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The economics of reducing sulfonamide residues in pork

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CHAPTER I. INTRODUCTION

As consumers have become more and more health conscious, they have become increasingly concerned about the long term effects of food additives and/or contaminants in the food supply. One area that has come under close scrutiny in recent years is the use of antimicrobials in the production of food animals. Consumer concerns about antibiotic residues and antibiotic resistance has led to increasing pressure to further restrict the use of compounds such as penicillin, tetracyclines, and sulfonamides in food animal production. The purpose of this study will be to examine a small segment of this issue, the occurrence of sulfonamide residues in pork, and to evaluate various strategies for effecting a reduction in these occurrences.

After defining the problem and stating the objectives of this study, the available literature will be examined in terms of benefits and concerns about antibiotic use in general and sulfonamide use in particular. Investigation of testing procedures and strategies will be followed by a discussion of the probable impacts of implementing these strategies. Finally, some conclusions and recommendations will be made given the available information.

Statement of Problem

Once an antimicrobial has been given to an animal, the compound is excreted from the tissues over a period of time.

The amount of time that this process takes varies depending on the compound given and the method of administration. Any remnants of an antimicrobial or its metabolites found in the tissues at the time of slaughter is referred to as a residue. More sophisticated and sensitive testing methods for detecting antimicrobial residues have been developed in recent years, allowing for the detection of very minute amounts of residues in animal tissue. This has made it increasingly clear that the concept of zero residues is an impractical goal that could only be met by totally foregoing the use of antibiotics in food animal production (Somogyi, 1987). Therefore safe residue limits or tolerance levels in meats and milk have been scientifically established for most antimicrobials and some other chemicals such as pesticides. To insure compliance with these limits in the U.S., the Food Safety and Inspection Service (FSIS) has organized a system of random testing to monitor the meat industry. In 1990, the FSIS tested 7,299 samples of food animals for antibiotic residues and found violative levels in 1.6 percent of those samples (Mathur, 1991).

The presence of residues in the meat supply is not the only reason that there is concern about the use of antibiotics in food animal production. It has been shown that the long term use of antibiotics, in either humans or animals, can cause some bacteria to develop increased resistance to those compounds. Research has also shown that antibiotic resistance can be transmitted between different species of bacteria through the actions of plasmids. The frequency with which such a transfer actually occurs is unknown. Theoretically, if a person were to ingest sufficient levels of residues over a period of time, a resident bacterial population could be established in their digestive tract that would be resistant to a particular drug.

One particular area of concern in the residue issue has been the high percentage of violative levels found in swine for the class of compounds known as the sulfonamides (sulfas). The number of violations reached a peak in 1977 when 13 percent of the swine carcasses tested had violative levels of sulfa residues. In 1991 these violations had been reduced to less than one percent but effecting a long term reduction in the incidence of sulfa residues is still a concern.

Sulfonamide residues are of concern for several reasons:

1. Sulfas appear to be 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 of the 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 the last 15 days prior to slaughter can cause violative residues in the tissue (Ashworth et al., 1986).

4. There is some evidence that sulfamethazine, the most commonly used of the sulfas, may be a carcinogen (Cordle, 1989).

Over the past 50 years, antibiotic use has become an important management tool for the livestock producer. Antibiotics have enabled the producer to decrease his/her per unit production costs and have allowed the producer some control over production risks by reducing the number and severity of disease outbreaks, controlling subclinical disease problems, and improving animal production efficiency. There are those who feel that antimicrobials have at least facilitated the development of the more intensive livestock production systems that we see in agriculture today (National Academy of Science, 1980). In general, antibiotics have aided in the development of a readily available meat, milk, and egg supply in an economical form for the American diet and have helped to reduce some of the risks embodied in animal production.

For the swine producer, sulfas and sulfa-antibiotic combinations have proven to be effective in preventing and/or treating some commonly occurring swine herd health problems such as atrophic rhinitis (McKean, 1986) and various respiratory ailments (Hillary et al., 1986). In addition, sulfonamides have also been shown to increase feed efficiency and growth rates in swine (Burbee et al., 1985; Samuleson et al., 1979; Straw and Raltson, 1987; Zimmerman, 1986). The ability to reduce feed expenditures is important to the hog producer since feed costs account for 68 percent of the total cash expense in a farrow to finish operation and about 40 percent of the total cash expense in a feeder pig producing or finishing operation (Shapouri et al., 1990). Sulfonamides are also easily administered and relatively inexpensive to use.

Since the sulfonamides are so important to the continued profitability of the swine industry and residues of these compounds pose a threat to the safety of the consumer, the problem then becomes: Where is the most cost effective and efficient point to intervene in the pork product food chain to insure the avoidance of sulfonamide residues in pork? If sulfonamide residues are not kept at safe levels, the industry will likely lose the availability of this product due to societal demands for its removal.

Objectives of the Study

The main objective of this study is to compare cost effectiveness of selected sulfonamide residue reduction strategies. The primary focus will be on determining cost effective intervention points for controlling the incidence of sulfonamide residues in the pork product food chain. Potential intervention points in the food production chain include: at the input level, at the production level, at the farm gate, and at the processing plant.

Testing strategies currently in use as well as potential testing procedures will be identified for each level. An economic evaluation of the effectiveness and cost of each of these procedures will be conducted.

Additionally, at each of the intervention points, a determination will be made concerning the level of testing necessary to assure a given probability of detecting a violative carcass.

Finally, potential impacts on pork production, production costs, and consumer demand will be analyzed for selected intervention strategies.

