industry supply curve to shift to the left (S_1 to S_2), since the industry supply curve is simply a summation of producer marginal cost curves. The magnitude of the shift in the

supply curve will depend on the pervasiveness of increased costs. Since the pork market is highly inelastic, a one percent decline in quantity will cause the price to increase by greater than one percent. An increase in costs can drive producers out of the market causing the industry supply to decrease (S_2). Also, increased prices will serve to hold producers into the market. However, if we assume the cost increases to be permanent and pervasive, new producers will not be attracted to the industry and the new industry supply (S_2) would remain to the left of the old supply curve (S_1) and the industry quantity will decline from Q_1 to Q_2. In this study the cost increases resulting from a movement away from sulfamethazine use are pervasive and permanent which causes a shift of the supply curve to the left. Thus, pork prices increase and the quantity produced declines in response.

For purpose of this study the FAPRI livestock model along is used for the economic analysis. The study assumes that feed efficiency will be used as a proxy to reflect average daily gain changes associated with the alternative scenarios evaluated. This is so because the FAPRI model lacks average daily gain equations. Also we need to incorporate into the model the fact that not all the hogs produced in U.S are treated with sulfamethazine. This is so because some hog producers choose not to use sulfamethazine for fear of economic embargoes in an event of residue violation. They are making decisions to reduce the probability of violative hog carcasses. However, the number of hogs actually treated with sulfamethazine is not known. It is true that the average daily gain improvement resulting from antibiotic use is assumed to be reflected by the feed efficiency number. It is also a fact that only some unknown percent of the hog produced in the U.S is raised with sulfamethazine use and thus there is the need to adjust the feed efficiency number obtained from Table 6.1

Table 6.1: Response of pigs to antibiotics during the starter stage (Hays Report)

Antibiotic	Feed Efficiency (in percent)	Average Daily Gain (in percent)
AUREO SP 250 (Sulfamethazine)	8.6	23.1
CSP 250 (Sulfathiazole)	8.3	19.4
TYLAN(Tylosin)	6.0	14.8
LINCOMIX (Lincomycin)	7.6	11.1
TETRACYCLINE	6.3	10.8

to reflect this. The study assumes that in adjusting the feed efficiency equation for the percent of hogs actually raised with sulfamethazine, the average daily gain is underestimated. Thus, for purpose of economic analysis the feed efficiency numbers are assumed to be those represented in Table 6.1. Also inherent in our assumption of a ban on sulfamethazine is the fact that the ban is imposed completely effective beginning the year a law is passed restricting the use of sulfamethazine in pork. In our analysis, this ban on sulfamethazine is assumed effective beginning year 1 (1993) in the results.

In projecting the results for changes in pork production and prices for an imposition of a sulfamethazine ban, the Food and Agricultural Policy Research Institutes FAPRI livestock model was used. The first scenario assumes that there are not any alternatives to sulfamethazine available for use in swine production. Equations adjusting for changes in cost of grain and and protein supplement were shocked by a value of 8.6 percent, with a decline in the swine feed efficiency of 8.6% in response to the sulfamethazine ban [23]. In the absence of any equation accounting for the average daily gain factor, feed efficiency was assumed to reflect the loss in average

daily gain of 23.1 percent. In addition, an increase in the mortality rate of 6 percent over the baseline was assumed in the absence of any other alternative to sulfamethazine use. The pig death rate loss was shocked to reflect this increase in mortality. The results that were obtained are tabulated and presented in Tables 6.4 - 6.9 and Figures 6.5 - 6.8. The tables provide for comparative analysis between the baseline levels, which is the original (current state) pre-ban model and is presented in chapter 5, and the results obtained with sulfamethazine restriction without the availability. The tables list the changes in prices, production and consumption levels. Table 6.4 provides for the changes in pork production levels, Table 6.5 lists changes in retail prices, changes in farm prices and sow prices are listed in Table 6.6 and Table 6.8 respectively and finally changes in consumption are given in Table 6.9.

The analysis is further extended by assuming the use of alternative compounds in swine production in response to a ban on sulfamethazine use. Since sulfamethazine as a feed additive in pork production is primarily used at pre-starter and starter levels, the alternatives presented here replace sulfamethazine sub-therapeutic use at pre-starter and starter stage only. Mortality rates are assumed constant over the original sulfamethazine pre-ban levels (baseline) since mortality rates are expected not be significantly higher or different between different alternative compounds. Using the FAPRI pork model, changes in prices, production and consumption levels were again projected for each scenario and compared with the baseline prices, and production and consumption levels. The baseline levels are the original pre-ban levels or the current state as it exists now. With no changes in mortality rates, only the grain cost equation and protein supplement cost equation were shocked for the relative decline in feed efficiency for a ban on sulfamethazine and use of the respective alternative com-

Table 6.2: Changes in feed efficiency and mortality associated with the use of different alternative compounds

Compound	Feed Efficiency (percent change)	Change in Mortality (percent change)
AUREO SP 250 (Sulfamethazine)	0.0	0.0
NONE (Ban)	8.6	6.0
CSP 250 (Sulfathiazole)	0.3	0.0
TYLAN (Tylosin)	2.6	0.0
LINCOMIX (Lincomycin)	1.0	0.0
TETRACYCLINE	2.3	0.0

pound. For example, in substituting tetracyclines to replace sulfamethazine, changes in feed efficiency associated with using tetracycline over sulfamethazine can be read from Table 6.2 & Table 6.1. The feed efficiency was assumed to increase by 8.6% over control group with sulfamethazine while for tetracycline it was estimated to be 6.3% improvement over the control group. The cost equations in the FAPRI model were thus, shocked for 2.3% (i.e. 8.6 - 6.3) decline in feed efficiency for a substitution of sulfamethazine by either of the tetracycline, chlortetracycline and oxytetracycline, in pork production. Similar calculations were done for other alternatives and different estimates obtained, which were then used to shock the cost equations to obtain different scenarios. The decline in feed efficiency with tylosin substitution was calculated to be 2.6%, for lincomycin it was 1.0% and finally, for sulfathiazole it was estimated to be 0.3%.

In general, the alternatives reduce the impact of a ban on sulfamethazine use in swine production. This can be seen from changes in production, consumption and price levels indicated in the respective tables. The changes in prices, production

and consumption are cushioned with the use of alternatives over the levels obtained for a sulfamethazine ban with no alternatives. Changes in supply at the producer and industry level in response to a ban on sulfamethazine and use of alternatives is given in Figure 6.2. The level of supply shift to the right over the ban level, without alternatives, depends on production cost adjustments of the alternatives. Thus, for each alternative considered there will be different results. General results are discussed.

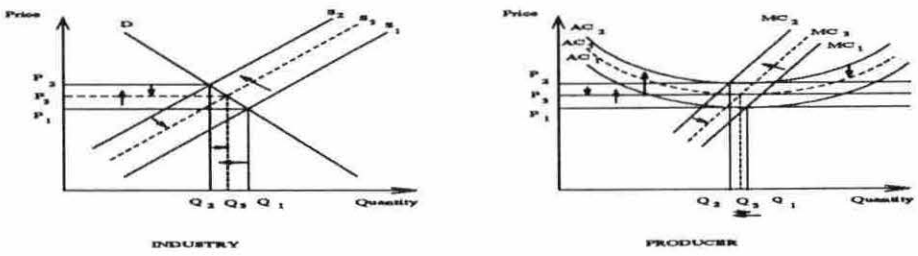

Figure 6.2: Effects of increased production costs on the individual pork producer and pork industry with use of alternative compounds to sulfamethazine

Results from the first scenario are shown in Tables 6.4 - 6.9. A ban on sulfamethazine assuming no alternative substitutes exist, projected a decrease in pork production (Table 6.4) of 2.32% by the end of the fourth year over the baseline levels. This estimate declined to 1.62% by the end of ninth year and then was at 2.01% by the end of tenth year. Retail prices, farm prices for barrows and gilts, and sow prices all showed a significant increase over the pre-ban or the baseline levels. The

retail price (Table 6.5) for example increased by 2.35% over the baseline level by the end of the tenth year. Increase in farm prices (Table 6.6) for barrows and gilts was projected to be significantly higher at 4.26% over the baseline farm prices for barrows and gilts for the tenth year of our study. Sow prices (Table 6.8) were up 3.39% over the baseline level. For most of the analysis, it can be generalized, there is a trend such that percentage change over the baseline is very small in the initial years of the supply shock as the industry adjusts. This percentage change over the baseline increases, in absolute value, with time as producers adjust to the alternative strategies. This adjustment is followed by a decline in the percentage change over baseline values before indicating an increase again by the end of the eighth year. There is a projected decrease of 2.01% (Table 6.9) in consumption of pork over the pre-ban levels by the end of tenth year. Our results indicate changes in consumption to be very closely followed by changes in production. However, this is not surprising since the product produced (pork) can not be stored over long periods of time and production is consumed at some price.

Use of tetracycline as a substitute for sulfamethazine cushioned the decrease in production and consumption levels and the increase in price levels of pork over the scenario of a ban on sulfamethazine without alternative substitutes. The production levels are projected to decline to a low of -0.78% (Table 6.4) over the baseline by end of third year as compared with -1.99% for the scenario where there is a complete ban on use of all compounds. This value declined further to -1.02% over the baseline by end of tenth year for the scenario run with tetracycline replacement and was lower than the -2.01% decline observed for the scenario with a complete ban on all compounds. In comparing tetracycline projected levels with sulfamethazine ban

levels, tetracycline levels indicate higher production for all years except the year of the shock. By the end of tenth year tetracycline production and consumption levels are projected to be still higher and price increase lower than ban levels. The retail price was projected to be 0.94% over the baseline by the end of the tenth year, a small increase when compared with the 2.35% increase over baseline projected for a scenario where use of all chemical compounds in pork production is assumed banned. The farm prices for barrows and gilts increased 2.07% (Table 6.6) over the baseline at the end of tenth year while sow prices were projected to be 1.70% (Table 6.8) over the baseline levels for the same year.

In using tylosin, an estimated loss of 2.6% (Table 6.2) in feed efficiency was assumed over pre-ban levels. With tylosin as an alternative to sulfamethazine in pork production, production is projected to decline 1.15% (Table 6.4) over the baseline level by end of the tenth year. Percentage decline in pork production (Table 6.4) is projected to remain lower with use of tylosin as an alternative than with a ban on sulfamethazine with no alternatives. Retail price (Table 6.5) by the end of tenth year is projected to be 1.41% higher over the baseline year. Sow prices were projected to be higher by 1.90% (Table 6.8) over the baseline at the end of the tenth year. Pork consumption with a decline of -1.15% (Table 6.9) over the baseline by the end of the tenth year still remained higher than the -2.01% decline projected over baseline for the first scenario where no alternatives to sulfamethazine are assumed. Farm prices for barrows and gilts (Table 6.6) showed an increase of 3.01% over the baseline by the end of the fifth year before declining to 2.33% over the baseline by the end of tenth year. Comparison between changes over baseline with the use of tylosin and with a ban on use of sulfamethazine without alternatives is presented in the tables.

Lincomycin was projected to show a decline in production levels over baseline levels but not by a very significant amount. The feed efficiency decline over sulfamethazine or pre-ban levels in this case was 1.0%. The decline in production (Table 6.4) is projected at only 0.45% by the end of tenth year over the baseline level. Changes in retail prices (Table 6.5) indicated a higher but insignificant increase in all years of analysis ranging anywhere between -0.51% to 1.03%. By the end of the eighth year, percentage increase in retail price for lincomycin replacement was estimated to be 0% before increasing to 0.47% by the end of the tenth year.

Sulfathiazole showed to be the best alternative to sulfamethazine as the results for baseline level and those obtained with sulfathiazole replacement were quite similar. The feed efficiency in swine is estimated to decline 0.3% over swine production with sulfamethazine. Production changes with sulfathiazole are projected to be negligible over the baseline levels for our analysis (Table 6.4). Prices did not show a significant change over the baseline levels. Percentage increase in retail prices (Table 6.5) is projected to vary between high of 0.51% and a low of 0%. For much of the study years, including the tenth year the percentage increase in retail prices was observed to be 0% over the baseline levels. In other words retail prices with the use of sulfamethazine were the same for almost all years as with the use of sulfathiazole. Farm prices for barrows and gilts (Table 6.6) indicated a small increase of 0.27% over the baseline levels at the end of the tenth year and remained within the range of 0.35% to 0% above the baseline in the study. Sow prices (Table 6.8) also indicated a small increase of 0.23% over the baseline by the end of the tenth year. Percent change in consumption (Table 6.9) levels for all years kept pace with percent change in production. By the tenth year consumption declined by -0.13% over the baseline levels.

Table 6.3: Changes over baseline levels following restriction (ban) on sulfamethazine use in pork production by the end of tenth year

Compound	Production	Retail price	Farm price	Sow price	Consumption
Sulfamethazine	17495	2.13	50.19	34.76	17450
Sulfathiazole	17471	2.13	50.33	34.84	17427
Lincomycin	17417	2.14	50.64	35.01	17373
Tetracycline	17316	2.15	51.23	35.42	17273
Tylosin	17293	2.16	51.36	35.83	17250
With Restrictions	17143	2.18	52.33	35.94	17100

In generalizing, significant increases in sow and farm prices, decrease in consumption and production levels are observed over the baseline levels (sulfamethazine use) with further restrictions (ban) on sulfamethazine use in pork production. These results are also true when replacing sulfamethazine in pork production with currently available alternatives. This incorporates retail pork price, farm prices for barrows and gilts, sow prices, and production and consumption levels. The changes in these variables are projected to be the least with use of sulfathiazole as an alternative. The changes in expected net returns is used to reflect producer investment and disinvestment decisions and is represented by changes in production levels. In our analysis we report the actual net returns for each year. However, it is assumed that current year returns work as expected returns for the following year. For a ban in sulfamethazine with no alternatives considered, the price increase was much higher than any of the projections obtained for a ban on sulfamethazine with a substitute replacement. For all alternatives, production and consumption levels are projected to be higher and closer to the baseline than those obtained for a ban in sulfamethazine without alternatives. In most part, use of sulfathiazole led to the least deviation from baseline levels, indicating minimum producer, industry, and consumer shocks. The results projected with the use of tylosin as an alternative for sulfamethazine provided the worst scenario amongst all other scenarios with alternatives. A quick look at Table 6.1 will help interpret and understand these observations.

Table 6.4: Changes in pork production following restrictions (ban) on sulfamethazine and use of different alternatives (million pounds)

Year	Baseline	WR	% change	Tetracycline	% change	% COR	Tylosin	% change	% COR	Lincomycin	% change	% COR	Sulfathiazole	% change	% COR
0	17234	17234	0.00%	17234	0.00%	0.00%	17234	0.00%	0.00%	17234	0.00%	0.00%	17234	0.00%	0.00%
1	17095	17101	0.04%	17098	0.02%	-0.02%	17099	0.02%	-0.02%	17097	0.01%	-0.02%	17096	0.005%	-0.03%
2	16538	16447	-.55%	16489	-0.30%	0.26%	16483	-0.33%	0.22%	16517	-0.13%	0.43%	16532	-0.04%	0.51%
3	17131	16790	-1.99%	16997	-0.78%	1.23%	16980	-0.88%	1.13%	17072	-0.34%	1.68%	17114	-0.09%	1.93%
4	17649	17239	-2.32%	17460	-1.07%	1.28%	17436	-1.20%	1.14%	17566	-0.47%	1.90%	17624	-0.14%	2.23%
5	17525	17168	-2.04%	17329	-1.12%	0.93%	17303	-1.27%	0.79%	17439	-0.50%	1.58%	17499	-0.15%	1.93%
6	17111	16848	-1.54%	16937	-1.02%	0.53%	16915	-1.15%	0.40%	17035	-0.44%	1.10%	17088	-0.13%	1.43%
7	17509	17310	-1.14%	17363	-0.83%	0.30%	17345	-0.93%	0.20%	17445	-0.37%	0.78%	17490	-0.11%	1.04%
8	18014	17797	-1.20%	17877	-0.76%	0.45%	17860	-0.86%	0.35%	17954	-0.33%	0.87%	17995	-0.10%	1.11%
9	17634	17349	-1.62%	17482	-0.86%	0.77%	17462	-0.98%	0.65%	17567	-0.38%	1.25%	17614	-0.11%	1.91%
10	17495	17143	-2.01%	17316	-1.02%	1.01%	17293	-1.15%	0.88%	17417	-0.45%	1.60%	17471	-0.14%	1.91%

COR: Change on Restriction
WR : With Restrictions (ban)

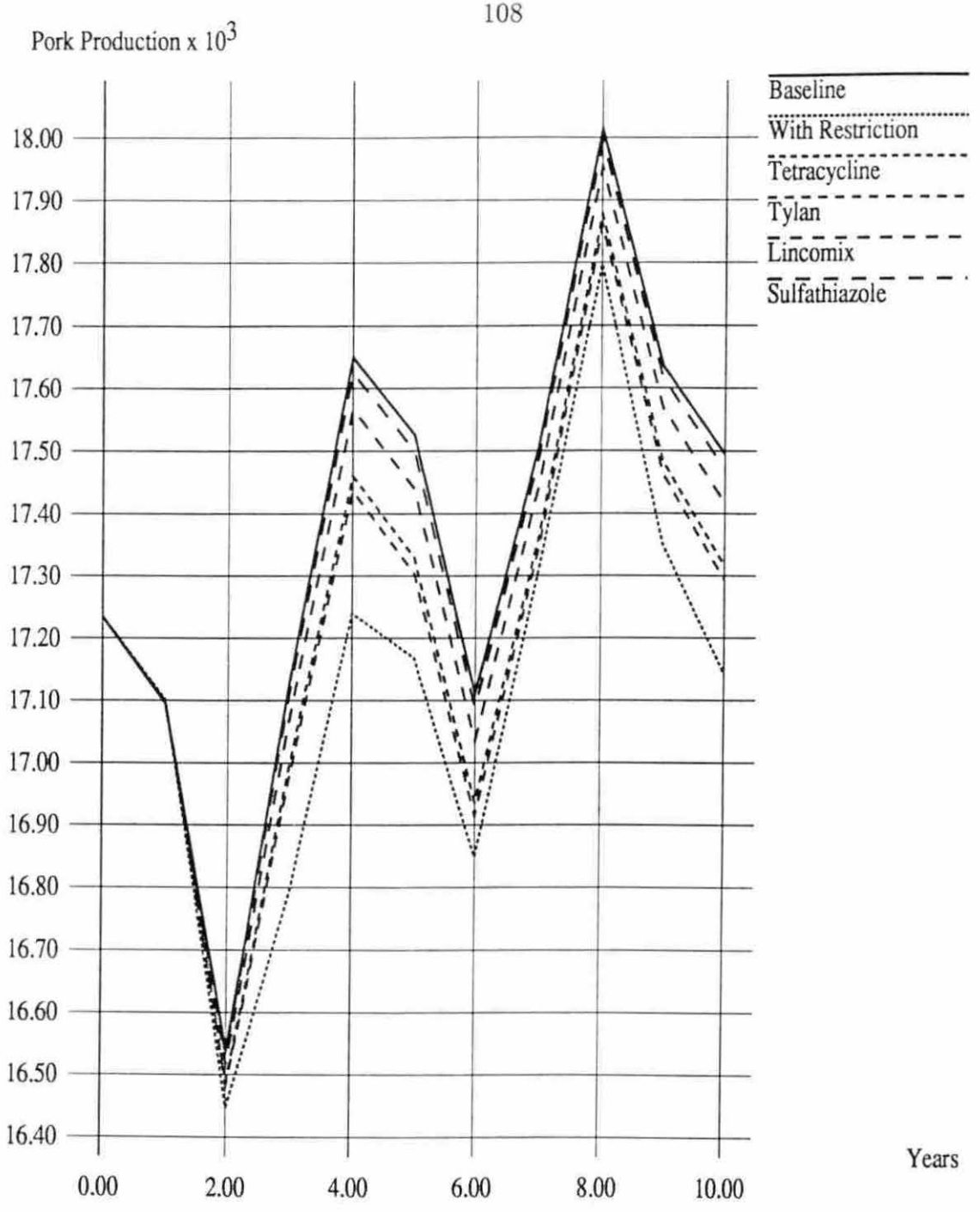

Figure 6.3: Changes in pork production following restrictions (ban) on sulfamethazine and use of different alternatives (million Pounds)

Table 6.5: Changes in retail price following restrictions (ban) on sulfamethazine and use of different alternatives(dollars per pound)

Year	Baseline	WR	% change	Tetracycline	% change	% COR	Tylosin	% change	% COR	Lincomycin	% change	% COR	Sulfathiazole	% change	% COR
0	1.98	1.98	0.00%	1.98	0.00%	0.00%	1.98	0.00%	0.00%	1.98	0.00%	0.00%	1.98	0.00%	0.00%
1	1.98	1.97	-0.51%	1.97	-0.51%	0.00%	1.97	-0.51%	0.00%	1.97	-0.51%	0.00%	1.98	0.00%	0.51%
2	2.00	2.01	0.50%	2.01	0.50%	0.00%	2.01	0.50%	0%	2.00	0.00%	-0.5%	2.00	0.00%	-0.5%
3	1.96	2.00	2.04%	1.99	1.53 %	-0.50%	1.99	1.53%	-0.50%	1.97	0.50%	-1.5%	1.97	0.50%	-1.5%
4	1.89	1.95	3.17%	1.92	1.59%	-1.56%	1.92	1.59%	-1.56%	1.90	0.53%	-2.6%	1.89	0.00%	-3.0%
5	1.95	2.01	3.08%	1.98	1.54%	-1.51%	1.99	2.05%	-1.00%	1.97	1.03%	-2.00%	1.96	0.51%	-2.49%
6	2.02	2.06	1.98%	2.05	1.48%	-0.48%	2.05	1.48%	-0.48%	2.03	0.50%	-1.46%	2.02	0.00%	-1.94%
7	1.99	2.01	1.01%	2.01	1.00%	0.00%	2.01	1.00%	0.00%	2.00	0.50%	-0.5%	1.99	0.00%	-1.00%
8	1.94	1.96	1.03%	1.95	0.51%	-0.51%	1.95	0.51%	-0.51%	1.94	0.00%	-1.02%	1.94	0.00%	-1.02%
9	2.04	2.07	1.47%	2.05	0.49%	-0.98%	2.06	0.98%	-0.49%	2.04	0.00%	-1.45%	2.04	0.00%	-1.45%
10	2.13	2.18	2.35%	2.15	0.94%	-1.4%	2.16	1.41%	-0.92%	2.14	0.47%	-1.83%	2.13	0.00%	-2.30%

COR: Change on Restriction
WR : With Restrictions (ban)

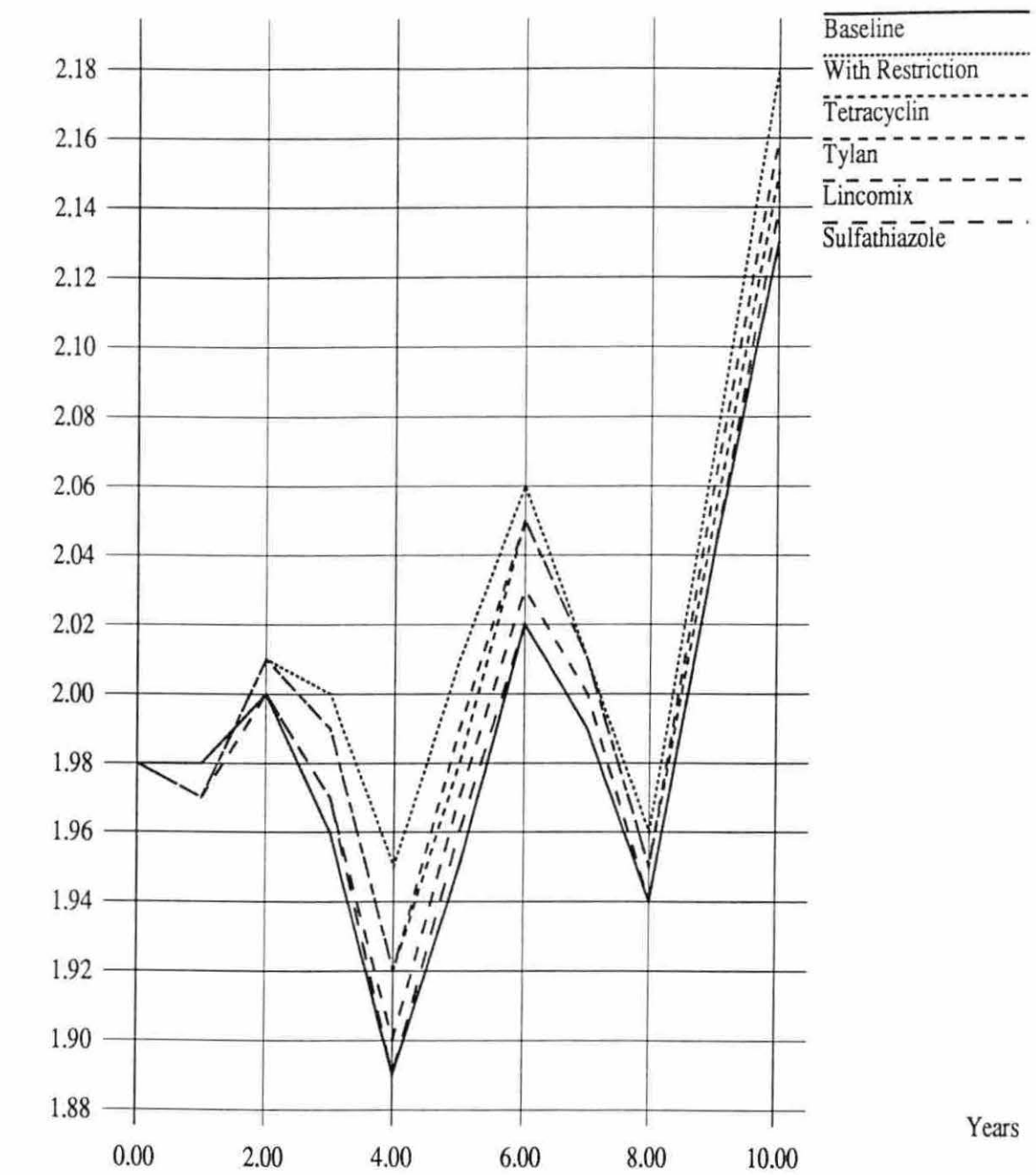

Figure 6.4: Changes in retail price following restrictions (ban) on sulfamethazine and use of different alternatives (dollars per pound)

Table 6.6: Changes in farm prices for barrows and gilts following restrictions (ban) on sulfamethazine and use of different alternatives(dollars per hundredweight)

Year	Baseline	WR	% change	Tetracycline	% change	% COR	Tylosin	% change	% COR	Lincomycin	% change	% COR	Sulfathiazole	% change	% COR
0	43.03	43.03	0.00%	43.03	0.00%	0.00%	43.03	0.00%	0.00%	43.03	0.00%	0.00%	43.03	0.00%	0.00%
1	46.07	46.07	0.00%	46.07	0.00%	0.00%	46.06	-0.02%	-0.02%	46.07	0.00%	0.00%	46.07	0.00%	0.00%
2	48.53	49.15	1.28%	48.86	0.68%	-0.59%	48.90	0.76%	-0.51%	48.67	0.29%	-0.98%	48.57	0.08%	-1.18%
3	45.83	48.02	4.79%	46.68	1.85%	-2.79%	46.79	2.09%	-2.56%	46.20	0.81%	-3.79%	45.94	0.24%	-4.33%
4	42.11	44.54	5.77%	43.19	2.56%	-3.03%	43.33	2.90%	-2.72%	42.58	1.12%	-4.40%	42.25	0.33%	-5.14%
5	45.79	48.07	4.98%	47.01	2.66%	-2.21%	47.17	3.01%	-1.87%	46.32	1.16%	-3.64%	45.95	0.35%	-4.41%
6	49.83	51.60	3.55%	51.00	2.35%	-1.16%	51.15	2.65%	-0.87%	50.34	1.02%	-2.44%	49.99	0.32%	-3.12%
7	47.06	48.15	2.32%	47.92	1.83%	-0.48%	48.03	2.06%	-0.25%	47.43	0.79%	-1.50%	47.17	0.23%	-2.04%
8	44.05	45.01	2.18%	44.71	1.50%	-0.67%	44.80	1.70%	-0.47%	44.34	0.66%	-1.49%	44.14	0.20%	-1.93%
9	46.82	48.27	3.10%	47.60	1.67%	-1.39%	47.70	1.88%	-1.18%	47.16	0.73%	-2.30%	46.92	0.21%	-2.80%
10	50.19	52.33	4.26%	51.23	2.07%	-2.10%	51.36	2.33%	-1.85%	50.64	0.90%	-3.23%	50.33	0.27%	-3.82%

COR: Change on Restriction
WR : With Restrictions (ban)

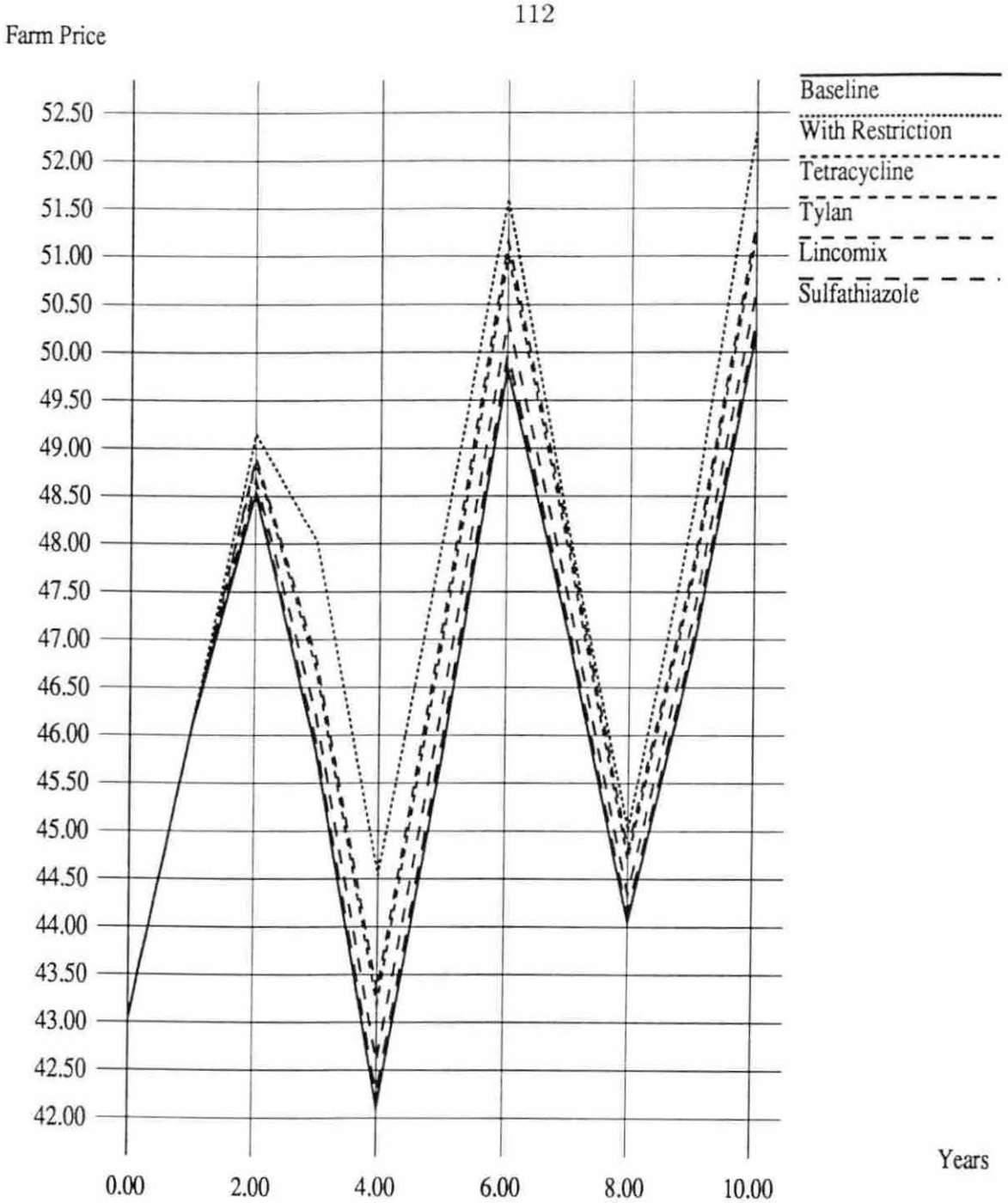

Figure 6.5: Changes in farm prices for barrows and gilts following restrictions (ban) on sulfamethazine and use of different alternatives (dollars per hundredweight)

Table 6.7: Changes in net returns, farrow - finish, following restrictions (ban) on sulfamethazine and use of different alternatives (dollars per hundredweight)

Year	Baseline	WR	% change	Tetracycline	% change	% COR	Tylosin	% change	% COR	Lincomycin	% change	% COR	Sulfathiazole	% change	% COR
0	1.28	1.28	0.00%	1.28	0.00%	0.00%	1.28	0.00%	0.00%	1.28	0.00%	0.00%	1.28	0.00%	0.00%
1	3.73	2.50	-33.00%	3.08	-17.4%	23.2%	3.00	-19.57%	20.04%	3.45	-7.5%	38%	3.64	-2.4%	45.6%
2	4.48	3.82	-14.73%	4.15	-7.3%	8.6%	4.10	-8.51%	1.30%	4.34	-3.1%	13.6%	4.44	-0.9%	16.2%
3	3.36	4.40	31.00%	3.59	5.22%	-18.4%	3.62	7.76%	-17.69%	3.46	2.98%	-27.36%	3.39	0.9%	-22%
4	-0.62	0.68	210%	-0.14	77.4%	-120.59%	-0.08	87.10%	-111.76%	-0.41	33.8%	-160%	-0.56	9.6%	182%
5	2.33	3.44	47.64%	2.94	26.12%	14.53%	3.02	29.68%	-12.29%	2.59	11.16%	-24.7%	2.41	3.43%	-29.9%
6	6.15	6.75	9.76%	6.70	8.93%	-0.74%	6.77	10.13%	-0.30%	6.39	11.00%	24.71%	6.22	1.14%	7.85%
7	2.42	2.30	-5.00%	2.65	9.42%	-15.21%	2.67	10.37%	-16.02%	2.52	4.13%	9.57%	2.45	1.24%	6.52%
8	-1.21	-1.47	-21.49%	-1.18	2.48%	19.7%	-1.18	2.48%	19.67%	-1.20	0.83%	18.37%	-1.20	0.83%	18.37%
9	0.68	0.88	29.00%	0.81	19.06%	-7.90%	0.83	21.97%	-5.66%	0.74	9.00%	15.9%	0.70	2.94%	20.45%
10	2.70	3.54	31.11%	3.06	13.26%	13.57%	3.11	15.20%	12.42%	2.85	5.55%	19.49%	2.74	1.48%	-22.6%

COR: Change on Restriction
WR : With Restrictions(ban)

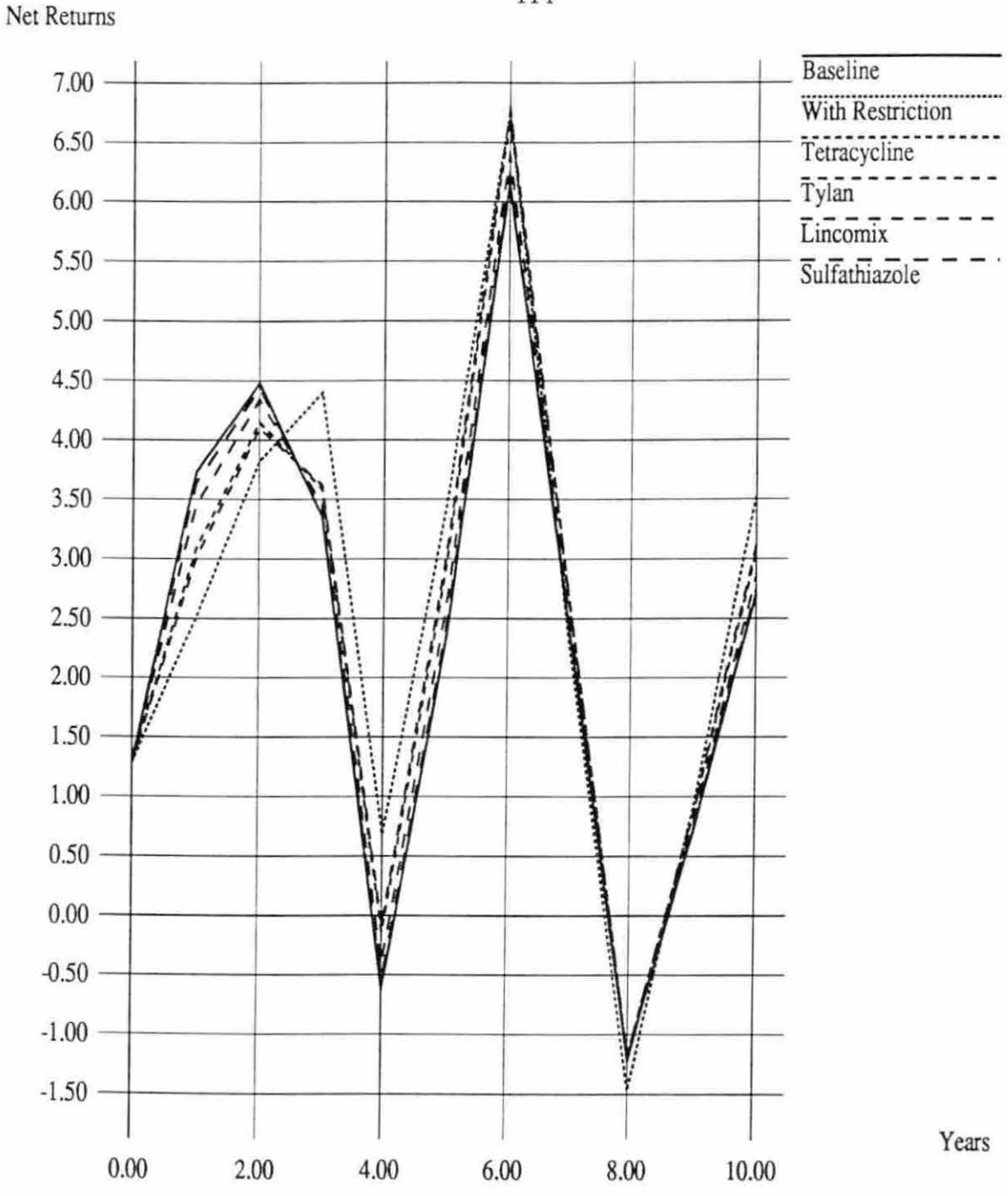

Figure 6.6: Changes in net returns following restrictions (ban) on sulfamethazine and use of different alternatives (dollars per hundredweight)