CHAPTER II. LITERATURE REVIEW

Introduction

Antimicrobial activity was first noted in the latter part of the 1800's. By the 1940's, antimicrobial agents, both naturally occurring and man-made, were being recognized and the concept of antimicrobial therapy in both human and veterinary medicine was well established. In fact, in the early 1940's sulfonamides were being used routinely to treat diseases such as pneumonia, diarrhea, and mastitis in food producing animals (Bevill, 1984). Since it was first discovered in the late 1940's that the use of antimicrobial compounds in the feed of poultry and livestock increased growth rates, leading to economic returns; these agents have become an important factor in food animal production and in the production of a economical food supply for the consumer.

Benefits of Antibiotic Use

Livestock production

Livestock production is an important aspect of the United States' agricultural economy. It is estimated that, on average, 52 percent of the nation's farm income is generated by livestock sales (Absher and Blosser, 1982). In 1991, total U.S. cash receipts from livestock and livestock products totaled $89 billion (Agricultural Statistics, 1992, personal communication). Annual receipts in 1990 for each livestock sector are shown in Table 1 and a breakdown of the distribution of the total receipts by sector is depicted in Figure 1.

The use of antibiotics is widespread throughout all of the food animal industry. Nearly 100 percent of all poultry, 90 percent of all swine, 60 percent of all feedlot cattle, and 75 percent of all dairy cattle raised in the U.S. have been fed and/or injected with antibiotics at some point in their growth period (Jukes, 1986). Even with this level of use, it

Table 1. 1991 U.S. Livestock Receipts (billions of dollars)

Cattle	$40
Dairy	18
Poultry	15
Hogs	12
Other	4
Total	$89

(Agricultural Statistics)

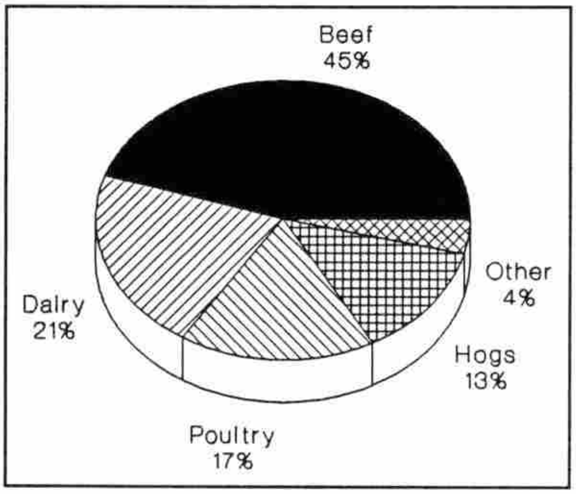

Figure 1. U.S. 1991 livestock receipts by sector

has been estimated that the cost of acute and chronic livestock diseases for U.S. producers continues to be in excess of $14 billion per year (Beran, 1987). Over the last 30 years the use of antibiotics has become more widespread and dosage levels have increased. However, this increase in use is generally attributed to an improvement in drug costs relative to benefits achieved rather than to a decrease in efficacy of the drugs (Beran, 1987).

Antibiotics in livestock production are currently used in two different ways; high or therapeutic levels and low or subtherapeutic levels. Therapeutic levels are used for treating clinical disease problems in livestock much the same way as in humans. Subtherapeutic or low levels are generally incorporated as a feed additive and most often used for disease prevention and to control subclinical disease.

An additional non-disease use of subtherapeutic antibiotics is for the improvement of animal growth performance. The exact biological mechanism by which increased growth and improved feed efficiency is accomplished is not precisely known. None-the-less, improvements in animal performance have been shown in numerous antibiotic feeding trials on many species of food-producing animals.

It is estimated that 30 percent of subtherapeutic antibiotic use is solely for the purpose of improving growth rates and/or increasing feed conversion efficiency (Institute of

Medicine, 1989). The importance of improving animal performance becomes apparent when you consider that it is estimated that feed costs range from 50 to 80 percent of the total cost of producing meat or animal products. Less efficient feed conversions of course mean increased feed costs per pound of livestock gain. Slower gains translate to both higher feed costs and increased costs from interest and facility expense as it takes longer for the animals to reach market weight. Subtherapeutic and therapeutic use of antibiotics also is vital in reducing animal mortality and morbidity from bacterial diseases, allowing for decreased per unit production costs.

By using antimicrobials to decrease animal health problems and improve animal production efficiency, producers have been able to reduce some of the risks embodied in animal production. There are those who feel that antimicrobials have at least facilitated the development of the more intensive livestock production systems that we see in agriculture today (National Academy of Science, 1980). While this hypothesis has not been proven, it is true that antibiotics have aided in the development of a readily available meat, milk, and egg supply in an economical form for the American diet. Beran indicates that antibiotics can be used, in part, to mask deficiencies in the production environment and/or the management of an operation, at least in the short run.

In addition to the direct benefits to the livestock producer in the form of reduced risks and increased efficiency, other benefits can accrue to society from the use of antibiotics.

Animal welfare benefits

Antibiotic use improves animal health and performance partly through reducing and/or removing clinical and subclinical diseases with their the associated stress and suffering. The Swann Committee in England noted that "disease is one of the principal causes of suffering in animals, and in all types of animals the use of antibiotics to control infection reduced the suffering and makes an important contribution to animal welfare" (Jukes, 1986). There has been some debate about whether or not the continued reliance on antibiotics has created an "unnatural" environment for many animals. Because of this view, some people have proposed a return to the more extensive production systems of the early 1900's. However, animals produced in this type of environment still suffer from many diseases, some of which have been all but eradicated in the more intensive production systems currently in use. It must be realized that livestock in extensive production systems are exposed to greater environmental extremes and increased numbers of internal parasites leading to a higher disease susceptibility (Hays, 1986). Generally, the use of antibiotics is considered to have a positive effect on animal welfare. Animal diseases were present in the environment long before man learned how to make use of antibiotics or housing and sanitation systems to reduce the incidence of disease.

Human health benefits

Antibiotics have been in use in the animal production industry for almost half a century. During that time, there has been a reduction in the incidence of several zoonotic diseases (Beran, 1987). This decrease can be attributed to the improved control of these diseases within the animal industry through the use of vaccines for some of the pathogens, the use of antibiotics as therapeutic and subtherapeutic agents, and/or improved management practices. More investigation is needed to firmly establish the role of antibiotics in the reduction of the zoonotic diseases and the following discussion indicates some possible areas of inquiry with regards to the use of antibiotics in pork production.

Leptospira interrogans pomona infections occurs in many animal species. In humans was commonly referred to as "swineherd's disease." While leptospirosis has been controlled in most species through the use of vaccines, the use of antibiotics cannot be ruled out as being a contributing factor in the control program as the leptospira bacterium is highly sensitive to several antibiotics (Beran, 1987).

In the early part of this century, prior to the use of antibiotics, *Erysipelothrix rhusiopathiae* was an occupational disease of packing plant workers. Between 1936 and 1938, there were over 100 cases reported among packing plant personnel in Philadelphia alone. Today it is considered a medical rarity. While there are vaccines available for the control of erysipelas, it is thought that the use of antibiotics especially in hog rations has aided in the reduction of the incidence of erysipelas in hogs and thus in people (Beran, 1987).

These two diseases are currently not involved in the issue of antibiotic resistance. However, they are inherently difficult to treat in humans and therefore are better controlled, whenever possible, through swine herd health programs (Beran, 1987). The possibility of increased incidence of zoonotic diseases in animals and then in humans following any restrictions in the use of antibiotics in animal production must be assessed along with all the other issues when considering policy changes concerning the use of antibiotics in food-producing animals.

Other benefits

There exists the potential for other benefits from the use of antibiotics in food animals. One potential benefit that needs to be more closely examined is the effect of antibiotic use on the food products produced by animals. Beran identifies five areas that need further study:

> 1. The improvement in metabolism and assimilation of nutrients due to the use of antibiotics. This improvement may optimize formation of muscle, milk, and eggs.

2. Reduced formation of toxins by bacteria and the subsequent absorption of microbial toxins. This reduction is due to lower bacterial numbers and should result in edible products freer of these toxins or their metabolites.

3. Antibiotic use leads to healthier animals and poultry that may produce tissues, milk, and eggs with more uniform balances of amino acids, fatty acids, vitamins and minerals.

4. Short term stress periods during growth may be reduced by the use of antibiotics, preventing glycogen breakdown to lactic acid with the resulting lowering of tissue pH and toughening of meat.

5. Antibiotics fed to animals may reduce long term stress periods, preventing the accompanying high muscle pH and drier darker meat and resulting in a more desirable and acceptable end product to the consumer.

The issue of using antibiotics in food animals is a very complex topic and these are but a few of the possible side benefits that often go unnoticed in the discussions. Further investigations need to be made into these benefits in the process of discussing any potential policy changes.

Concerns about Antibiotic Use

As important as antimicrobial use is to the livestock industry, such use is not without its drawbacks and problems. Since about 1952, the majority of the meat consumed by Americans has been raised with the use of antimicrobials (Jukes, 1986). Many of these animals have been fed low or subtherapeutic levels over extended periods of time. Generally, antibiotic use is classified as subtherapeutic if it is used at a rate of up to 200 mg/ton of feed for a period longer than

2 weeks (Jukes, 1986; National Academy of Science, 1980). It is this long term aspect of antibiotic use that has created apprehensions among some scientists and consumers. Such long term use of antibiotics has been shown to favor the development of bacteria that are not as susceptible (more resistant) to that antibiotic at that dosage level. Since many foodborne illnesses are caused by zoonotic bacteria that are naturally occurring (most notably the *Salmonella* bacteria), there has been increasing concern raised about the possibility of antibiotic resistant bacteria entering the food supply. Furthermore, research has shown that antibiotic resistance can be transmitted between some bacterial species and strains by plasmids (small pieces of genetic material termed R-factors). This transmission of R-factors creates a further risk that resistant, but non-harmful bacteria, could transfer the genetic material necessary for resistance to other, disease-causing bacteria. Either the zoonotic bacteria or these altered bacteria could then cause an outbreak of disease in the human population that could be difficult to control due to bacterial resistance to the more commonly used antibiotics. The frequency with which this sequence of events could or does occur is currently the topic of heated debate within the scientific community. These concerns becomes more acute when it is recognized that several of the antibiotics used in livestock

production-in particular penicillin and the tetracyclines-are also important in the treatment of human diseases.

Estimating the costs of foodborne illnesses

Foodborne illnesses are a surprisingly common occurrence in the U. S. It is estimated that, annually, 3 percent to 14 percent of the population will become ill due to microorganisms in food and that 9,000 of these cases will result in death (Roberts and van Ravensway, 1989). Estimating the cost to society of such illnesses is a complex task. Simply obtaining data on how often each type of illness occurs is formidable due to a lack of surveillance systems for many of these diseases. Even for those conditions such as salmonellosis that have a surveillance system, data collection is complicated because the manifestation of foodborne illnesses is often mild enough that the patient does not require care by a physician or even realize that they are suffering from a specific illness other than "the flu."