Table 6.8: Changes in sow prices following restrictions (ban) on sulfamethazine and use of different alternatives (dollars per hundredweight)

Year	Baseline	WR	% change	Tetracycline	% change	% COR	Tylosin	% change	% COR	Lincomycin	% change	% COR	Sulfathiazole	% change	% COR
0	34.00	34.00	0.00%	34.00	0.00%	0.00%	34.00	0.00%	0.00%	34.00	0.00%	0.00%	34.00	0.00%	0.00%
1	37.07	36.93	-0.38%	37.00	-0.19%	0.19%	36.99	-0.22%	0.16%	37.04	0.08%	0.30%	37.06	-0.03%	0.35%
2	37.26	37.55	0.79%	37.42	0.43%	-0.35%	37.44	0.48%	-0.29%	37.33	0.19%	-0.59%	37.28	0.05%	-0.72%
3	35.46	36.87	3.98%	36.01	1.55%	-2.33%	36.08	1.75%	-2.14%	35.70	0.68%	-3.17%	35.54	0.23%	-3.61%
4	32.55	34.14	4.88%	33.27	2.21%	-2.55%	33.36	2.49%	-2.28%	32.86	0.95%	-3.75%	32.64	0.28%	-4.39%
5	33.85	35.24	4.11%	34.62	2.27%	-1.76%	34.72	2.57%	-1.48%	34.18	0.97%	-3.01%	33.95	0.30%	-3.66%
6	35.55	36.54	2.78%	36.26	2.00%	-0.77%	36.35	2.25%	-0.52%	35.86	0.87%	-1.86%	35.64	0.25%	-2.46%
7	34.17	34.72	1.61%	34.68	1.49%	-0.12%	34.74	1.67%	0.06%	34.39	0.64%	-0.95%	34.23	0.18%	-1.41%
8	31.77	32.24	1.48%	32.15	1.20%	-0.28%	32.19	1.32%	-0.16%	31.94	0.54%	-0.93%	31.82	0.16%	-1.30%
9	33.21	33.97	2.29%	33.64	1.29%	-0.97%	33.70	1.48%	-0.79%	33.40	0.57%	-1.68%	33.26	0.15%	-2.09%
10	34.76	35.94	3.39%	35.36	1.70%	-1.64%	35.42	1.90%	-1.44%	35.01	0.72%	-2.59%	34.84	0.23%	-3.06%

COR: Change on Restriction
WR : With Restrictions (ban)

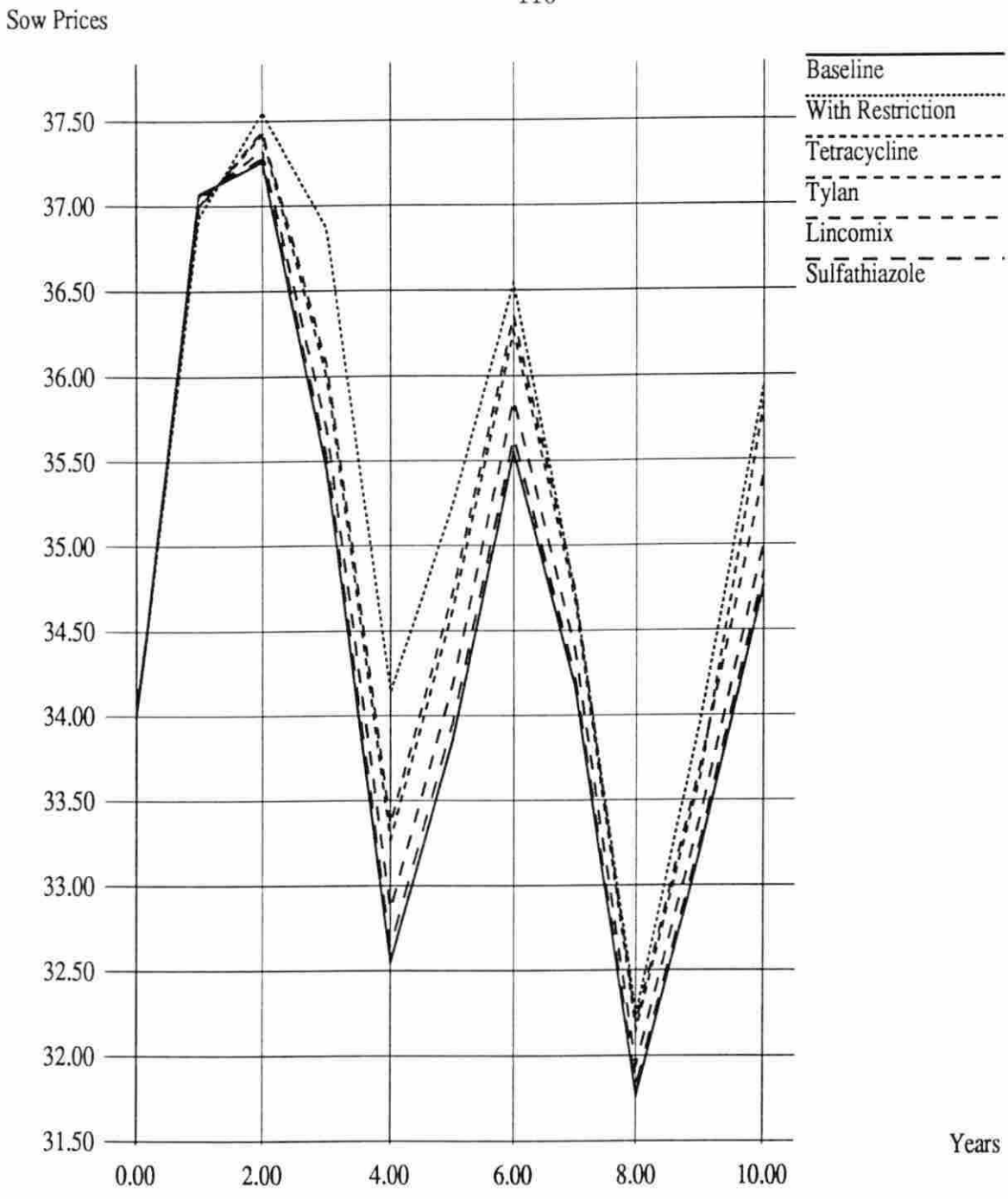

Figure 6.7: Changes in sow prices following restrictions (ban) on sulfamethazine and use of different alternatives (dollars per hundredweight)

Table 6.9: Changes in pork consumption following restrictions (ban) on sulfamethazine and use of different alternatives (million pounds)

Year	Baseline	WR	% change	Tetracycline	% change	% COR	Tylosin	% change	% COR	Lincomycin	% change	% COR	Sulfathiazole	% change	% COR
0	17475	17475	0.00%	17475	0.00%	0.00%	17475	0.00%	0.00%	17475	0.00%	0.00%	17475	0.00%	0.00%
1	17413	17418	0.03%	17416	0.02%	-0.01%	17416	0.02%	-0.01%	17415	0.01%	-0.02%	17414	0.01%	-0.02%
2	16859	16773	-0.51%	16813	-0.27%	0.24%	16807	-0.31%	0.20%	16839	-0.12%	0.39%	16853	-0.04%	0.48%
3	17381	17050	-1.90%	17250	-0.75%	1.17%	17250	-0.85%	1.07%	17233	-0.33%	1.61%	17324	-0.10%	1.84%
4	17865	17453	-2.31%	17676	-1.06%	1.28%	17652	-1.19%	1.14%	17782	-0.46%	1.89%	17840	-0.14%	2.22%
5	17905	17545	-2.01%	17708	-1.10%	0.93%	17683	-1.24%	0.79%	17819	-0.48%	1.56%	17879	-0.15%	1.90%
6	17510	17243	-1.52%	17335	-1.00%	0.53%	17312	-1.13%	0.40%	17433	-0.44%	1.10%	17487	-0.13%	1.42%
7	17722	17521	-1.13%	17575	-0.83%	0.31%	17556	-0.94%	0.20%	17657	-0.37%	0.78%	17702	-0.11%	1.03%
8	17978	17764	-1.19%	17842	-0.76%	0.44%	17824	-0.86%	0.34%	17918	-0.33%	0.87%	17960	-0.10%	1.10%
9	17620	17338	-1.60%	17468	-0.86%	0.75%	17449	-0.97%	0.64%	17553	-0.38%	1.24%	17600	-0.11%	1.51%
10	17450	17100	-2.01%	17273	-1.01%	1.01%	17250	-1.15%	0.88%	17373	-0.44%	1.60%	17427	-0.13%	1.91%

COR: Change on Restriction
WR : With Restrictions (ban)

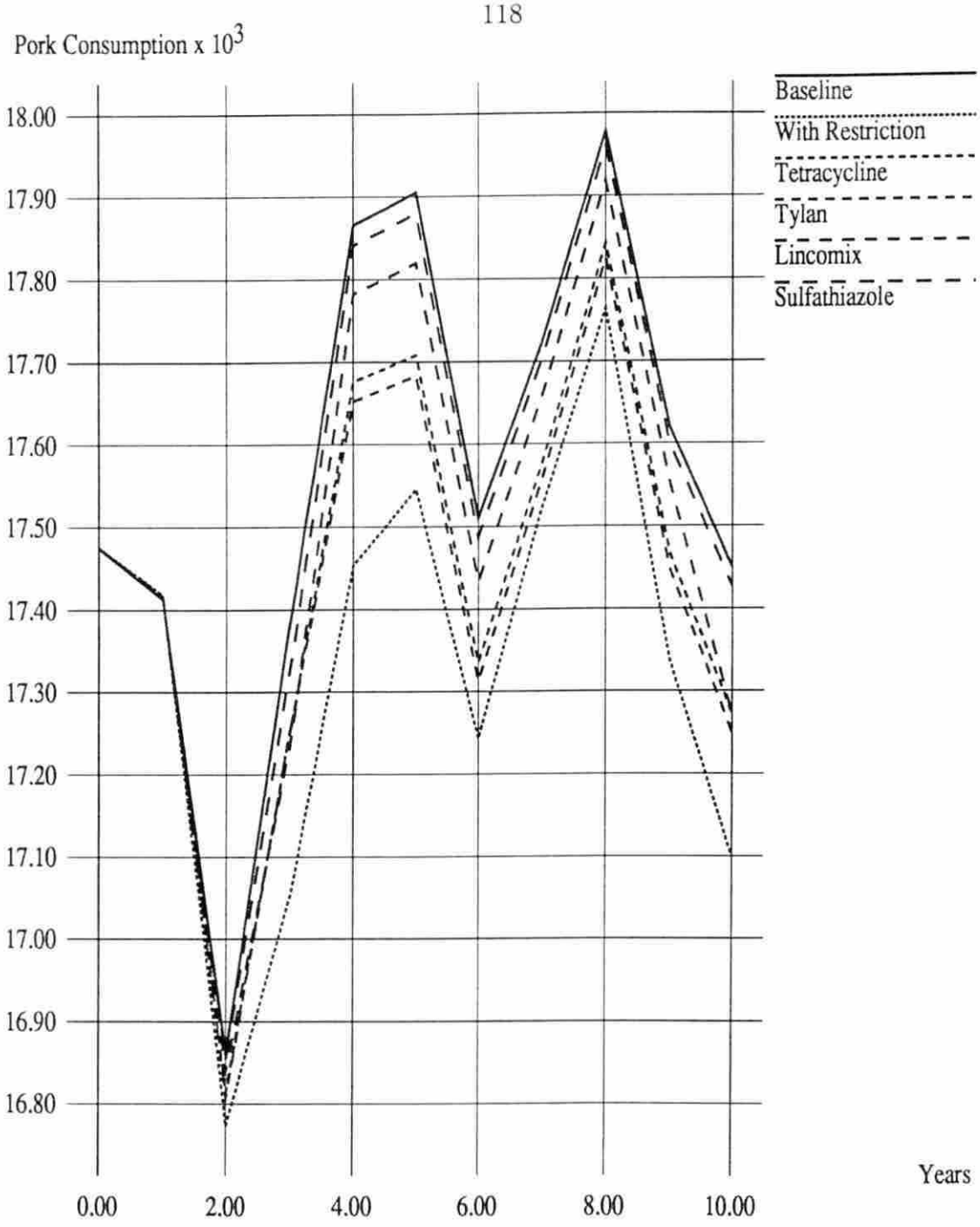

Figure 6.8: Changes in pork consumption following restrictions (ban) on sulfamethazine and use of different alternatives (million Pounds)

6.2 Changes in demand

In the earlier section of the chapter it is assumed that there are no changes in demand in response to a ban on sulfamethazine use. The purpose of this section is to incorporate demand changes in response to a ban on sulfamethazine under two circumstances. Firstly, where no alternatives are available to replace sulfamethazine use in pork production in response to further restrictions on its use and secondly, where there are alternatives to replace sulfamethazine use.

It is hypothesized that there will be perceived changes in views of consumers about the safety and wholesomeness of pork and pork products in response to a ban on sulfamethazine use in pork production. This will cause the consumers to demand more of pork at the same price. According to Berger, if the consuming public perceives the strategy of banning sulfamethazine to result in a more wholesome, safer food supply, then the consumer demand will increase causing the demand curve to shift in a rightward direction, from D_1 to D_2 (Figure 6.9). The resultant shift in the demand curve would push the prices from the P_1 level to a higher level, P_2 with a simultaneous increase in industry quantity from Q_1 to Q_2.

Berger's study analyzed two demand shift scenarios. Firstly, it was assumed that consumers would be willing to pay 1% more for safer compound and residue free pork product and secondly, that the consumer's will be willing to pay 5% more for residue and compound free meat. The combined effect of shifts in demand coupled with changes in supply are difficult to interpret and a little complicated to forecast. However, the FAPRI model allows for these interactions between supply and demand shifts and allow for adjustments over time. Tables 6.14 - 6.25 are estimates of these changes incorporated into the FAPRI pork model.

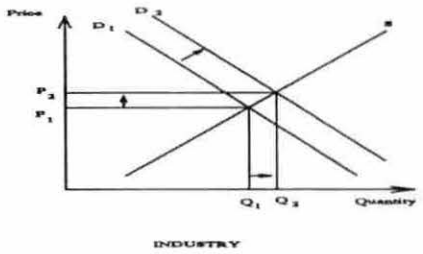

Figure 6.9: Change in demand due to consumer perception of an improved safety in pork following a ban on sulfamethazine

Further, use of alternatives over sulfamethazine in swine production will lead to changes in production, consumption and price levels over the baseline levels. Even though these alternatives are presently considered safe in their use, for human health and although their usage is presumed free of residue violations, due to consumer perception of meat containing chemical compounds, changes in demand with the use of any alternative will be smaller than the situation where there is a complete ban on use of any chemical compound in swine production. For purpose of comparison it is assumed that shifts in demand are same for all the alternatives evaluated:

1. Sulfathiazole (CSP 250)

2. Lincomycin (lincomix)

3. Tylosin (tylan)

4. Tetracycline: chlortetracycline (aureomycin) and oxytetracycline (terramycin)

In the absence of a true measure two demand shifts are evaluated. For the ban, demand shifts of 1 and 5 percent are evaluated. Corresponding shifts for the use of alternatives are 0.5 percent and 4 percent respectively. For example, the comparable demand shifts when a ban represents a 5 percent shift is a 4 percent shift for the alternative scenarios. A 1 percent shift resulting from a ban is reflected by a 0.5 percent shift for the alternative scenarios. These changes in demand are then coupled with the respective changes in supply established in the previous section.

Results obtained from this analysis are tabulated and presented in Tables 6.14 - 6.25 . A comparative analysis of percentage change in levels over baseline and ban levels is also included in the tables. The results are also graphed and presented in Figures 6.10 - 6.21. Changes in production, consumption and prices over the baseline and as compared between different alternatives can be seen with the use of the graphical presentations.

For a 1 percent increase in demand, under a total ban of sulfamethazine with no alternative substitutes, total production remained significantly lower than the baseline. This may be explained in part by higher rates of death incidence in the absence of alternative compounds to sulfamethazine use. Also production costs increase under such scenarios, causing supply to shift to the left. An increase in demand of 1 percent is simply not sufficient to offset these higher expenses of the producers causing the supply to decrease or shift to the left resulting in production levels much below the baseline. The increase in price levels both at the retail and farm level are significant. Production and consumption still fall below the baseline levels.

It is interesting to observe that for a 0.5 percent change in demand (willingness to pay) coupled with the use of alternatives to sulfamethazine and changes in supply,

Table 6.10: Assumptions for different scenarios following a ban on Sulfamethazine while allowing alternatives.

Compound	Decrease in Feed Efficiency (%)	Change in Demand (%)	Change in Mortality (%)
Tetracycline	2.3	0.0	0.0
Tetracycline	2.3	0.5	0.0
Tetracycline	2.3	4.0	0.0
Tylosin	2.6	0.0	0.0
Tylosin	2.6	0.5	0.0
Tylosin	2.6	4.0	0.0
Lincomycin	1.0	0.0	0.0
Lincomycin	1.0	0.5	0.0
Lincomycin	1.0	4.0	0.0
Sulfathiazole	0.3	0.0	0.0
Sulfathiazole	0.3	0.5	0.0
Sulfathiazole	0.3	4.0	0.0
None	8.6	0.0	6.0
None	8.6	1.0	6.0
None	8.6	5.0	6.0

the total production nearly equaled or even exceeded the base levels by insignificantly small values in case of both sulfathiazole and lincomycin. The total production remained slightly lower for the scenario of tetracycline and tylosin use. There is a better compromise in loss of feed efficiency with tylosin and tetracycline as compared to a situation where there are no substitutes to replace sulfamethazine. Cost increases associated with replacing sulfamethazine with available alternatives is less than costs associated with restrictions on sulfamethazine with no substitute replacements. This when coupled with an increase in consumer confidence leading to a 0.5 percent increase in demand, due to consumer perceptions of compound and residue free meat

Table 6.11: Changes over baseline levels following restrictions (ban) on sulfamethazine use and an increase in demand by 1% and the use of alternatives with an increase in demand of 0.5% in pork production at the end of tenth year

Compound	Production	Retail price	Farm price	Sow price	Consumption
Sulfamethazine	17495	2.13	50.19	34.76	17450
Sulfathiazole	17557	2.14	50.28	34.85	17511
Lincomycin	17502	2.14	50.59	35.03	17457
Tetracycline	17401	2.16	51.18	35.36	17357
Tylosin	17378	2.16	51.31	35.43	17334
With Restriction	17000	2.23	54.15	37.04	16958

products, is sufficient to raise production levels to almost equal baseline production. The sow, retail and pork prices are projected to still increase and remain higher in all years of our analysis.

Price increases associated with using tylosin and tetracycline to replace sulfamethazine are projected to be much higher than baseline levels. For sulfathiazole and lincomycin, the projected results are slightly different in that the production levels (in percent) are higher only by insignificant amounts over the baseline production level. Prices in general show high variability for these two compounds, moving up and down the baseline price levels. This becomes clear with graphical representations of results projected for sow prices (Figure 6.14), farm prices (Figure 6.12), and pork retail price (Figure 6.11). The expected decline in feed efficiency with the use of sulfathiazole as a substitute to sulfamethazine is only 0.3 percent (Table 6.2). The effect on cost following an almost negligible percent decline in feed efficiency is more than offset by a corresponding increase in willingness to pay of 0.5 percent. For higher prices in the initial years following substitution of sulfamethazine with sulfathiazole, due

Table 6.12: Changes over baseline levels following restrictions (ban) on sulfamethazine use and an increase in demand by 5% and the use of alternatives with an increase in demand of 4% in pork production at the end of tenth year

Compound	Production	Retail price	Farm price	Sow price	Consumption
Sulfamethazine	17495	2.13	50.19	34.76	17450
Sulfathiazole	18142	2.15	50.06	34.98	18092
lincomycin	18087	2.16	50.36	35.15	18037
Tetracycline	17985	2.17	50.92	35.47	17936
Tylosin	17961	2.18	51.05	35.54	17912
With Restriction	17661	2.24	53.72	37.09	17614

to higher costs, the producers over react and produce more than the actual demand. This drives the price down until the time where supply falls short of demand and the price increases. A 0.5 percent increase in demand is sufficient to offset the increase in costs even where sulfamethazine is replaced by lincomycin.

Finally, an anticipated increase of 4 percent in pork demand with the alternative substitutes to sulfamethazine leads us to production and consumption levels which are much higher than the baseline and also production and consumption levels obtained for all the earlier scenarios. An increase of 5 percent in demand for meat free of any compounds indicated higher prices for sow, barrow and gilts, and retail level at all times mainly because the cost of operating without alternative compounds is much higher. However, in this scenario the quantity produced and consumed is projected to be higher than baseline levels. In situations where there are alternatives to sulfamethazine use, prices fall to levels even below the baseline mainly to encourage sale of excess pork and avoid large accumulation on ending stocks.

% change in demand	Baseline	Ban	Tetracycline	Tylsoin	Lincomycin	Sulfathiazole
0	2.37	2.68	2.57	2.59	2.47	2.42
1 & 0.5	2.37	2.94	2.54	2.56	2.45	2.34
5 & 4.0	2.37	2.73	2.35	2.37	2.25	2.20

Table 6.13: Changes in average net returns for changes in demand following restrictions on sulfamethazine use in pork production (dollars per hundredweight)

A brief glance at Tables 6.11 and 6.12 which lists the changes in pork production, pork consumption, sow price, farm price and retail price, adjusting for changes in demand, at the end of the tenth year helps in understanding the effects of the use of each alternative compound in response to a ban on sulfamethazine in pork production.

The values expressed in the net returns are the actual net returns observed for each year of our study. However, these values can also be assumed to operate as expected net returns on the basis of which the producers base their future investment decisions. There is a time lag between the observed returns and the realization of investment decisions based on expected net returns. A close analysis of net returns tables indicates an average net returns of $2.37 per hundredweight for the baseline. For each scenario, the average net returns remain the highest for a complete ban on all antibiotic compounds in pork production. The avearge net return values obtained for sulfathiazole are the closet to the baseline followed by lincomycin, tetracycline and finally, tylosin. This can be seen from table 6.13.

Table 6.14: Changes in pork production following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 1% compared with use of alternatives and an increase in consumer demand of 0.5% (million pounds)

Year	Baseline	With Restrictions 1% increase	percentage change	Tetracyline 0.5% increase	percentage change	Tylosin 0.5% increase	percentage change	Lincomycin 0.5% increase	percentage change	Sulfathiazole 0.5% increase	percentage change
0	17234	17234	0.00%	17234	0.00%	17234	0.00%	17234	0.00%	17234	0.00%
1	17095	17102	0.04%	17097	0.01%	17097	0.01%	17095	0.00%	17094	-0.01%
2	16538	16418	-0.72	16517	-0.13%	16511	-0.16%	16545	0.04%	16560	0.13%
3	17131	16711	-2.45%	17075	-0.32%	17058	-0.42%	17152	0.12%	17193	0.36%
4	17649	17131	-2.93%	17572	-0.44%	17548	-0.57%	17679	0.17%	17738	0.50%
5	17525	17054	-2.68%	17445	-0.46%	17420	-0.59%	17556	0.18%	17617	0.52%
6	17111	16737	-2.19%	17037	-0.43%	17014	-0.56%	17135	0.14%	17189	0.46%
7	17509	17200	-1.76%	17439	-0.40%	17420	-0.51%	17522	0.07%	17568	0.33%
8	18014	17679	-1.85%	17939	-0.42%	17922	-0.51%	18017	0.02%	18059	0.25%
9	17634	17215	-2.37%	17549	-0.48%	17530	-0.59%	17631	0.01%	17683	0.28%
10	17495	17000	-2.83%	17401	-0.53%	17378	-0.67%	17502	0.04%	17557	0.35%

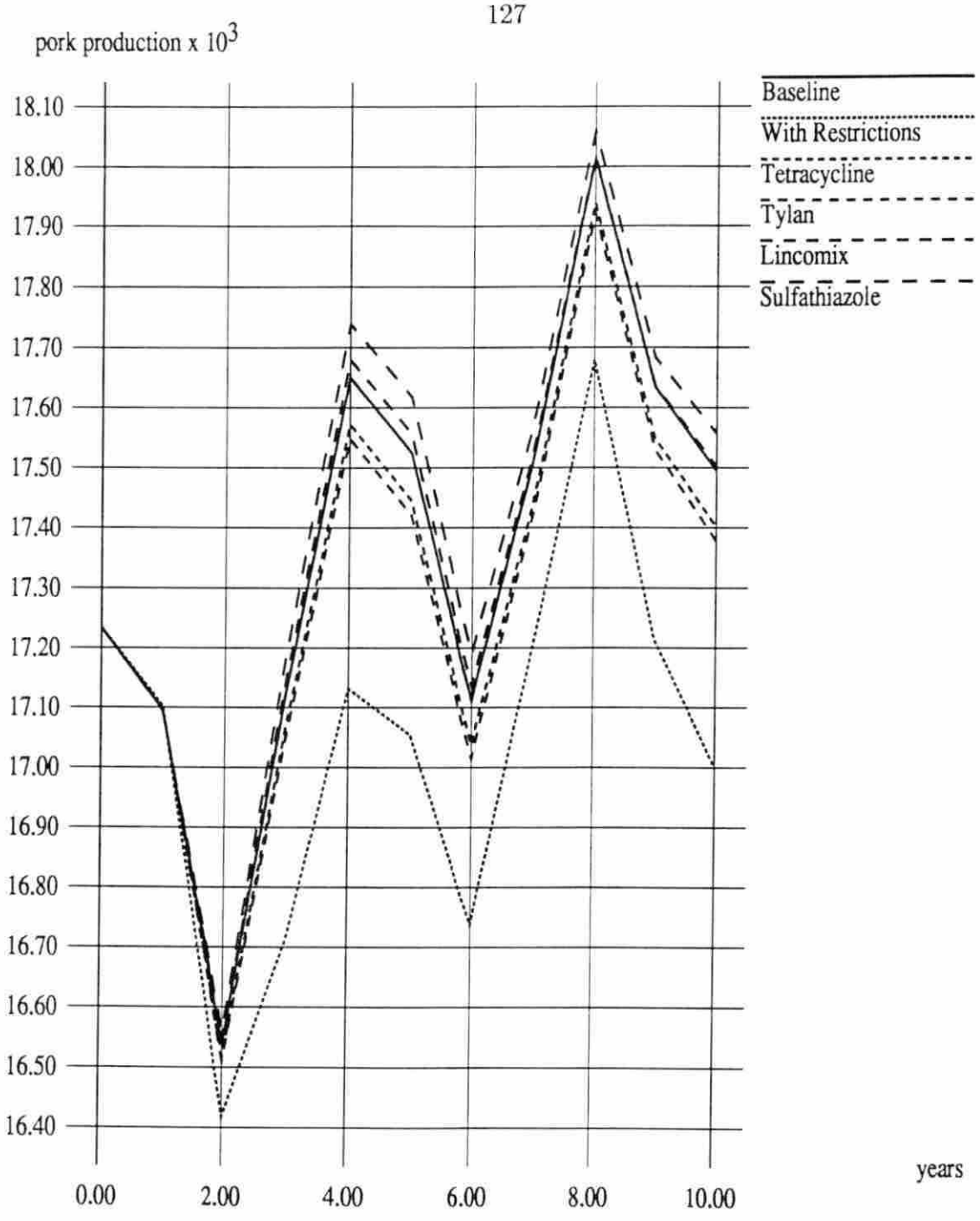

Figure 6.10: Changes in pork production following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 1% compared with use of alternatives and an increase in consumer demand of 0.5% (million pounds)

Table 6.15: Changes in pork retail price following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 1% compared with use of alternatives and an increase in consumer demand of 0.5% (million pounds)

Year	Baseline	With Restrictions 1% increase	percentage change	Tetracyline 0.5% increase	percentage change	Tylosin 0.5% increase	percentage change	Lincomycin 0.5% increase	percentage change	Sulfathiazole 0.5% increase	percentage change
0	1.98	1.98	0.00%	1.98	0.00%	1.98	0.00%	1.98	0.00%	1.98	0.00%
1	1.98	2.00	1.00%	1.99	0.51%	1.99	0.51%	1.99	0.51%	1.99	0.51%
2	2.0	2.05	2.50%	2.02	1.00%	2.02	1.00%	2.01	0.50%	2.01	0.50%
3	1.96	2.06	5.10%	1.99	1.53%	1.99	1.53%	1.98	1.02%	1.97	0.51%
4	1.89	2.00	1.00%	1.91	1.05%	1.92	1.59%	1.90	0.53%	1.89	0.00%
5	1.95	2.05	5.12%	1.98	1.50%	1.98	1.54%	1.96	0.51%	1.95	0.00%
6	2.02	2.10	4.00%	2.04	0.99%	2.05	1.49%	2.03	0.50%	2.02	0.00%
7	1.99	2.05	3.01%	2.01	1.00%	2.01	1.01%	2.00	0.50%	1.99	0.00%
8	1.94	1.99	2.58%	1.96	1.00%	1.96	1.03%	1.95	0.52%	1.94	0.00%
9	2.04	2.11	3.43%	2.06	0.98%	2.06	0.98%	2.05	0.49%	2.04	0.00%
10	2.13	2.23	4.70%	2.16	1.40%	2.16	1.41%	2.14	0.47%	2.14	0.47%

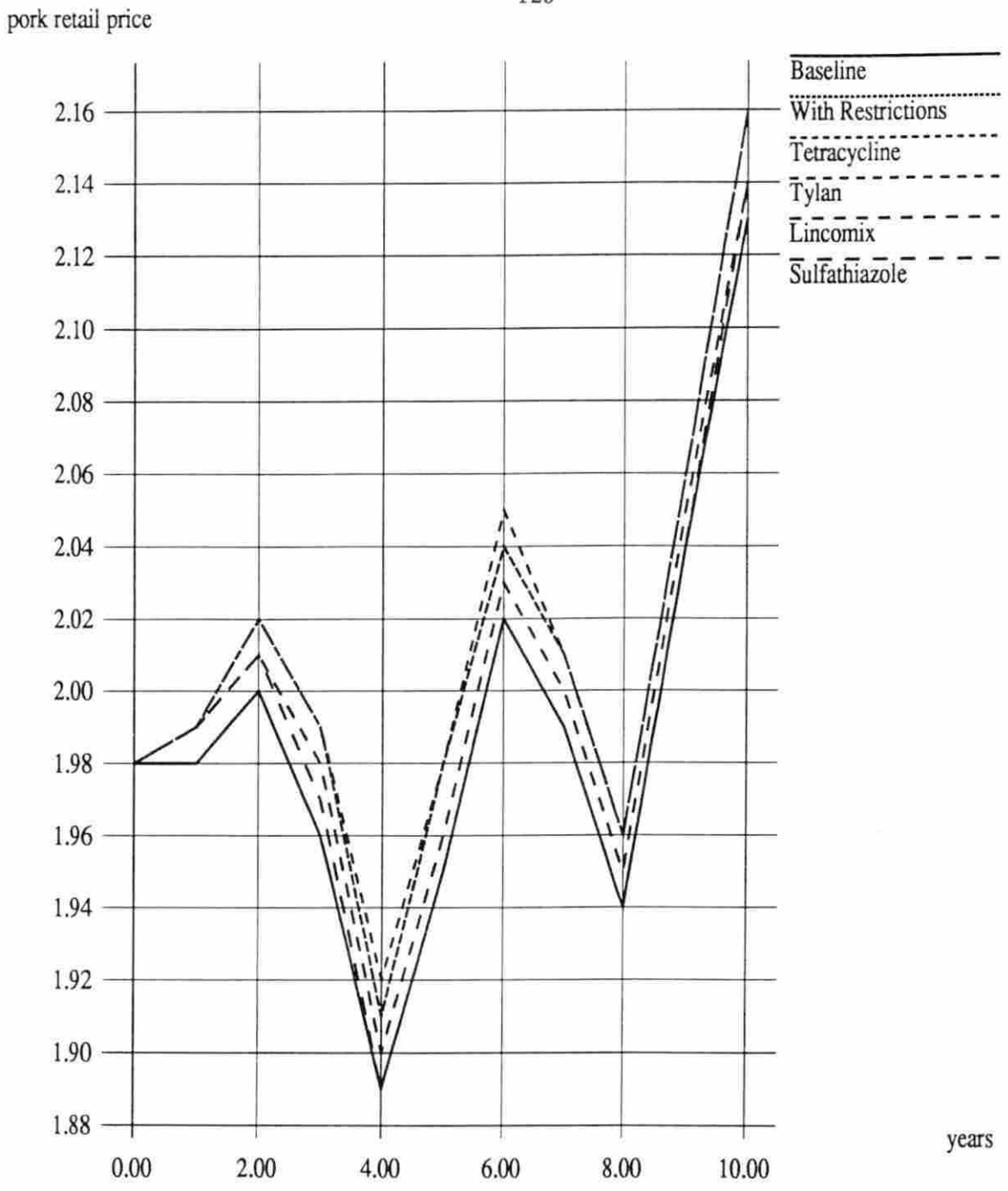

Figure 6.11: Changes in pork retail price following restrictions (ban) on sulfamethazine use and with increase in consumer demand of 1% compared with use of alternatives and increase in consumer demand of 0.5% (dollars per pound)

Table 6.16: Changes in farm prices for barrows and gilts following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 1% compared with use of alternatives and an increase in consumer demand of 0.5% (million pounds)

Year	Baseline	With Restrictions 1% increase	percentage change	Tetracyline 0.5% increase	percentage change	Tylosin 0.5% increase	percentage change	Lincomycin 0.5% increase	percentage change	Sulfathiazole 0.5% increase	percentage change
0	43.03	43.03	0.00%	43.03	0.00%	43.03	0.00%	43.03	0.00%	43.03	0.00%
1	46.07	46.93	1.80%	46.50	0.93%	46.50	0.93%	46.51	0.96%	46.51	0.96%
2	48.53	50.34	3.72%	49.15	1.28%	49.19	1.36%	48.96	0.89%	48.86	0.68%
3	45.83	49.49	7.99%	46.63	1.75%	46.74	1.99%	46.14	0.68%	45.88	0.11%
4	42.11	46.03	9.31%	42.93	1.95%	43.07	2.27%	42.32	0.50%	41.99	-0.28%
5	45.79	49.65	8.43%	46.67	1.92%	46.83	2.27%	45.99	0.44%	45.62	-0.37%
6	49.83	53.21	6.78%	50.72	1.79%	50.88	2.10%	50.06	0.46%	49.71	-0.24%
7	47.06	49.55	5.30%	47.83	1.64%	47.94	1.80%	47.34	0.59%	47.08	0.04%
8	44.05	46.32	5.15%	44.75	1.59%	44.84	1.80%	44.37	0.73%	44.17	0.27%
9	46.82	49.80	6.36%	47.64	1.75%	47.74	1.96%	47.20	0.81%	46.96	0.30%
10	50.19	54.15	7.90%	51.18	1.97%	51.31	2.23%	50.59	0.80%	50.28	0.18%