Calculating the total economic cost of foodborne illness is a fairly new area of endeavor. In the past, the emphasis was mainly on the deaths resulting from an illness and the calculation of the cost to society was based on the human capital method of calculation. This method involves determining the present value of the anticipated income streams that would have been produced by the person who died. There has also been some research into the "willingness to pay" method of valuing human life from the consumer demand theory approach but there is currently a lack of consensus among researchers about the validity of survey results (Roberts, 1988). Landefeld and Seskin (1982) have attempted a hybrid approach between these two views, estimating that the cost to society is $372,000 for each death that occurs due to foodborne illnesses. This figure is about four times higher then the cost calculated by the human capital method (Roberts, 1988). Landefeld and Seskin's figures are still considered to be underestimates of the actual value of life lost as they only consider measurable economic losses such as lost wages and do not address the non-monetized costs such as pain and suffering (Roberts, 1988).

The true economic cost of any foodborne illness is not simply the cost of the human illness in terms of loss of life or loss of productivity but must be much more inclusive. Many courts are now recognizing this fact and are awarding compensation for pain and suffering in foodborne illness cases. Other associated costs include; leisure time lost, averting behavior, travel for treatment, and child care. Additionally, there are the costs incurred by the food industry following an outbreak of a foodborne illness; product recalls, investigation costs, reduced consumer demand in response to adverse publicity, liability lawsuits, etc. And finally there are costs to society through the public health sector; costs associated with disease surveillance, disease outbreak costs, and the cost of clean up after an outbreak. Figure 2 summarizes those costs as identified by Roberts (1986) that need to be considered when attempting to ascertain the true economic cost of foodborne diseases to society.

1. Human illness costs
    a. Medical costs
    b. Loss of Productivity/income
    c. Pain and Suffering
    d. Leisure time lost
    e. Averting behavior costs
    f. Risk aversion cost
    g. Child care costs
    h. Travel costs
2. Industry costs
    a. Recalls/destruction of product
    b. Reduced consumer demand due to adverse publicity
    c. Cost of investigating source of problem
    d. Changes in production to prevent future problems
    e. Liability lawsuits
    f. Product spoilage due to chronic microbial contamination
    g. Disrupted work schedules due to employee illness
3. Public Health Sector costs
    a. maintaining disease surveillance
    b. investigating outbreaks
    c. clean-up costs

Figure 2. Costs of foodborne disease (Roberts, 1989, p. 473)

Calculating the societal cost of foodborne illnesses in general is difficult in itself. Determining the proportion of foodborne illness, and associated costs, that can be attributed to antibiotic resistant bacteria is an even more complex and inexact process. Add to it the complicating factor of determining the percentage of the resistant cases that can be traced to the feeding of antibiotics subtherapeutically and the procedure becomes still more intricate.

Of the various organisms involved in the antibiotic resistance/foodborne illness issue, *Salmonella* is the one that has been most frequently studied. The Center for Disease Control (CDC) has maintained surveillance data on the incidence and severity of salmonellosis cases since the 1960's which makes *Salmonella* easier to study than some other bacteria (Steele and Beran, 1984). Also, *Salmonella* is a naturally occurring, zoonotic bacteria that has shown a high propensity to develop and transfer resistance. A four year study (1979-1981) of 312 livestock production or slaughter units, found that *Salmonella* was isolated from 5 percent of the broiler units, 5 percent of the swine units, 9 percent of the beef units and 60 percent of the swine slaughter facilities surveyed. The study also found that 82 percent of these *Salmonella* isolates were drug resistant (Fagerberg, 1986). Because of these facts, much of the following discussion will focus on *Salmonella*.

The CDC receives reports of 40,000 to 50,000 cases of salmonellosis annually (Frappaolo, 1986; Roberts, 1989; Institute of Medicine, 1989). These are classified by Roberts as being the moderate to severe cases. Estimates of the number of these cases that are resistant to one or more antibiotics range from 7,500 (Institute of Medicine, 1989) to 10,000 (CDC data base) cases annually. It is generally accepted that 70 percent of these or roughly 5,250 to 7,000 cases annually can be traced to animal sources. The National Resources Defense Council (NRDC) projected that 50 percent of the antibiotic resistant strains of bacteria in animals can be attributed to the use of subtherapeutic antibiotics while the Institute of Medicine maintains that up to 90 percent of the resistant strains can be traced to subtherapeutic use of antibiotics. Given this projection, from 3,500 to 4,725 of the cases of *Salmonella* reported to the CDC annually can be attributed to the subtherapeutic use of antibiotics in food animal production. Estimates of mild cases that are never seen by a doctor and/or cases that are never diagnosed as *Salmonella* range from 10-100 times the reported cases (Institute of Medicine, 1989). Therefore, the total number of cases of salmonellosis in the U.S. each year that could be attributed to the subtherapeutic use of antibiotics could range from 35,000 to 472,500. It is expected that from 50 to 300 of these cases will result in death (Institute of Medicine, 1989;Frappaolo, 1986) (see Appendix A for calculations). The IOM report emphasizes that these estimates are tentative and highly variable. More information is needed before definitive conclusions can be made.

At the present time, Landefeld and Seskin's figures are considered to be the best estimate of disease costs. They estimated the cost to society of each salmonellosis death at $372,000 (1985 dollars). If the number of deaths due to antibiotic resistant *Salmonella* that are related to the use of subtherapeutic antibiotics are 50 to 300 per year (as calculated above), this would put the cost to society between $18 million and $112 million per year.

The cost of non-fatal salmonellosis can also be approximated. Roberts estimates that each case of salmonellosis that is severe enough to be hospitalized costs society approximately $4,350 (Roberts, 1988). Each case that is severe enough to be seen by a doctor but does not require hospitalization costs roughly $680 (Roberts, 1988). Mild cases that required no treatment but still result in a loss of wages and/or leisure time are expected to cost $221 each (Roberts, 1988).