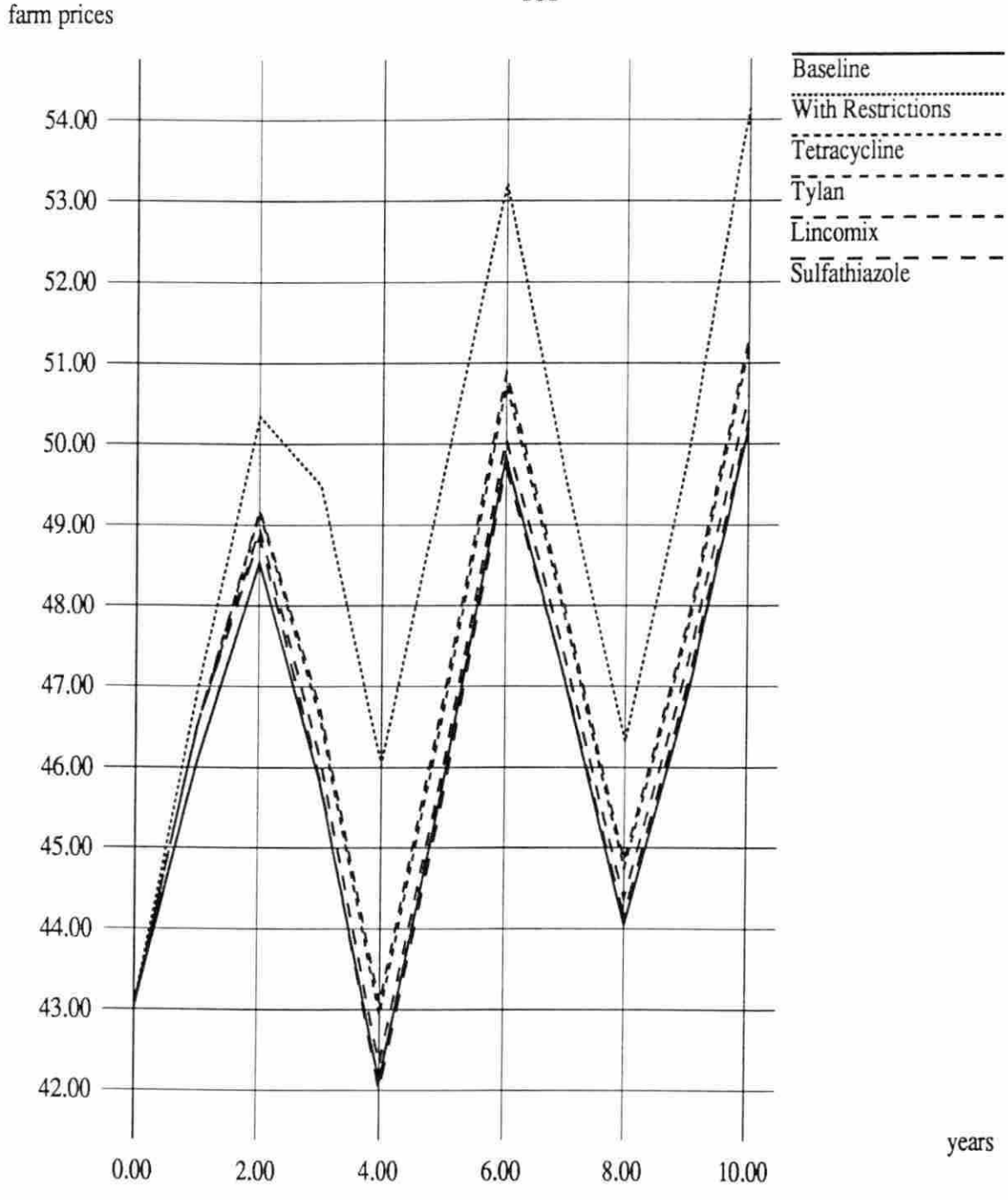

Figure 6.12: Changes in farm prices for barrows and gilts following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 1% compared with use of alternatives and an increase in consumer demand of 0.5% (dollars per hundredweight)

Table 6.17: Changes in net returns following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 1% compared with use of alternatives and an increase in consumer demand of 0.5% (million pounds)

Year	Baseline	With Restrictions 1% increase	percentage change	Tetracyline 0.5% increase	percentage change	Tylosin 0.5% increase	percentage change	Lincomycin 0.5% increase	percentage change	Sulfathiazole 0.5% increase	percentage change
0	1.28	1.28	0.00%	1.28	0.00%	1.28	0.00%	1.28	0.00%	1.28	0.00%
1	3.73	2.20	-41.00%	3.52	-8.45%	3.44	-5.6%	3.89	4.29%	4.09	9.65%
2	4.48	3.80	15.10%	4.45	-1.79%	4.40	-0.67%	4.63	3.35%	4.73	5.58%
3	3.36	4.71	40.20%	3.54	6.25%	3.57	5.36%	3.41	1.49%	3.33	-0.89%
4	-0.62	1.03	266.00%	-0.41	45.16%	-0.34	33.87%	-0.67	8.06%	-0.82	32.26%
5	2.33	3.87	66.10%	2.60	14.60%	2.67	11.60%	2.26	-3.00%	2.08	-10.73%
6	6.15	7.20	17.00%	6.42	5.53%	6.49	4.39%	6.11	-0.65%	5.94	-3.41%
7	2.42	2.54	5.00%	2.56	7.02%	2.59	5.79%	2.43	0.41%	2.36	-2.48%
8	-1.21	-1.33	-9.90%	-1.14	5.78%	-1.14	5.78%	-1.16	-4.13%	-1.17	-3.31%
9	0.68	1.24	82.4%	0.86	26.47%	0.87	26.47%	0.78	14.71%	0.74	8.82%
10	2.70	4.16	54.10%	3.02	13.70%	3.07	11.85%	2.81	4.07%	2.07	0.00%

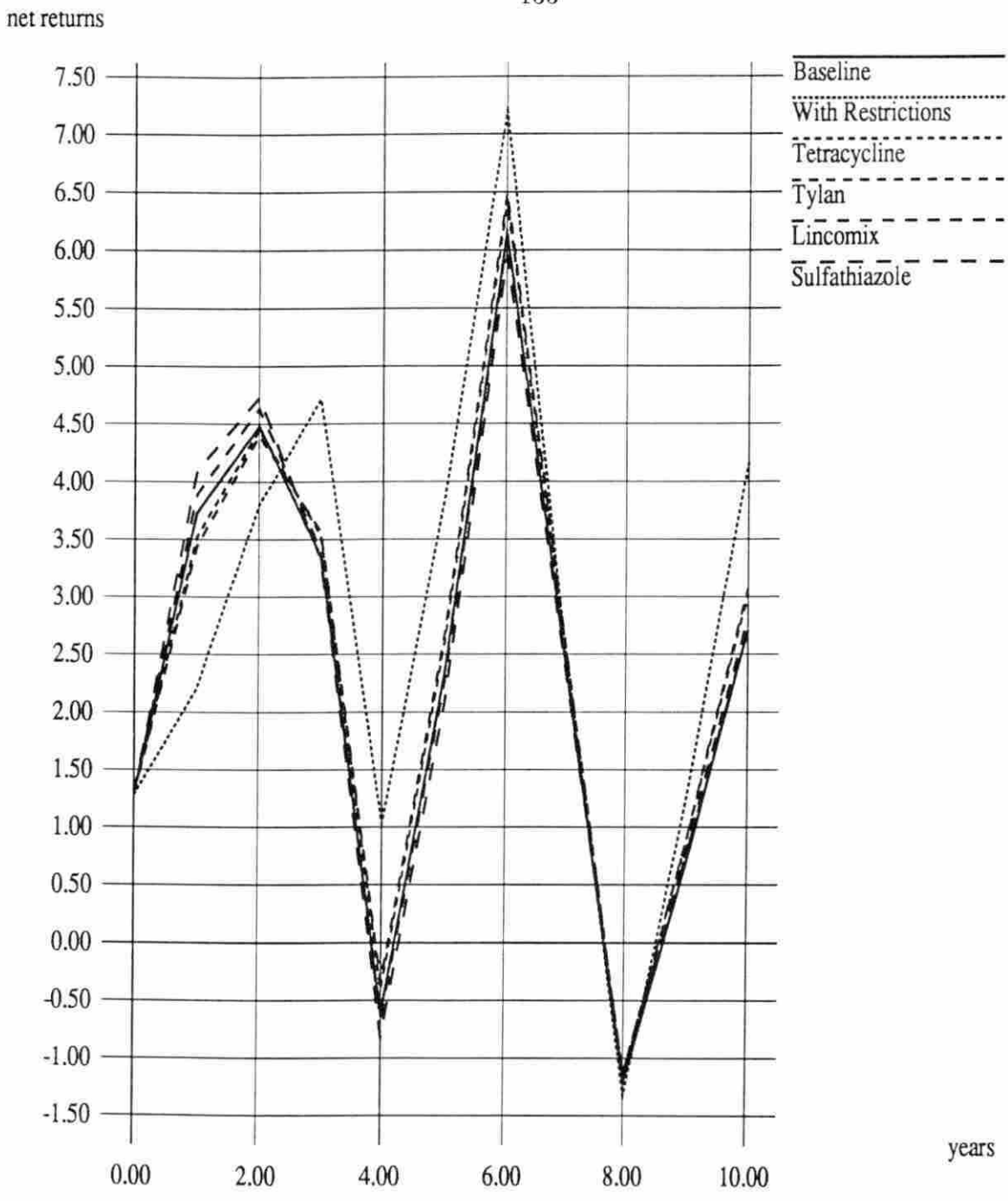

Figure 6.13: Changes in net returns following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 1% compared with use of alternatives and an increase in consumer demand of 0.5% (dollars per hundredweight)

Table 6.18: Changes in sow prices following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 1% compared with use of alternatives and an increase in consumer demand of 0.5% (million pounds)

Year	Baseline	With Restrictions 1% increase	percentage change	Tetracyline 0.5% increase	percentage change	Tylosin 0.5% increase	percentage change	Lincomycin 0.5% increase	percentage change	Sulfathiazole 0.5% increase	percentage change
0	34.00	34.00	0.00%	34.00	0.00%	34.00	0.00%	34.00	0.00%	34.00	0.00%
1	37.07	37.52	1.21%	37.36	0.78%	37.35	0.76%	37.40	0.89%	37.42	0.94%
2	37.26	38.34	2.90%	37.67	1.10%	37.69	1.15%	37.58	0.86%	37.53	0.72%
3	35.46	37.86	6.76%	36.01	1.55%	36.08	1.75%	35.70	0.68%	35.53	0.20%
4	32.55	35.16	8.00%	33.11	1.72%	33.21	2.03%	32.71	0.49%	32.49	-0.18%
5	33.85	36.26	7.12%	34.42	1.68%	34.52	1.97%	33.98	0.38%	33.75	-0.30%
6	35.55	37.54	5.60%	36.10	1.55%	36.19	1.80%	35.70	0.42%	35.48	-0.20%
7	34.17	35.60	4.18%	34.65	1.40%	34.71	1.58%	34.36	0.56%	34.20	0.09%
8	31.77	33.05	4.00%	32.20	1.35%	32.25	1.51%	31.99	0.69%	31.87	0.36%
9	33.21	34.90	5.08%	33.71	1.50%	33.76	1.66%	33.46	0.75%	33.83	0.36%
10	34.76	37.04	6.55%	35.36	1.73%	35.43	1.93%	35.03	0.78%	34.85	0.26%

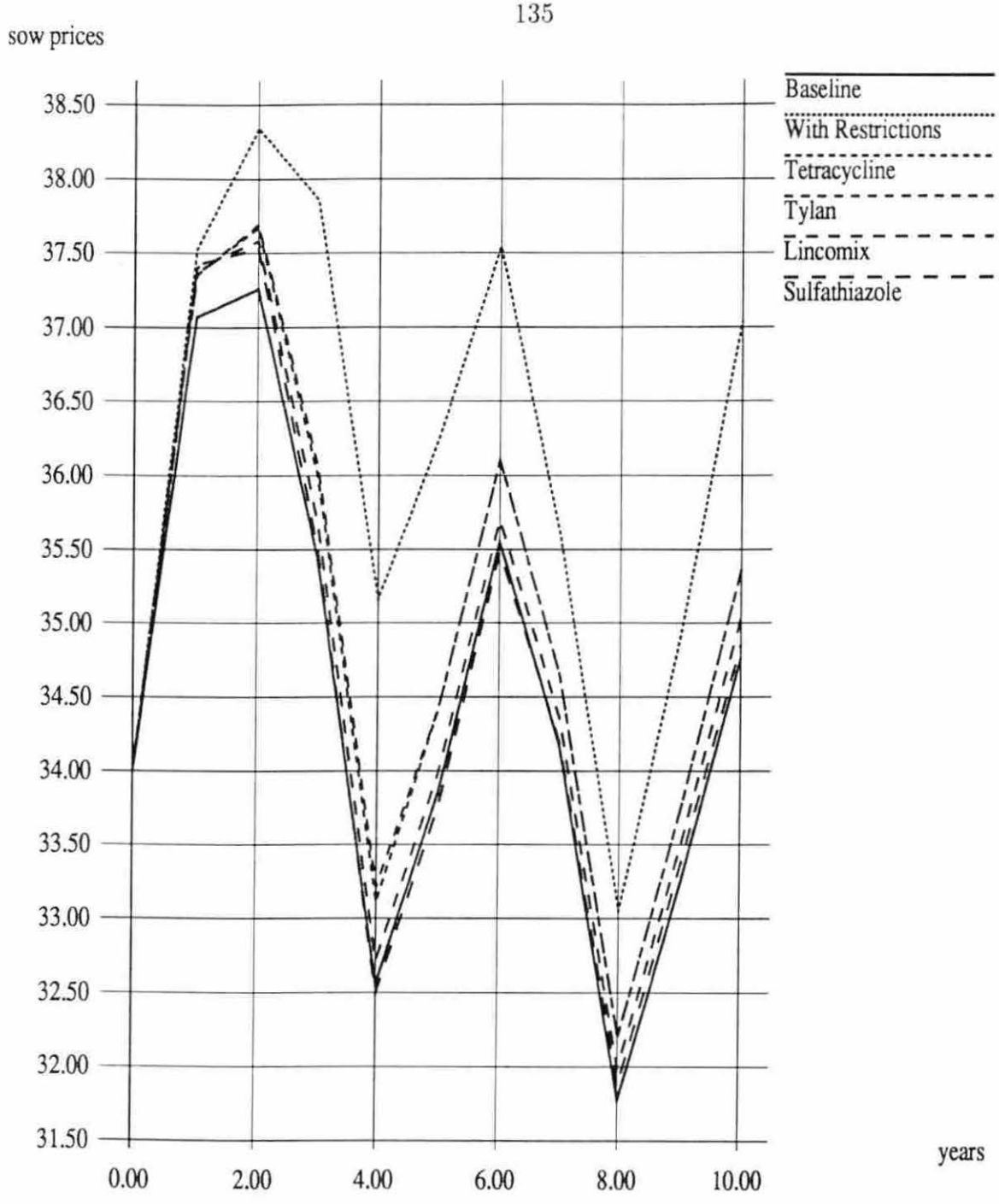

Figure 6.14: Changes in sow prices following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 1% compared with use of alternatives and an increase in consumer demand of 0.5% (Dollars per hundredweight)

Table 6.19: Changes in pork consumption following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 1% compared with use of alternatives and an increase in consumer demand of 0.5% (million pounds)

Year	Baseline	With Restrictions 1% increase	percentage change	Tetracyline 0.5% increase	percentage change	Tylosin 0.5% increase	percentage change	Lincomycin 0.5% increase	percentage change	Sulfathiazole 0.5% increase	percentage change
0	17475	17475	0.00%	17475	0.00%	17475	0.00%	17475	0.00%	17475	0.00%
1	17413	17423	0.06%	17416	0.02%	17417	0.02%	17415	0.01%	17414	0.00%
2	16859	16742	-0.60%	16837	-0.13%	16831	-0.16%	16864	0.03%	16878	0.11%
3	17381	16973	-2.35%	17326	-0.32%	17309	-0.41%	17401	0.12%	17441	0.34%
4	17865	17345	-2.91%	17788	-0.43%	17764	-0.56%	17894	0.16%	17952	0.49%
5	17905	17430	-2.65%	17825	-0.45%	17800	-0.58%	17937	0.18%	17997	0.51%
6	17510	17132	-2.15%	17435	-0.42%	17412	-0.55%	17534	0.14%	17589	0.45%
7	17722	17411	-1.75%	17651	-0.40%	17632	-0.50%	17735	0.07%	17781	0.33%
8	17978	17646	-1.85%	17904	-0.41%	17887	-0.50%	17982	0.02%	18024	0.26%
9	17620	17205	-2.35%	17536	-0.47%	17516	-0.59%	17621	0.01%	17668	0.27%
10	17450	16958	-2.80%	17357	-0.53%	17334	-0.66%	17457	0.04%	17511	0.35%

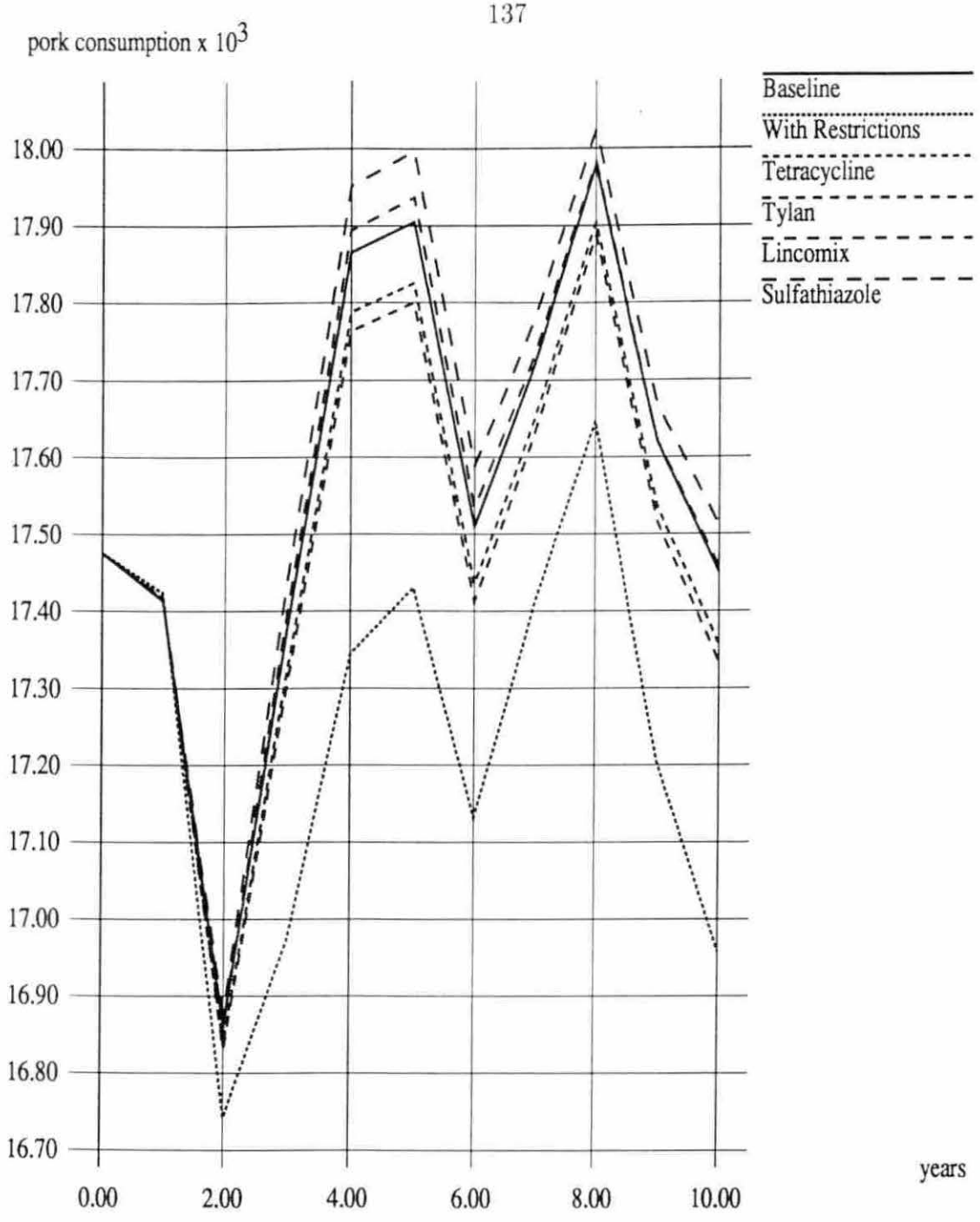

Figure 6.15: Changes in consumption following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 1% compared with use of alternatives and an increase in consumer demand of 0.5% (million pounds)

Table 6.20: Changes in pork production following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 5% compared with use of alternatives and an increase in consumer demand of 4% (million pounds)

Year	Baseline	With Restrictions 5% increase	percentage change	Tetracyline 4% increase	percentage change	Tylosin 4% increase	percentage change	Lincomycin 4% increase	percentage change	Sulfathiazole 4% increase	percentage change
0	17234	17234	0.00%	17234	0.00%	17234	0.00%	17234	0.00%	17234	0.00%
1	17095	17090	-0.03%	17086	-0.05%	17086	-0.05%	17084	-0.06%	17083	-0.07%
2	16538	16635	0.59%	16716	1.08 %	16709	1.03 %	16746	1.26%	16762	1.35%
3	17131	17324	1.13%	17630	2.91 %	17612	2.81 %	17711	3.39%	17755	3.64%
4	17649	18004	2.01%	18361	4.03 %	18335	3.89 %	18472	4.66%	18533	5.01%
5	17525	17961	2.49%	18268	4.24 %	18242	4.09 %	18385	4.91 %	18448	5.27%
6	17111	17516	2.37%	17753	3.75 %	17728	3.61 %	17859	4.37 %	17917	4.71%
7	17509	17806	1.70%	17998	2.79 %	17977	2.67 %	18091	3.32 %	18142	3.62%
8	18014	18185	0.95%	18399	2.14 %	18379	2.03 %	18484	2.61 %	18531	2.87%
9	17634	17758	0.70%	18030	2.25 %	18009	2.13 %	18121	2.76 %	18170	3.04%
10	17495	17661	0.95%	17985	2.80 %	17961	2.66 %	18087	3.38 %	18142	3.70%

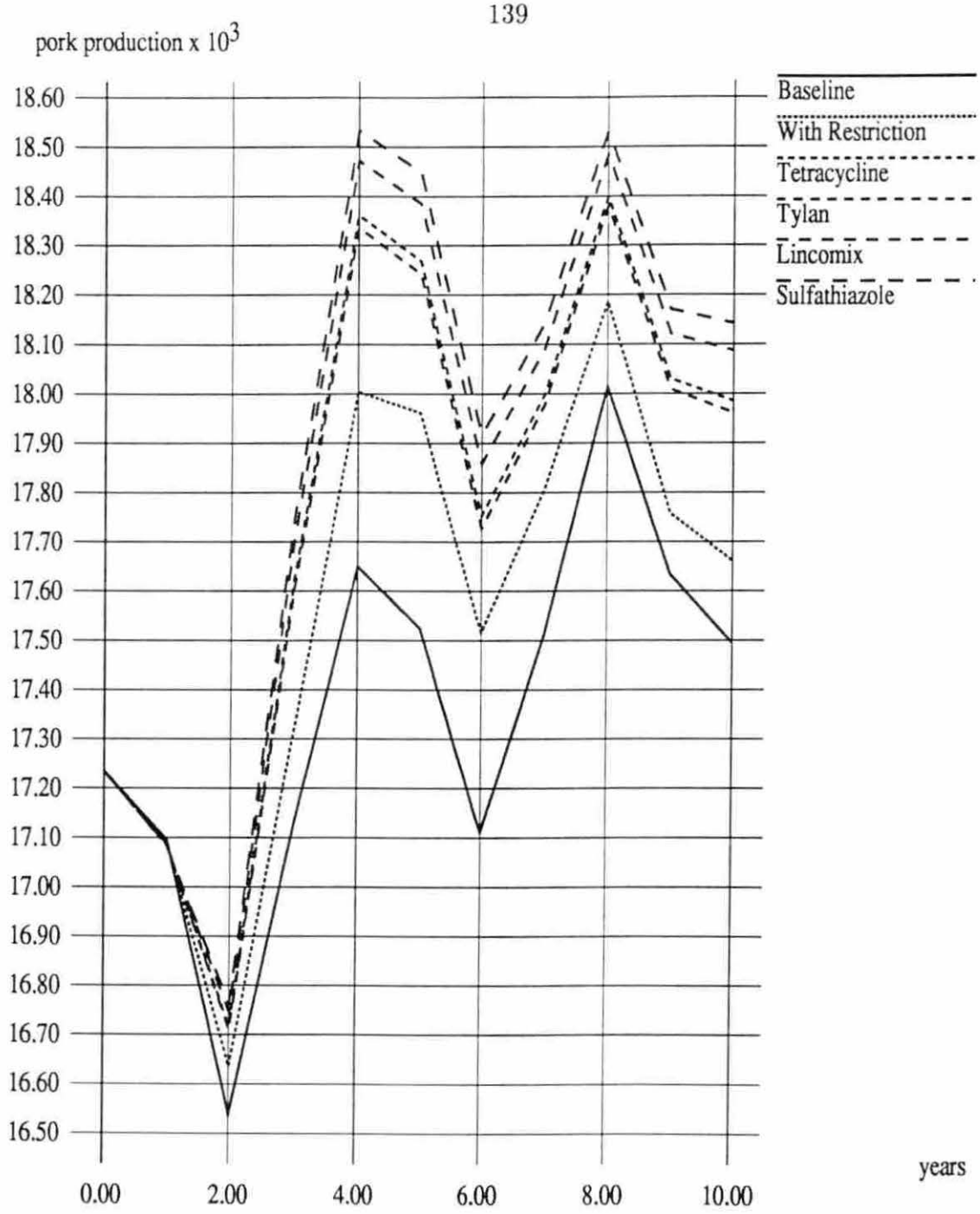

Figure 6.16: Changes in pork production following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 5% compared with use of alternatives and an increase in consumer demand of 4% (million pounds)

Table 6.21: Changes in pork retail price following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 5% compared with use of alternatives and an increase in consumer demand of 4% (dollars per pound)

Year	Baseline	With Restrictions 5% increase	percentage change	Tetracyline 4% increase	percentage change	Tylosin 4% increase	percentage change	Lincomycin 4% increase	percentage change	Sulfathiazole 4% increase	percentage change
0	1.98	1.98	0.00%	1.98	0.00%	1.98	0.00%	1.98	0.00%	1.98	0.00%
1	1.98	2.11	6.57%	2.08	5.05%	2.08	5.05%	2.08	5.05%	2.08	5.05%
2	2.00	2.13	6.50%	2.09	4.50%	2.09	4.50%	2.08	4.00%	2.08	4.00%
3	1.96	2.07	5.61%	2.00	2.04%	2.00	2.04%	1.99	1.53%	1.98	1.02%
4	1.89	1.96	3.70%	1.89	0.00%	1.89	0.00%	1.87	-1.0%6	1.86	-1.59%
5	1.95	2.01	3.08%	1.94	-0.5%1	1.94	-0.5%1	1.92	-1.5%4	1.91	-2.05%
6	2.02	2.07	2.48%	2.02	0.00%	2.02	0.00%	2.00	-0.9%9	1.99	-1.49%
7	1.99	2.05	3.02%	2.01	1.01%	2.01	1.01%	1.99	0.00%	1.99	0.00%
8	1.94	2.05	4.12%	1.98	2.06%	1.98	2.06%	1.97	1.55%	1.96	1.03%
9	2.04	2.14	4.90%	2.09	2.45%	2.09	2.45%	2.07	1.47%	2.07	1.47%
10	2.13	2.24	5.16%	2.17	1.88%	2.18	2.35%	2.16	1.41%	2.15	0.94%

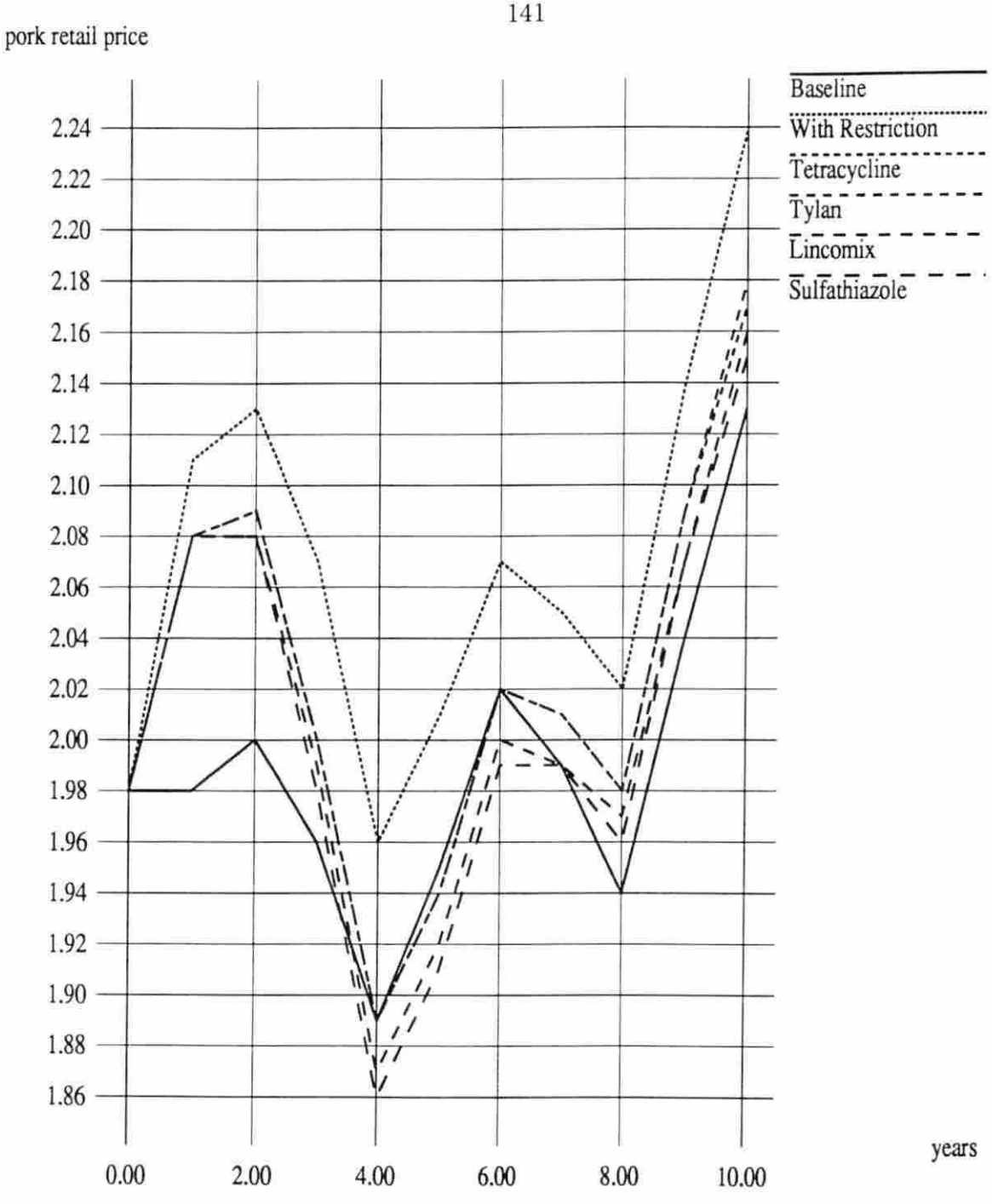

Figure 6.17: Changes in pork retail price following restrictions on sulfamethazine use and with an increase in consumer demand of 5% compared with use of alternatives and an increase in consumer demand of 4% (dollars per pound)

Table 6.22: Changes in farm prices for barrows and gilts following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 5% compared with use of alternatives and an increase in consumer demand of 4% (dollars per hundredweight)

Year	Baseline	With Restrictions 5% increase	percentage change	Tetracyline 4% increase	percentage change	Tylosin 4% increase	percentage change	Lincomycin 4% increase	percentage change	Sulfathiazole 4% increase	percentage change
0	43.03	43.03	0.00%	43.03	0.00%	43.03	0.00%	43.03	0.00%	43.03	0.00%
1	46.07	50.48	9.57%	49.59	7.64%	49.59	7.64%	49.60	7.66%	49.60	7.66%
2	48.53	52.72	8.63%	51.15	5.40%	51.20	5.50%	50.94	4.97%	50.83	4.74%
3	45.83	49.03	6.98%	46.21	0.83%	46.33	1.09%	45.72	-0.24%	45.46	-0.81%
4	42.11	43.92	4.30%	41.19	-2.18%	41.32	-1.88%	40.60	-3.59%	40.29	-4.32%
5	45.79	46.97	2.58%	44.41	-3.01%	44.56	-2.69%	43.76	-4.43%	43.41	-5.20%
6	49.83	51.00	2.35%	48.76	-2.15%	48.91	-1.85%	48.10	-3.47%	47.75	-4.17%
7	47.06	48.76	3.61%	47.04	-0.04%	47.16	0.21%	46.52	-1.15%	46.24	-1.74%
8	44.05	46.49	5.54%	44.85	1.82%	44.94	2.02%	44.43	0.86%	44.21	0.36%
9	46.82	50.00	6.79%	47.85	2.20%	47.96	2.43%	47.40	1.24%	47.15	0.70%
10	50.19	53.72	7.03%	50.92	1.45%	51.05	1.71%	50.36	0.34%	50.06	-0.26%

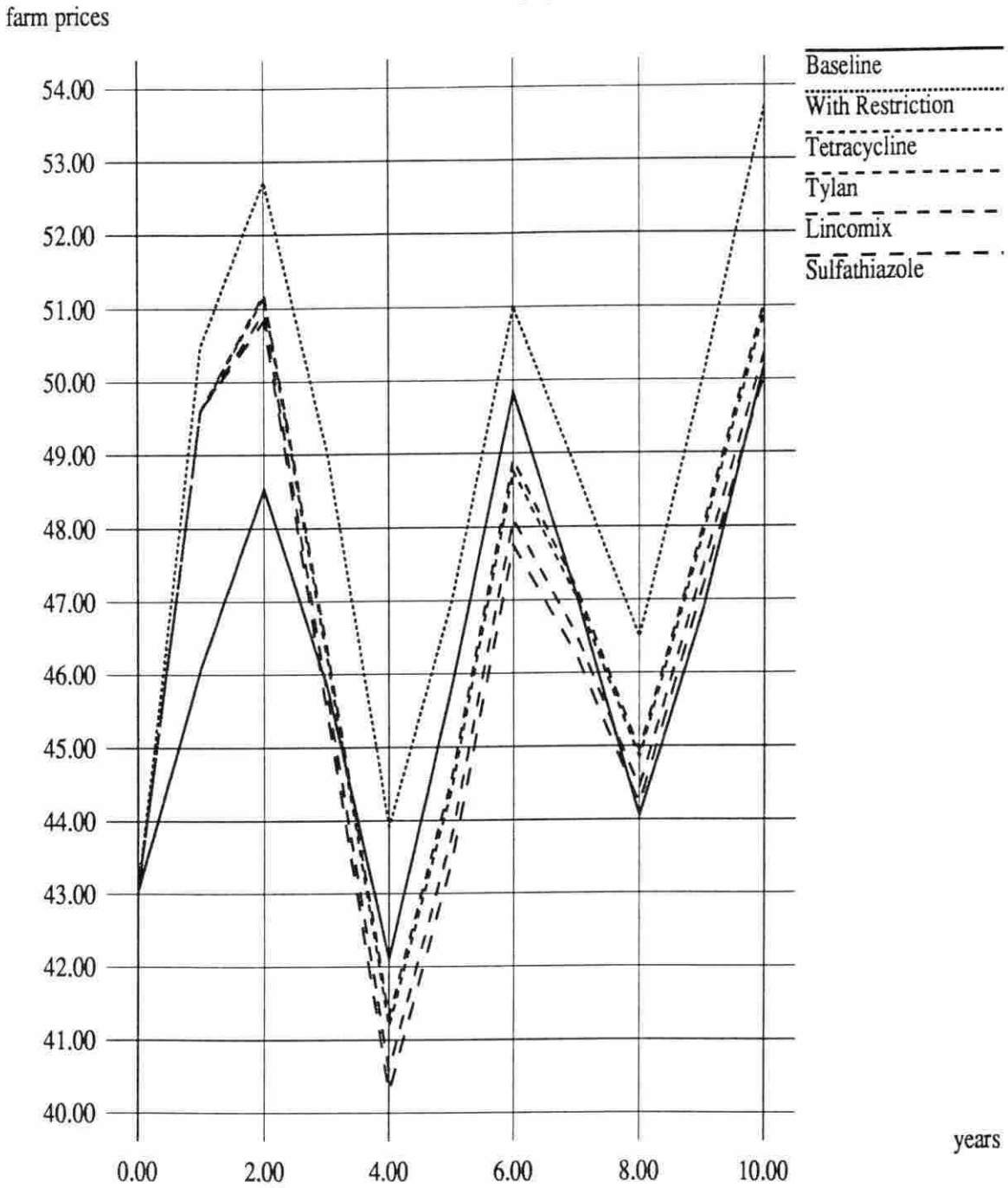

Figure 6.18: Changes in farm prices for barrows and gilts following restrictions (ban) on sulfamethazine use and with increase in consumer demand of 5% compared with use of alternatives and increase in consumer demand of 4% (dollars per hundredweight)

Table 6.23: Changes in net returns following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 5% compared with use of alternatives and an increase in consumer demand of 4% (dollars per hindredweight)

Year	Baseline	With Restrictions 5% increase	percentage change	Tetracyline 4% increase	percentage change	Tylosin 4% increase	percentage change	Lincomycin 4% increase	percentage change	Sulfathiazole 4% increase	percentage change
0	1.28	1.28	0.00%	1.28	0.00%	1.28	0.00%	1.28	0.00%	1.28	0.00%
1	3.73	5.84	56.57%	6.69	79.36%	6.60	76.94%	7.05	89.01%	7.25	94.37%
2	4.48	6.24	39.29%	6.50	45.09%	6.46	44.20%	6.66	48.66%	6.75	50.67%
3	3.36	4.27	27.08%	3.13	-6.85%	3.17	-5.65%	2.99	-11.01%	2.92	-13.10%
4	-0.62	-1.10	77.42%	-2.16	248.39%	-2.11	240.32%	-2.41	288.71%	-2.53	308.06%
5	2.33	1.18	-49.36%	0.32	-86.27%	0.39	-83.26%	0.01	-99.57%	-0.15	-106.44%
6	6.15	4.99	-18.86%	4.44	-27.80%	4.51	-26.67%	4.14	-32.68%	3.97	-35.45%
7	2.42	1.76	-27.27%	1.77	-26.86%	1.81	-25.21%	1.61	-33.47%	1.53	-36.78%
8	-1.21	-1.14	-5.79%	-1.03	-14.88%	-1.02	-15.70%	-1.08	-10.74%	-1.11	-8.26%
9	0.68	1.46	114.71%	1.09	60.29%	1.11	63.24%	1.00	47.06%	0.95	39.71%
10	2.70	3.75	38.89%	2.78	2.96%	2.82	4.44%	2.59	-4.07%	2.49	-7.78%