Morbidity estimates for antibiotic resistant salmonellosis that can be attributed to animal sources, as calculated above, totaled 34,750 cases to 472,200 cases annually. Using a weighted average, the cost per case for non-fatal salmonellosis is expected to be $700 (Roberts, 1989). Therefore, the social cost of non-fatal cases, attributable to the use of subtherapeutic antibiotics in animal production ranges from just over $24 million to almost $331 million annually. The total cost of the resistant *Salmonella* cases that can be attributed to animal sources is thus estimated to be between $42 million and $443 million annually.

Other foodborne bacterial diseases that are involved in the animal production/antibiotic resistant bacteria issue include; *E. Coli*, *Camphylobacter*, and *Listeria*. A summary of the total number of cases observed annually for each of these diseases and an estimate of the social costs resulting from them is presented in Table 2. Little work has been done in connecting antibiotic resistance of these illnesses to antibiotic use in livestock production. This area deserves more investigation as the CRC Handbook lists 46 disease entities in animals caused by 50 ethological agents which may be treated with antibiotics and sulfonamides (Beran, 1987). Any or all of these could possibly be developing resistance and could cost society billions of dollars in deaths, lost productivity, etc. each year.

Table 2. Medical and productivity costs due to selected foodborne bacterial diseases [a]
(1987 dollars)

Foodborne disease	Annual # of cases	Estimated Total Cost (million dollars)
Campylobacteriosis[b]	2,100,000	1,470
E. Coli	50,000	60
Listeria	1,581	213
TOTAL	2,151,581	1,743

[a]from Roberts, 1989
[b]Campylobacterosis is based on 100% of the cases from foodborne sources.

Antibiotic residues

Another issue that has been raised in conjunction with the use of antibiotics in food animals is that of drug residues remaining in meat and milk. Once an antimicrobial is given to an animal, the compound is excreted from the body over a period of time. The amount of time that this process takes varies depending on the drug given and the method of administration. The risk to human health is accepted as being fairly low by most scientists. There are only a few cases where antibiotic residues in food directly resulted in harm to human health (Somogyi, 1989) and there has been no epidemiological evidence that antibiotic residues contribute to sensitizing consumers to drugs such as penicillin. The occurrence of allergic reactions in humans due to ingestion of foods containing antibiotic residues has been very low and mostly limited to cases involving milk (Beran, 1987). Furthermore, most common antibiotics have been shown to be degraded through cooking meats thus reducing the chance of ingesting antibiotic residues (Beran, 1987). However, there has been some apprehension about the possibility of drug residues in the meat causing non-zoonotic bacteria in humans to develop resistance to that antibiotic. More study into antimicrobial residues is called for to establish the possibility of such a link.

Due to the sophistication and sensitivity now available in testing for drug residues, it has been accepted by most of the scientific community that the concept of zero tolerance is an impractical goal except for known carcinogens (Raynaud et al., 1989). Therefore residue limits or tolerance levels in meats and milk have been established for most antimicrobials and some other chemicals such as pesticides. To insure compliance with these limits in the U.S., the Food Safety and Inspection Service (FSIS) has instituted programs to monitor the meat industry. In 1990, the FSIS inspected 7,299 samples of food animals for antibiotic residues and found violative levels in 1.6 percent of those samples (Mathur, 1991).

One particular area of concern in the residue issue has been the prevalence of sulfonamide residue violations, particularly in swine. In the 1970s, the Food and Drug Administration (FDA) determined that many of the older uses of sulfonamides did not have sufficient data to meet approved safety criteria (Cordle, 1989). The sulfonamides have since become a focal point in the drug residue issue for several reasons; they are excreted from the tissues more slowly than some of the other antimicrobials, there is emerging evidence that sulfa residues are not broken down during the cooking process as are some other residues (Fischer et al., 1990), it has been discovered that as little as 2 ppm of sulfamethazine in the feed fed during the last 15 days prior to slaughter can cause violative residues in the tissue (Ashworth et al., 1986), and there is some emerging evidence that sulfamethazine may be a carcinogen (Cordle, 1989).

In 1977, the sulfa residue violation rate in swine was 13 percent but through increased education and awareness on the part of producers the violation rate had dropped to 0.76 percent in 1990 (Mathur, 1991). However, vigilance on the part of the regulating bodies and continued education of producers is necessary to insure that these residue levels continue to be low and decline even further.

If there are costs to society from antimicrobial residues, they have not been estimated. This lack is partially because of the paucity of documented cases in which drug residues have caused harm to human health. However this is an area requiring further study.

Impact on exports

The European Community's (EC) 1989 ban on importation of hormone treated meat emphasized that the U.S. livestock industry is truly operating in an international marketplace. Any policy decisions made in this country on the antibiotic issue will not only affect prices through the changes in national supply and demand but will also have an impact on prices through changes in the export markets.

The sulfonamides are currently a focal point in this context due to a sulfamethazine residue violation in pork shipped to Japan in June of 1990. The Japanese are considering tightening controls so that 100 percent the pork imports will be tested for sulfa residues if another violation occurs. Since the testing procedure takes several days and since much of the pork shipped from the U.S. to Japan is fresh chilled rather than frozen, this would backup shipments of pork and could seriously damage the fresh pork trade in this market.

It is estimated that total exports of pork add $2.50 to the value of each hog sold in the U.S. and that the Japanese market alone accounts for 55 to 65 percent of the export market for U.S. pork (Rod Smith, 1990).

Effects of Restricting Antibiotic Use

There have been several proposals to further restrict the use in animal production compounds that are also used for human disease therapy. Penicillin and tetracyclines are the drugs most often mentioned as they are frequently used in human medicine. The FDA has also considered banning the use of some or all of the sulfonamides due to a lack of data concerning the carcinogenicity of these compounds. The banning of any or all of these drugs would have implications for several different groups.

Livestock producers

Livestock producers would feel the most immediate effect of any ban. A partial or total ban on subtherapeutic antibiotics would impact overall animal performance. It is estimated that feed costs range from 50 to 80 percent of the total cost of producing meat or animal products. Less efficient feed conversions mean increased feed costs per pound of livestock gain. Slower gains translate to both higher feed costs and increased costs from interest and facility expense as it takes longer for the animals to reach market weight.

A ban on the subtherapeutic and/or therapeutic use of antibiotics could lead to an increase in animal mortality and morbidity from bacterial diseases, pushing production costs still higher.

Overall impacts from a potential ban will depend on several factors including: which compounds are banned or regulated to lower levels of use, which livestock species and disease problems are affected, and the availability and efficacy of substitutes. Additionally, adjustments in management strategies may also be a necessary response. Producers who are in a position to adopt the management practices and production technologies necessitated by reduced antibiotic use would experience increased short run profits as farm prices rise in response to reduced production and increased costs. However, these profits would erode over time as the industry adjusts to the new management practices and production methods and market prices settle in on the point where "normal" profits are again available in the industry.

Since this paper is specifically focused on swine production, a closer look at the impacts of antibiotic use and the possible restriction of such use on the production of pork is in order.

In the United States, approximately 85 percent of all the starter rations, 75 percent of all the grower rations, and 60 percent of all the finisher rations fed to hogs are medicated (Cromwell, 1983). A 1991 survey by *Hog Farm Management* found that over 84 percent of the producers responding use a feed grade medication in their growing/finishing rations. Fifty-two percent cited growth promotion as the primary objective of using such feeds compared to 44 percent citing disease suppression as the reason for feeding antibiotics. The ability to reduce expenditures on feed is important to the hog producer since feed costs account for about 60 percent of the total expense in a farrow to finish operation, about 48 percent of the total expense in a feeder pig producing operation, and about 69 percent of the total expense in a feeder pig finishing operation (Iowa State University Extension Service). Beran estimates that the cost of adding antimicrobial drugs to livestock rations is about 3.75 percent of the total ration cost. It is difficult to draw general conclusions and to make blanket recommendations about antimicrobial use in livestock production. Experimental results tend to underestimate the response from antibiotic use since animals in research facilities can be expected to be healthier and raised in a more ideal environment than the average farm animal (Hays, 1986;

Zimmerman, 1986; Cromwell, 1983). Typically, younger or poor-doing animals have the best responses to antibiotic use (Braude, 1953). Responses can also vary depending on the herd's general health and disease level, as well as on the cleanliness of the environment (Prescott and Baggot, 1988). This would seem to indicate that the best responses from antibiotics will be seen on operations with poorer management and that better managed farms may see less response.

Studies have shown that the expected advantage from using antibiotics in pork production, on average, across all age groups, would be a 2 percent to 7.6 percent increase in feed efficiency and a 4 percent to 17.7 percent increase in the rate of gain (Cromwell, 1983; Hays, 1986; Beran, 1987; Zimmerman, 1986). The best response to antibiotic use is in pigs weaned at less than 6 weeks of age which may show up to a 40 percent improvement in growth rates in the starter phase (Stevermer, 1976). The return on investment at the highest levels of feed efficiency is about $2 per dollar invested in the antimicrobials. This means returns of over $3.5 billion annually for the U.S pork industry (Beran, 1987).

Antibiotics have also been shown to be effective in improving the reproductive performance of sows. Studies have indicated a 4 percent increase in litter size (Zimmerman, 1986) and a 10 percent improvement in conception rates (Cromwell, 1983) following the feeding of antimicrobials.

Table 3 summarizes the net economic benefit per market hog from the use of antibiotics as calculated by Zimmerman (1986). The net economic benefit is calculated at $2.64 per market hog. The largest benefit (38 percent) results from an increase in the rate of gain. Improved reproductive efficiency accounts for an additional 36 percent of the benefit (15 percent for improved farrowing rates while increased live pigs born accounts for 21 percent). The importance of these benefits becomes apparent when you consider that from 1981 to 1990, The average margin over all costs in a farrow to finish operation was about $12 per hog marketed (Iowa Swine Enterprise Record).

Table 3. Economic benefit from antibiotic use in swine (net per market hog)

Feed efficiency	$0.25 (9%)
Rate of gain	1.00 (38%)
Farrowing rate	0.39 (15%)
Live pigs born	0.56 (21%)
Reduced mortality	0.44 (17%)
Total	$2.64

(adapted from Zimmerman by Preston, 1987)

The swine industry will be impacted by further restrictions on the use of antibiotics-particularly if the restrictions involve cutbacks in the subtherapeutic use of penicillins and tetracyclines. Currently the pork production industry is especially dependent on these compounds as available substitutes have been shown to be relatively less effective under current management practices (Burbee et al.,1985). Tylosin and tetracyclines account for about 55 percent of antibiotic usage during the finishing phase (Cromwell, 1983). Banning or limiting the use of sulfonamides would have an impact on many pork producers as sulfa-antibiotic combinations account for 50 percent of the total usage of antibiotics in the starter and grower phases.