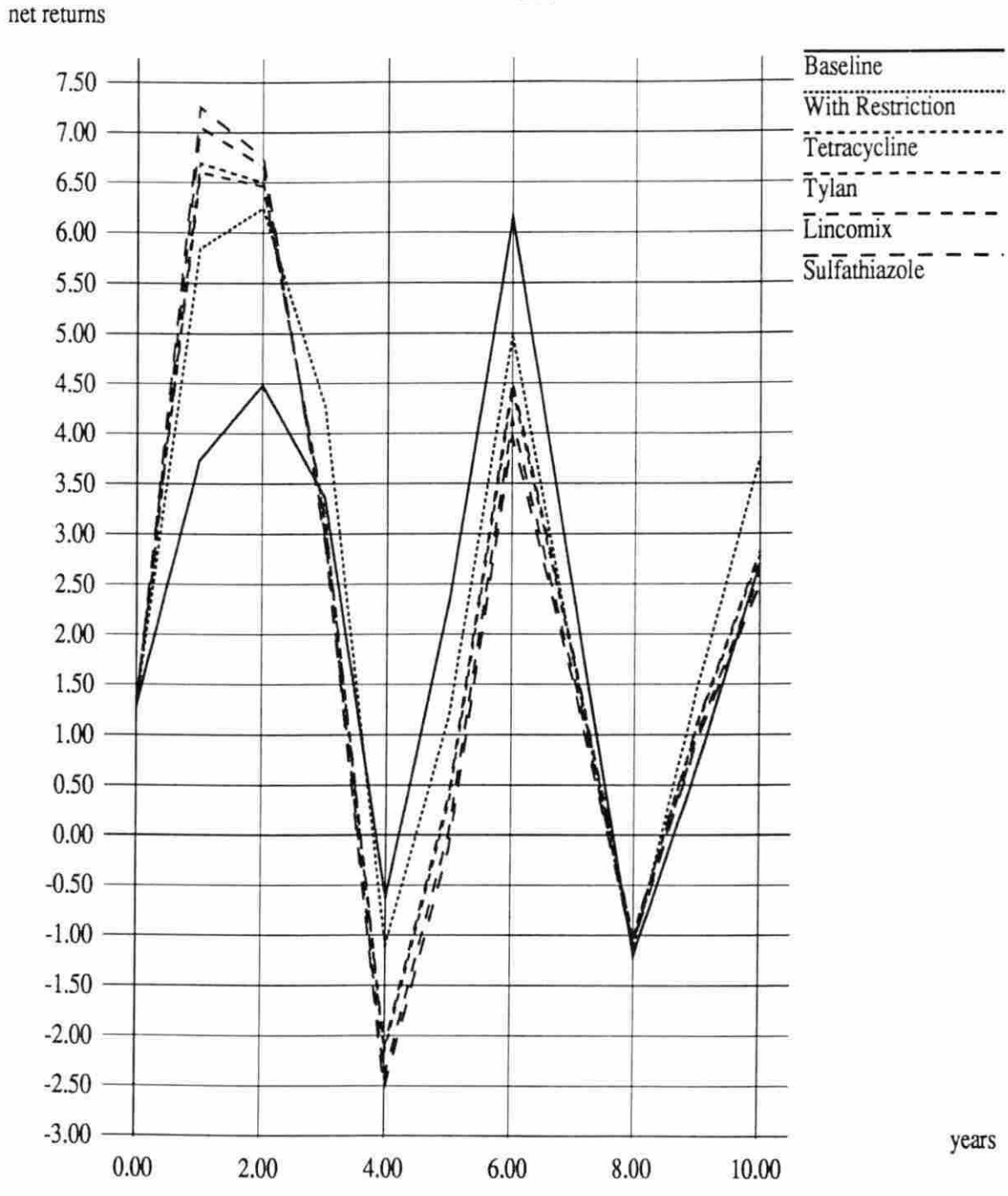

Figure 6.19: Changes in net returns following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 5% compared with use of alternatives and an increase in consumer demand of 4% (dollars per hundredweight)

Table 6.24: Changes in sow prices following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 5% compared with use of alternatives and an increase in consumer demand of 4% (dollars per hundredweight)

Year	Baseline	With Restrictions 5% increase	percentage change	Tetracyline 4% increase	percentage change	Tylosin 4% increase	percentage change	Lincomycin 4% increase	percentage change	Sulfathiazole 4% increase	percentage change
0	34.00	34.00	0.00%	34.00	0.00%	34.00	0.00%	34.00	0.00%	34.00	0.00%
1	37.07	40.47	9.17%	39.95	7.77%	39.94	7.74%	40.00	7.90%	40.03	7.98%
2	37.26	40.39	8.40%	39.41	5.77%	39.44	5.85%	39.31	5.50%	39.26	5.37%
3	35.46	37.82	6.66%	35.95	1.38%	36.02	1.58%	35.63	0.48%	35.46	0.00%
4	32.55	33.90	4.15%	32.07	-1.47%	32.16	-1.20%	31.68	-2.67%	31.47	-3.32%
5	33.85	34.69	2.48%	33.08	-2.27%	33.17	-2.01%	32.66	-3.52%	32.44	-4.17%
6	35.55	36.30	2.40%	34.98	-1.60%	35.07	-1.35%	34.57	-2.76%	34.36	-3.35%
7	34.17	35.30	3.31%	34.31	0.41%	34.38	0.61%	34.00	-0.50%	33.83	-1.00%
8	31.77	33.42	5.19%	32.49	2.27%	32.54	2.42%	32.25	1.51%	32.12	1.10%
9	33.21	35.33	6.38%	34.10	2.68%	34.16	2.86%	33.85	1.93%	33.71	1.51%
10	34.76	37.09	6.70%	35.47	2.04%	35.54	2.24%	35.15	1.12%	34.98	0.63%

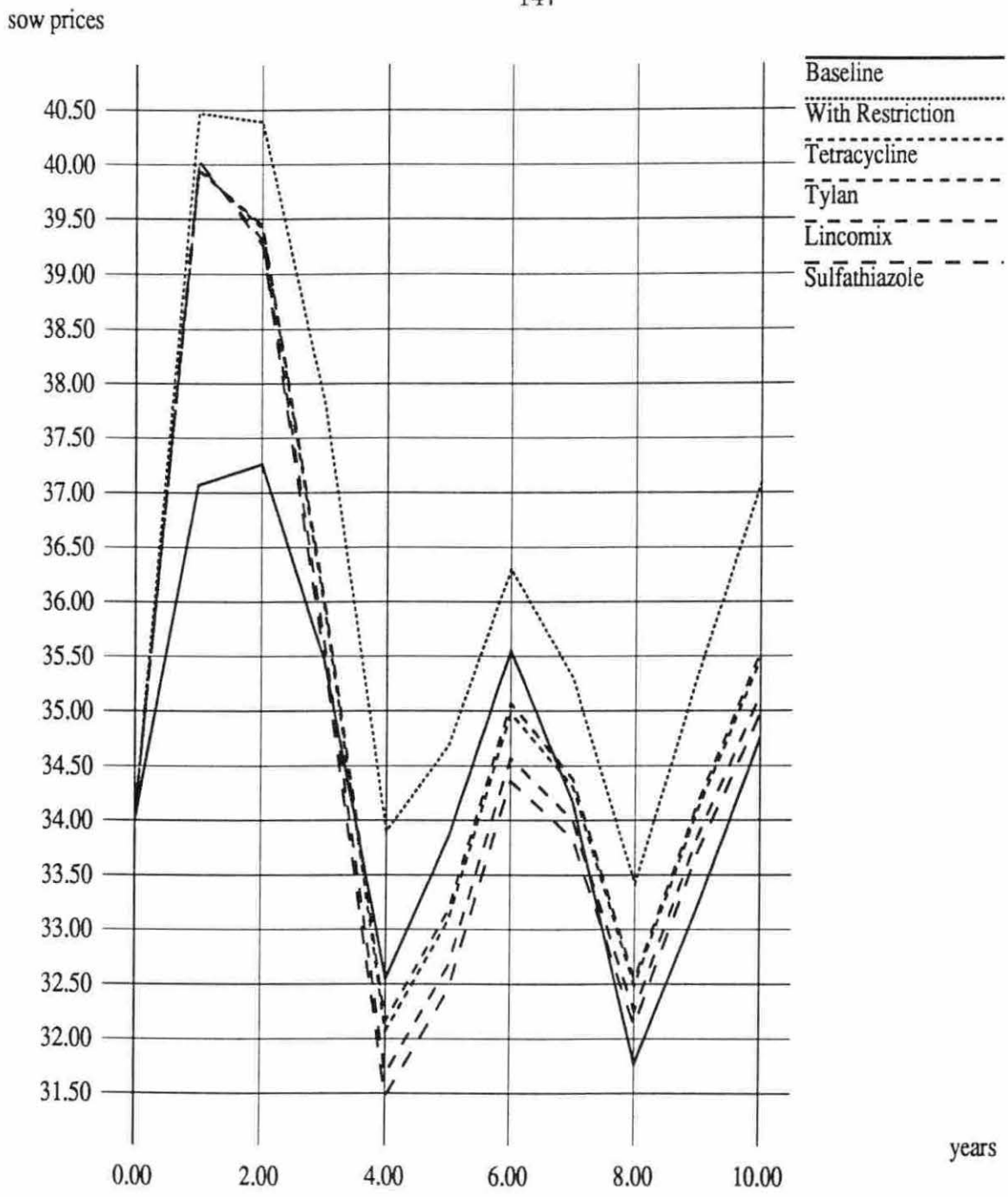

Figure 6.20: Changes in sow prices following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 5% compared with use of alternatives and an increase in consumer demand of 4% (dollars per hundredweight)

Table 6.25: Changes in pork consumption following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 5% compared with use of alternatives and an increase in consumer demand of 4% (million pounds)

Year	Baseline	With Restrictions 5% increase	percentage change	Tetracyline 4% increase	percentage change	Tylosin 4% increase	percentage change	Lincomycin 4% increase	percentage change	Sulfathiazole 4% increase	percentage change
0	17475	17475	0.00%	17475	0.00%	17475	0.00%	17475	0.00%	17475	0.00%
1	17413	17426	0.07%	17418	0.03%	17418	0.03%	17416	0.02%	17415	0.01%
2	16859	16935	0.45%	17014	0.92%	17008	0.88%	17042	1.09%	17058	1.18%
3	17381	17569	1.08%	17866	2.79%	17849	2.69%	17945	3.24%	17988	3.49%
4	17865	18213	1.95%	18572	3.96%	18547	3.82%	18683	4.58%	18744	4.92%
5	17905	18341	2.44%	18651	4.17%	18624	4.02%	18767	4.81%	18831	5.17%
6	17510	17918	2.33%	18157	3.70%	18132	3.55%	18264	4.31%	18322	4.64%
7	17722	18024	1.70%	18217	2.79%	18196	2.67%	18311	3.32%	18362	3.61%
8	17978	18154	0.98%	18366	2.16%	18347	2.05%	18452	2.64%	18498	2.89%
9	17620	17744	0.70%	18014	2.24%	17993	2.12%	18104	2.75%	18153	3.02%
10	17450	17614	0.94%	17936	2.79%	17912	2.65%	18037	3.36%	18092	3.68%

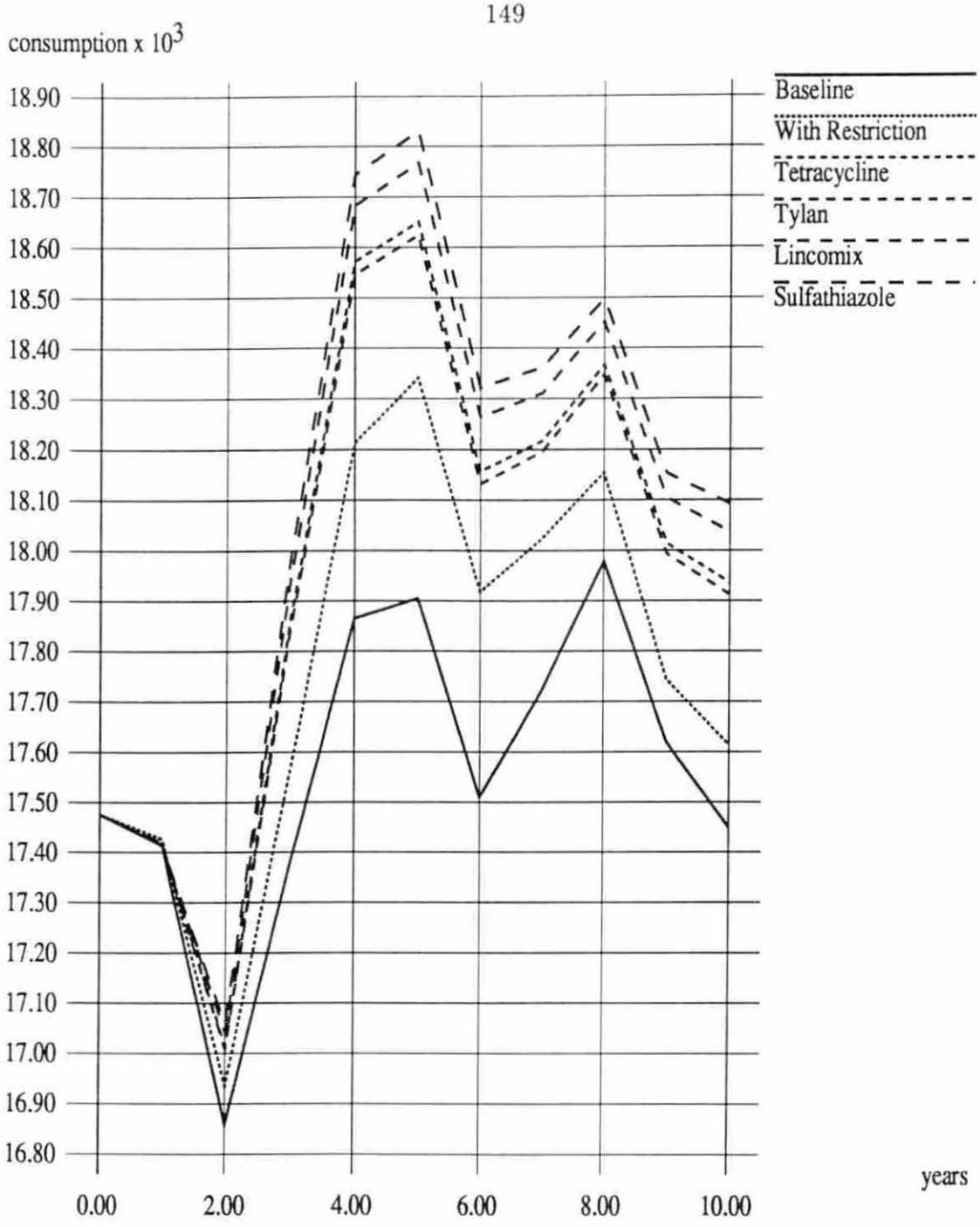

Figure 6.21: Changes in consumption following restrictions (ban) on sulfamethazine use and with an increase in consumer demand of 5% compared with use of alternatives and an increase in consumer demand of 4% (million pounds)

6.3 Summary

In summarizing the projected scenarios of pork production, an increase in all price levels over baseline price levels accompanied by a reduction in production and consumption levels over baseline was observed for all the scenarios considered where we assume no changes in demand. The impact on pork production following a ban on sulfamethazine use was the largest where there were no available alternatives to sulfamethazine. Significant increase in price levels and a significant decrease in production and consumption levels over the baseline was observed for this scenario. The lowest impact was obtained for sulfathiazole as an alternative to sulfamethazine. For a change in demand of 0.5 percent in response to use of alternatives, production and consumption levels were marginally lower than baseline for tetracycline and tylosin. For lincomycin the results projected indicated levels to approximate baseline levels very closely, while use of sulfathiazole indicated higher production and consumption levels along with variability of sow prices, farm prices for barrows and gilts, and pork retail price. Higher production and consumption levels and variable price levels over baseline levels is observed with the use of all other alternative compounds when coupled with a 4 percent increase in demand. The best results were observed for sulfathiazole use followed by lincomycin, then tetracycline and finally, tylosin. Marginal increases in pork retail, sow, and farm prices, high production and consumption levels over baseline for pork were projected for a ban on sulfamethazine while allowing for the use of sulfathiazole. Use of sulfathiazole as a substitute to sulfamethazine indicated variable price levels with production and consumption levels higher than baseline for scenarios incorporating changes in demand. For the other scenarios results observed with the use of sulfathiazole approximated baseline price

levels, and production and consumption levels very well. Results projected for a ban on sulfamethazine use without alternatives indicated higher sow, farm and pork retail prices and lower production and consumption levels for all scenarios except when coupled with a 5 percent increase in demand where although the price levels remained higher than baseline, the production and consumption levels were higher than baseline.

CHAPTER 7. SUMMARY AND CONCLUSIONS

7.1 Summary

The increased response to antibiotics in the presence of nutritional stresses is of economic importance to livestock producers, since it is seldom economically desirable for the producer to provide the nutrient sources or levels necessary to promote maximum rate of gain. However, numerous studies support the idea that the major benefit derived from the inclusion of antibiotics as routine feed additives result from their suppression or control of subclinical or nonspecific diseases.

It is well recognized that antibiotics effective in improving the performance of animals have one thing in common, their ability to suppress or inhibit the growth of certain micro-organisms. Their chemical composition and bacterial spectrum varies greatly. Some of the effective antibiotics are readily absorbed into the vascular system of the host animal, whereas others are hardly absorbed at all.

The chemical composition, bacterial spectrum, and absorption and excretion patterns of these drugs certainly influences bactericidal and bacteriostatic properties and effectiveness against specific systemic infections. These same characteristics, however, are less associated with growth promoting activities.

Many users perceive pressure from regulatory forces in response to their continued usage of sulfamethazine. "Lot" testing using "SOS" can cause major market

disruption with producers potentially at risk of losing shipment with each delivery, thus, causing economic losses to producer. Embargoes for "violative residues" can be very costly, interfering with orderly marketing and increasing production costs due to sale of hogs of heavier than desirable weight. This has discouraged many a sulfamethazine users into discontinuing working with sulfamethazine.

Residue violations are usually preceded by inappropriate management practices which in turn result in embargoes enforcing economic costs on producer. In response to a ban on sulfamethazine in pork production, alternate modes of pork production that may be considered are :

1. A ban on sulfamethazine with no alternatives to consider

2. More and new research to arrive at a new alternative compound to substitute the use of sulfamethazine in pork production

3. A ban on sulfamethazine followed by use of existing alternative compounds

Removal of older antibiotics from use in livestock will increase cost of production as it will force use of drugs still covered with patent protection in addition to removing some of effective antibiotics in terms of increased rate and efficiency of gain.

On an average, it takes FDA about three and a half years to process NADA's (New Animal Drug Applications). It takes a company 3-10 years to develop data for filing. Thus, it is 7-15 years before eventually a drug is developed and marketed at an average cost of 3-30 million dollars. This rules out the possibility of developing a new drug which may be economical and as efficient as sulfamethazine even in the near future.