Some industry specialists speculate that the intensive production practices of today's hog industry would decline in importance if antibiotics were not available for use in pork production. Others contend that these operations have effective management in place and would be very adept at positioning the operation and making the necessary adjustments. In 1986, antibiotic feed additives for the purpose of growth promotion were banned in Sweden. The result has been decreased feed efficiencies, slower growth rates and increased incidence of disease problems in Sweden's swine herds. Preliminary reports indicate that it is the top producers whose costs have increased the most due to this ban ("Sweden: Ban...", 1989). This would suggest that antibiotic use in the Swedish pork industry was not merely a strategy to substitute for top level management but was a component of an overall system of effective management tools.

In summary, restrictions on the use of antibiotics in pork production would likely lead to declines in production efficiency, increased production costs, and increased prices for pork products. Weaning ages would increase, as would the length of time between farrowings to allow for more thorough physical cleaning and disinfecting of the premises. Farrowings per female year would decline, trimming hog inventories, reducing pork supplies in the marketplace, and increasing market prices to consumers (National Academy of Sciences, 1980). These changes would also lead to production cost increases. Current management practices for many production systems dictate that the movement of animals from farrowing units to nursery facilities to finishing units be closely coordinated in order to efficiently utilize all facilities. Since antibiotics aid these management strategies, limitations on antibiotic use could reduce the return per dollar invested in buildings and equipment.

Consumers

Due to the nature of the market for agricultural products, it is reasonable to project that supply shifts could cause a substantial price adjustment to the consumer at least in the short run (Burbee et al., 1985). A small reduction in supply would cause a significant consumer price increase. For example, a 1983 task force estimated that banning antibiotics in the pork industry alone would lead to increased consumer costs of 2 billion dollars per year through increased food costs (Cromwell, 1983). A 1981 report by the Council for

Agricultural Science and Technology estimated that banning penicillin and the tetracyclines would cost the consumer 3.5 billion dollars per year through increased food costs. A study in 1979 indicated that such a ban would reduce supplies of meat by 1 percent for beef, 3.6 percent for pork, 2.4 percent for chicken, and 4.8 percent for turkeys. It is estimated that meat supplies would not recover for at least 5 years following a ban (Burbee, 1980). The industry would likely be quite unstable during this adjustment phase.

The USDA estimated in 1978 that banning subtherapeutic use of penicillin, the tetracyclines, and sulfonamides and banning all uses of nitrofurans (and assuming no immediate substitutes) would result in increases in consumer retail prices as detailed in Table 4. The low end of the range is based on the assumption of moderate efficacy of drug use while the upper figure is the result of assuming high efficacy of drug use.

Table 4. Projected percentage change in retail prices following a ban of subtherapeutic antimicrobial use

	1st. year	after 5 years
Beef	2.7-10.4%	0.0-0.7%
Pork	4.5-14.7%	1.0-3.2%
Poultry	10.3-27.6%	2.2-5.6%

(Council for Agricultural Science and Technology, 1981)

The pharmaceutical industry

It is estimated that almost one-half of the 31 million pounds of antibiotics produced annually are used in animal production (Institute of Medicine, 1989). In 1990, sales of feed additives and pharmaceuticals for use in livestock production in the U.S totaled over $2.8 billion, up 9.2 percent from 1989 ("U.S. sales...", 1991). If antibiotic use in livestock production was banned or even restricted, the loss of these sales would have a definite effect on the pharmaceutical industry in terms of loss of income and would lead to shifts in production patterns.

Intensification in research and development of new drugs would occur as demand for substitutes increased. However, pharmaceutical company representatives have expressed concern that antibiotic restrictions or bans without adequate scientific substantiation could have a decided negative impact on the development of new compounds ("The Antibiotic Controversy: The Science", 1985). Liss and Batchelor have reported that the capitalized cost of developing the average new chemical entity has been calculated to be $32 million (1967 dollars or $113 million in 1989 dollars). New compounds require an average of more than 10 years beyond market introduction to return the cost of capital to the company. Few companies will be willing to risk this level of investment and time when the potential exists that a compound could suddenly be restricted or banned without an adequate scientific basis. In fact, the low numbers of new antimicrobials that have been introduced in recent years has been attributed to this uncertainty in the market (Bird, 1990). Ultimately the dampening effect of this uncertainty is bound to extend to human medicine as well.

Consumer Response to the Antibiotic Issue

The consuming public has become more aware of possible food hazards in recent years and the public has also become increasingly more self-reliant as they attempt to determine the safety of the foods they eat. Most consumers attempt to determine their level of risk using the conflicting claims by the media and complex laboratory data that is difficult to translate into practical guidelines (Burbee and Kramer, 1986). It is important that producers and others associated with the food animal industry be as open and sensitive as possible about the benefits and risks of antibiotic use.

How informed is the general public about antibiotic use in food-producing animals? Kramer and Penner have reported on a 1983 survey by Kansas State University that pointed out some interesting misconceptions. Nearly 60 percent of those surveyed believed that antibiotics increased the cost of food production. Only 25 percent knew that antibiotics have an important role in reducing the cost of food. The study showed that 67 percent of those surveyed indicated that they were willing to pay more for their meat products if they were labeled as being free of animal drugs, added hormones, and other chemicals.

A 1989 poll of consumers by the Food Marketing Institute (FMI) found that when asked an open ended question about what they perceived was the greatest threat to the safety of the food they eat, only 1 percent of the respondents indicated that they were concerned about antibiotics in the food chain. However, when asked to select from a list of possible health hazards, 61 percent indicated that they felt antibiotics were a serious hazard and an additional 26 percent felt that they were somewhat of a hazard (Food Marketing Institute, 1989). These results seem to indicate that while the shopping public perceives that there is a risk associated with the use of antibiotics, it does not seem to be one of their major (or immediately thought of) concerns.