In the preceding chapter the alternatives considered in response to a ban on use of sulfamethazine were provided. It was assumed that due to perceived safety of pork, consumers would demand more pork in response to a ban on use of sulfamethazine. Further, the study also assumed that the increase in willingness to pay would be larger for pork produced without the use of any alternative compounds as compared with pork produced with use of alternative compounds to sulfamethazine. The study assumes five scenarios for these responses as their information is not readily available. For pork produced without any alternative compounds to sulfamethazine, two scenarios were assumed, a 1 percent and a 5 percent increase in consumer demand (willingness to pay). Pork produced with use of alternative compounds to sulfamethazine, were expected to face a lower increase in demand (willingness to pay) but higher than that with sulfamethazine use. Two scenarios were assumed: a 0.5 percent increase in demand and a 4 percent increase in demand. To account for the possibility where they may be no increase in demand in response to a ban of sulfamethazine in pork production, another scenario was considered.

In our study the best alternative that comes up in response to a ban on sulfamethazine is sulfathiazole. However, the issue remains if a ban on sulfamethazine drug in pork production will eventually lead to a ban in use of sulfa drugs in general for purpose of pork production. If yes, we need to need to review our search for the next best alternative. This is suggested by our study to be lincomix. Although lincomix is commonly used in pork production, it is not well absorbed systemically and is thus less effective in combating respiratory diseases. Tetracyclines would seem to be a effective compound in such a situation. Thus, to come to conclude which is the best alternative to sulfamethazine depends on the future use of sulfathiazole and

sulfa drugs in pork production. Tetracyclines, chlortetracycline and oxytetracycline, remain the most viable and safe alternatives.

7.2 Ideas for further research

This study has assumed for purposes of economic analysis the changes in demand to vary between 0.5 percent to 5 percent for different scenarios. These estimates were arbitrary and based on some indirect research. An attempt to evaluate the actual willingness to pay and willingness to accept of consumers in response to a ban on sulfamethazine while allowing alternative compounds needs to be estimated and studied. In this study it was assumed that consumers may respond by increasing their willingness to pay anywhere between 0.5 percent and 4 percent for use of alternate drugs. In response to a ban of sulfamethazine with no alternatives to consider, these figures were assumed to be between 1 and 5 percent.

This study has recommended alternative strategies in response to a ban on sulfamethazine. It is suggested that further research be carried to study if any of these evaluated policies have structured impacts on the industry and producers in that how are the smaller producers going to adapt themselves versus the larger producers and which of the two will have to absorb most of the cost increases. Also it needs to be estimated how the industry will adapt to the changes if any of the evaluated strategies was to be implemented. What are the implications for management practices and how is the industry going to convince the consumers about the safety of pork and pork products when produced with these alternative compounds, such that they demand more. What are the economic implications of these changes on the industry and the economy? This study in an attempt to study the most feasible

alternative to sulfamethazine in pork production did not study the consumer and producer surplus changes for different scenarios. Further analysis in an attempt to study a good alternative to sulfamethazine in pork production should also involve consumer and producer surplus analysis both before and after a ban on sulfamethazine under assumptions of no alternatives and available alternatives. Finally, the present study assumes exports and imports to be exogenously determined. However, a ban on sulfamethazine is expected to infact impact upon the pork exports and imports of the country. Since in the present the use of sulfamethazine has not been banned in the U. S., studies on Germany's pork export and import market, where use of sulfamethazine in pork production has been banned, can be used to extrapolate the effects of a similar ban in United States. These are some of the questions this study has left unanswered and which require further study.

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APPENDIX FAPRI PORK MODEL EQUATIONS

Pork Documentation, 2SLS, 1965-1990

1. Log of Per Capita Pork Consumption, Wholesale Wt. basis

LOG(PKPCCW) = 0.335

- 0.861*LOG(PKRETP/PCIUW)

+ 0.360*LOG(BFRETP/PCIUW)

+ 0.008*LOG(CKRETP/PCIUW)

+ 0.145*LOG((ZCENFABW/POPTOTW)/PCIUW)

- 0.907*(POP75PW/POPTOTW)

- 0.047*D845

ELASTICITIES:

PKRETP = -0.86

BFRETP = 0.36

CKRETP = 0.008

INCOME = 0.145

PKRETP = Pork retail price

BFRETP = Beef retail price

CKRETP = Chicken retail price

PCIUW = Consumer price index, Total of all items

POPTOTW = Total pop. including armed forces overseas

POP75W = Population-U.S., Age 75+

ZCENFABW = Personal consumption expenditure, Food and Beverage

DUM83 = 1 in 1983, 0 otherwise

DUM84 = 1 in 1984, 0 otherwise

2. Pork ending stocks, U.S.

PKSTK = - 167.125
- 14768.61*(PKRETP-PKRETP(-1))/PPIW
+ 0.030*PKPROD
+ 52.639*SHIFT78
+ 139.517*DUM73
+ 127.501*DUM75

ELASTICITIES:

PKRETP = -0.92

PKPROD = 1.50

PKRETP = Pork retail price

PKRETP(-1) = Lag of pork retail price

PKPROD = Pork, Total production

PPIW = PPI, All items, U.S

SHIFT78 = 1 if ztime ¿ 1977, 0 otherwise

DUM73 = 1 in 1973, 0 otherwise

DUM75 = 1 in 1975, 0 otherwise

3. Pork total production

PKPROD = 594.207
+ 0.330*(PKSOWKS + PKBORKS)
+ 0.147*(PKBAGKSD + PKBAGKSI)
+ 0.0005*(TREND*(PKBAGKSD + PKBAGKSI))

ELASTICITIES:

PKSOWKS = 0.11

PKBORKS = 0.02

PKBAGKSD = 0.83

PKBAGKSI = 0.004

PKSOWKS = Hogs, Sow slaughter

PKBORKS = Hogs, Boar slaughter

PKBAGKSD = Hogs, Barrow and gilt domestic slaughter

PKBAGKSI = Hogs, Barrow and gilt imported slaughter

TREND = ztime - 1964

4. Hogs, Sows farrowed

PKSOWFAR = 986.17
+ 0.911*PKHOGNBR(-1)
+ 0.015*(TREND*PKHOGNBR(-1))

+ 0.836*(PKGLTADD)

- 0.383*(PKSOWKS)

- 987.67*DUM78

- 941.728*DUM75

+ 946.856*D701

ELASTICITIES:

PKHOGNBR(-1) = 0.74

PKGLTADD = 0.33

PKSOWKS = -0.15

PKHOGNBR(-1) = Hogs, Breeding hogs on farm, Dec. 1st

PKGLTADD = Hogs, Gilts added to the breeding herd

PKSOWKS = Hogs, Sow slaughter

TREND = ztime - 1964

DUM78 = 1 in 1978, 0 otherwise

DUM75 = 1 in 1975, 0 otherwise

DUM701 = 1 in 1970 and 1971, 0 otherwise

5. 7-market sow price / PPI, All items, U.S

LOG(PKSOWPM/PPIW) = 3.677

- 0.305*LOG(PKSOWKS + PKBORKS)

+ 1.269*LOG(PKRETP/PPIW)

- 1.308*LOG(ZWRHP20W/PPIW)

- 0.233*SHIFT88

+ 0.217*D723

ELASTICITIES:

PKSOWKS = -0.305

PKBORKS = -0.305

PKRETP = 1.269

ZWRHP20W = -1.308

PKSOWKS = Hogs, Sow slaughter

PKBORKS = Hogs, Boar slaughter

PKRETP = Pork retail price

PPIW = PPI, All items, U.S

ZWRHP20W = Average hourly earnings, Food and Kind products

SHIFT88 = 1 if ztime > 1987, 0 otherwise

D723 = 1 in 1972 and 1973, 0 otherwise

6. 7-market Barrow and gilt price / PPI, All items, U.S

LOG(PKBAGPM/PPIW) = 8.427

- 0.453*LOG(PKBAGKSD + PKBAGKSI)

+ 1.396*LOG(PKRETP/PPIW)

- 0.664*LOG(ZWRHP20W/PPIW)

- 0.130*SHIFT88

- 0.138*D667

ELASTICITIES:

PKBAGKSD = -0.45

PKBAGKSI = -0.45

PKRETP = 1.396

ZWRHP20W = -0.664

PKBAGKSD = Hogs, Barrow and gilt domestic slaughter

PKBAGKSI = Hogs, Barrow and gilt imported slaughter

PKRETP = Pork retail price

PPIW = PPI, All items, U.S

ZWRHP20W = Average hourly earnings, Food and kind

SHIFT88 = 1 if ztime > 1987, 0 otherwise

D667 = 1 in 1966 and 1967, 0 otherwise

7. Hogs, Boar slaughter

PKBORKS = - 993.74383
+ 0.115*PKHOGNBR(-1)
+ 0.084*(PKSOWKS - PKGLTADD)
+ 332.462*LOG(TREND)
+ 219.829*DUM66

ELASTICITIES:

PKHOGNBR(-1) = 1.24

PKSOWKS = 0.52

PKGLATDD = 0.52

PKHOGNBR = Hogs, Breeding hogs on farms, Dec. 1

PKSOWKS = Hogs, Sow slaughter

PKGLTADD = Hogs, Gilts added to the breeding herd

TREND = ztime - 1964

DUM66 = 1 in 1966, 0 otherwise

8. Hogs, Barrow and gilt domestic slaughter (PKBAGKS - PKBAGKSI)

PKBAGKSD = - 15754.13
+ 0.502*PKPIGCRP
+ 0.943*PKHOGFRM(-1)
+ 6116.49*SHIFT83
- 4578.51*DUM73
+ 3614.79*DUM76

ELASTICITIES:

PKPIGCRP = 0.58

PKHOGFRM(-1) = 0.60

PKPIGCRP = Hogs, Pig crop

PKHOGFRM = Hogs, market hogs on the farm, Dec. 1

SHIFT83 = 1 if ztime > 1982, 0 otherwise

DUM73 = 1 in 1973, 0 otherwise

DUM76 = 1 in 1976, 0 otherwise

9. Hogs, Number of breeding hogs added to herd

PKHOGNBR - PKHOGNBR(-1) = - 3132.28

+ 1522.06*((CPPKSLHG)/(CPPKGRAN + CPPKSUPP))

+ 821.22*((CPPKSLHG(-1))/(CPPKGRAN(-1)

+ CPPKSUPP(-1)) - 43.23*TREND

+ 534.44*D778 - 779.04*D867

ELASTICITIES:

CPPKSLHG = 0.10

CPPKGRAN = -0.06

CPPKSUPP = -0.05

CPPKSLHG = Pork, Cost of production, Slaughter hog receipts

CPPKGRAN = Pork, Cost of production, Cash expense for grain

CPPKSUPP = Pork, Cost of production, Cash expense for protein supplements

TREND = ztime - 1964

D778 = 1 in 1977 and 1978, 0 otherwise

D867 = 1 in 1986 and 1987, 0 otherwise

10. Hogs, Sow slaughter

PKSOWKS = 4268.35

+ 0.304*PKHOGNBR(-1)

- 1138.88*((CPPKSLHG + CPPKCLSW)/

(CPPKGRAN + CPPKSUPP + CPPKPAST

+ CPPKVET + CPPKHAUL + CPPKMARK

+ CPPKBED + CPPKFLE + CPPKREP

+ CPPKLABR + CPPKMANU))

- 720.659*SHIFT75

+ 756.027*DUM66

- 938.293*DUM73

- 610.353*DUM76

ELASTICITIES:

PKHOGNBR(-1) = 0.53

CPPKSLHG = -0.32

CPPKGRAN = 0.12

CPPKSUPP = 0.09

PKHOGNBR = Hogs, Breeding hogs on farms, Dec. 1

CPPKSLHG = Pork, Cost of production, Slaughter hog receipts

CPPKCLSW = Pork, Cost of production, Cull sow receipts

CPPKGRAN = Pork, Cost of production, Cash expense for grain

CPPKSUPP = Pork, Cost of production, Cash expense for protein supplements

CPPKPAST = Pork, Cost of production, Cash expense for pasture

CPPKVET = Pork, Cost of production, Cash expense for veterinarian and med.

CPPKHAUL = Pork, Cost of production, Cash expense for livestock hauling

CPPKMARK = Pork, Cost of production, Cash expense for marketing

CPPKBED = Pork, Cost of production, Cash expense for bedding

CPPKFLE = Pork, Cost of production, Cash expense for fuel, lube, and elec.

CPPKREP = Pork, Cost of production, Cash expense for repairs

CPPKLABR = Pork, Cost of production, Cash expense for hired labor

CPPKMANU = Pork, Cost of production, Cash expense for manure credit

PPIW = PPI, All items, U.S

SHIFT75 = 1 if ztime > 1974, 0 otherwise

DUM66 = 1 in 1966, 0 otherwise

DUM73 = 1 in 1973, 0 otherwise

DUM76 = 1 in 1976, 0 otherwise

Pork Identities

1. U.S breeding hogs on farm, Dec. 1

   PKHOGNBR = 0.99*PKHOGNBR(-1) + PKGLTADD - PKSOWKS

2. U.S pig crop

   PKPIGCRP = PKSOWFAR*PKPIGILT

3. Pork supply

   PKSUPP = PKPROD + PKSTK(-1) + PKIMPT

4. Pork, civilian disappearance, Carcass wt., U.S

   PKCDIS = PKSUPP - PKEXPT - PKSTK

5. Per capita pork consumption, Carcass wt.

   PKPCCW = PKCDIS/POPTOTW

6. Per capita pork consumption, Retail wt.

   PKPCCR = PKPCCW*PKRETCNV

7. U.S market hogs on farms, Dec. 1

   PKHOGFRM = (1-PKPIGD)*(PKHOGFRM(-1))
   + (PKPIGCRP - PKBAGKSD - PKBAGKSI)

Pork, Cost of production

1. Pork, Cost of production, Slaughter hog receipts

CPPKSLHG = - 1.28
+ 0.957*PKBAGPM

ELASTICITIES:

PKBAGPM = 1.03

PKBAGPM = Hogs, Barrow and gilt, seven market price

2. Pork, Cost of production, Cull sow receipts

CPPKCLSW = 10.91
+ 0.066*PKSOWPM
- 1.377*PKPIGLIT
- 0.469*D801234

ELASTICITIES:

PKSOWPM = 1.05

PKPIGLIT = -4.18

PKSOWPM = Hogs, Sow seven market price

PKPIGLIT = Hogs, pigs per litter

D801234 = 1 in 1980, 1981, 1982, 1983, and 1984, 0 otherwise

3. Pork, Cost of production, cash expense for grain

CPPKGRAN = - 1.678

+ 4.042*CRPFRM(-1)

+ 2.978*CRPFRM

ELASTICITIES:

CRPFRM = 0.48

CRPFRM(-1) = 0.65

CRPFRM = Corn season average farm price

4. Pork, Cost of production, Cash expense for protein supplements

CPPKSUPP = 3.529

+ 0.042*SMP44D(-1)

+ 1.713*D734

ELASTICITIES:

SMP44D(-1) = 0.68

SMP44D = Soybean meal price, Decatur 44 percent protein

D734 = 1 in 1973 and 1974, 0 otherwise

5. Pork, Cost of production, Cash expense for veterinary and medicine

CPPKVET = 0.067

+ 0.005*PPIW

+ 0.058*D756

ELASTICITIES:

PPIW = 0.84

PPIW = PPI, All items, US

D756 = 1 in 1975 and 1976, 0 otherwise

6. Pork, Cost of production, Cash expense for livestock hauling

CPPKHAUL = 0.024
+ 0.001*PPICFULW
+ 0.032*SHIFT86

ELASTICITIES:

PPICFULW = 0.67

PPICFULW = PPI, Ind. comm., Fuel and related

SHIFT86 = 1 if ztime > 1985, 0 otherwise

7. Pork, Cost of production, Cash expense for marketing

CPPMARK = 0.067
+ 0.002*PPIW
+ 0.001*PKBAGPM
+ 0.044*DUM78

ELASTICITIES:

PPIW = 0.58

PKBAGPM = 0.20

PPIW = PPI, All items, US

PKBAGPM = Hogs, Barrow and gilt seven market price

DUM78 = 1 in 1978, 0 otherwise

8. Pork, Cost of Production, Cash expense for bedding

CPPKBED = - 0.005
+ 0.001*PPIW
+ 0.039*DUM81

ELASTICITIES:

PPIW = 1.03

PPIW = PPI, All items, US

DUM81 = 1 in 1981, 0 otherwise

9. Pork, Cost of production, Cash expense for fuel, lube, and electricity

CPPKFLE = 0.166
+ 0.018*PPICFULW
+ 0.327*SHIFT86

ELASTICITIES:

PPICFULW = 0.82

PPICFULW = PPI, Ind. commod., Fuel and related

SHIFT86 = 1 if ztime > 1985, 0 otherwise

10. Pork, Cost of production, Cash expense for repairs

CPPKREP = 0.193
+ 0.020*PPICMETW
- 0.166*DUM88

ELASTICITIES:

PPICMETW = 0.91

PPICMETW = PPI, Ind. commodity, Metals and products

DUM88 = 1 in 1988, 0 otherwise

11. Pork, Cost of production, Cash expense for hired labor

CPPKLABR = - 0.212
+ 0.166*ZWRHP20W
+ 0.091*D845

ELASTICITIES:

ZWRHP20W = 1.21

ZWRHP20W = Average hourly earnings, Food and kind products

D845 = 1 in 1984 and 1985, 0 otherwise

12. Pork, Cost of production, Cash expense for manure credit

CPPKMANU =- 0.058

- 0.0008*PPICHMW

- 0.0006*PPICPETW

ELASTICITIES:

PPICHMW = 0.43

PPICPETW = 0.22

PPICHMW = PPI, Chemicals and allied products

PPICPETW = PPI, Ind. commodity, Ref. petrol products

13. Pork, Cost of production, Cash expense for general farm overhead

CPPKGFO = - 0.279

+ 0.025*PPIW

+ 1.504*D867

+ 0.508*SHIFT88

ELASTICITIES:

PPIW = 1.10

PPIW = PPI, All items, US

SHIFT88 = 1 if ztime > 1987, 0 otherwise

14. Pork, Cost of production, Cash expenses for insurance and taxes

CPPKTAX = 0.225

+ 0.0004*FIVLAND

+ 0.002*ZTXCBSPW

+ 0.115*DUM85

ELASTICITIES:

FIVLAND = 0.35

ZTXCBSPW = 0.28

FIVLAND = Farm income, Value of land

ZTXCBSPW = Ind. bus. tax-state and local prp.

DUM85 = 1 in 1985, 0 otherwise

15. Pork, Cost of production, Cash expense for interest

CPPKINT = 0.738

+ 0.011*(CPPKEXP*ZINTAAA)

+ 2.417*DUM82

+ 2.407*DUM86

ELASTICITIES:

ZINTAAA = 0.02

CPPKEXP = 0.008

CPPKEXP = All pork expenses

ZINTAAA = Yield for corporate bond

DUM82 = 1 in 1982, 0 otherwise

DUM86 = 1 in 1986, 0 otherwise

16. Pork, Cost of production, Cash expense for capital replacement

CPPKCAPR = 1.937

+ 0.037*PPIW

- 1.623*DUM74

+ 1.136*DUM79

ELASTICITIES:

PPIW = 0.62

PPIW = PPI, All items, US

DUM74 = 1 in 1974, 0 otherwise

DUM79 = 1 in 1979, 0 otherwise