The issue of antibiotic use in animal production and its possible connection to human illnesses is an important and controversial one not only for the consuming public but for the scientific community as well. However, because of the unfamiliar, technical nature of the issue, it is one that consumers have a difficult time evaluating on their own. Because of the complexity of the topic, it is easy for consumer concerns to quickly escalate to disproportionate levels, leading to a decline in consumer confidence in the safety of the food supply. To improve the confidence and respect of the consuming public, the entire industry from producers through processors must police itself diligently to prevent any incidences of misuse of antibiotics and other chemicals. Furthermore, the industry must bring any available, substantiated information on this subject to the public in an easily understandable form as rapidly as the information becomes available.

Summary

It has been shown that the use of antibiotics in food animal production is important to the livestock industry. Drugs such as sulfonamides are useful management tools for the livestock producer, aiding in the reduction of animal morbidity and mortality, as well as enhancing animal performance and efficiency. Because of the use of antibiotics, production costs are reduced which results in lower cost of food products to consumers.

However, the use of antibiotics is not without problems and controversy. There are real concerns that need to be addressed about the development of bacteria that are resistant to common antimicrobial therapy. The potential losses to society from deaths and illnesses caused by resistant bacteria are thought to be high, but confirming the causal link between the use of antibiotics in food animal production and these losses will require further research.

The occurrence of antibiotic residues, especially sulfa resides, is also of grave concern. Several strategies involving adjustments in management practices, the changing of testing levels and procedures, and/or changes in the regulations affecting compounds such as the sulfonamides have been suggested to effect a permanent reduction in residue violations. Some of these strategies will be examined and evaluated in the following sections.

In conclusion, the issues surrounding the use of antibiotics in food animal production are complex, involving large sections of the U.S. economy including agricultural production, meat processing, and the pharmaceutical industry. At issue also is the risk to human health, both real and perceived. Much more investigation of this issue is needed to establish the facts. In the meanwhile, there are steps that those in the food product chain can take to reduce some of the risks and concerns especially in the area of sulfonamide residues.

CHAPTER III. METHODS OF TESTING FOR SULFONAMIDE RESIDUES

There are several tests that can be used to identify sulfonamide residues in pork tissue. Some of these, such as thin-layer chromatographic fluorescence and the Swab Test on Premises (STOP), were developed to detect the presence of any antibiotic residues in food animal tissue. Other tests such as the Sulfa-on-Site and the E-Z Screen test were developed specifically to detect sulfonamide residues. This section will look at how and where each of these tests are used as well as the advantages and disadvantages of each test.

The Food Safety Inspection Service laboratories use thin-layer chromatographic fluorescence of tissue from the liver to ascertain if there are residues present in a given carcass. The concentration of residues in muscle tissue is calculated to be one-third of the concentration found in liver tissue (Randecker et al., 1989). Thin-layer chromatography is considered to be the most reliable of all the residue tests but requires relatively highly trained personnel to perform it as well as sophisticated equipment. An additional drawback of this test is that it requires two days for confirmation of the results. Since all sampled carcasses as well as any animals from the same farm must be held until negative results are received, this fairly lengthy delay means that the processor could face severe bottlenecks and increased costs. Increased costs at the processor level would result in lower prices received by the producer and/or higher prices paid by the consumer. Because of these fairly substantial drawbacks, this test is rarely used as a screening test. The development of screening tests such as the Swab Test on Premises (STOP) and the Sulfa-on-Site (SOS) test, has been important in that they allow the FSIS to more efficiently utilize their laboratory facilities by indicating which carcasses are suspected of having violative residues. Then the more reliable thin-layer chromatography test can be used to confirm whether or not a violation has actually occurred.

The Swab Test on Premises (STOP) was first used in the late 1970's as a screening test for residues both on the farm and in the packing plant. It involves a microbiological culture of a swab of the kidney tissue. If there is no growth of sensitive organisms on the culture medium within 18 hours, then it is assumed that there are antimicrobial residues present in the carcass and that these residues are inhibiting bacterial growth. While this test is considered to be accurate 98 percent of the time, a positive STOP test must be confirmed by further laboratory analysis with the thin-layer chromatography method described above (Raynaud et al., 1989). Thus the time delay before a residue violation can be as great as three days for a given carcass when the STOP test is used. However, since only those carcasses that have actually tested positive with the STOP test must be held, the bottlenecks caused by using this test are less than those resulting from using the thin-layer chromatography methodology for screening a population.

Presently, the 100 largest hog processing facilities are routinely using the Sulfa-On-Site (SOS) test to screen for sulfonamide residues. This test is a simplified version of thin-layer chromatography and is capable of providing both qualitative and semi-quantitative results from a urine sample. The SOS test is calibrated so that it can indicate whether only the liver contains potentially violative levels or if the muscle tissue is likely to contain violative levels. However, any positive SOS test generally results in the carcass being held for further testing of the muscle tissue in the FSIS laboratories.

Since the SOS test uses urine samples and not animal tissue, it has the advantage that it can be used pre- as well as post-slaughter. This is important since it is practically impossible to remove sulfa residues from a carcass but it is fairly simple to remove them from a live animal. The SOS test can be used to screen animals before they are slaughtered so that any suspect animals can be held back until they are no longer showing any traces of residues. In addition, this test is flexible enough to be used to identify environmental contamination by detecting sulfonamide residues in such things as feed, flush water, manure, etc. This allows the producer to detect problems before residue violations occur.

The SOS procedure is fairly simple and can be easily performed by anyone with some laboratory skills. However, due to the additional skills need to make quantitative estimates and the equipment needed to perform the test, this procedure is probably better suited to use in a veterinary practice or at the processor level instead of at the producer level (McKean, 1988).

The E-Z Screen card test is an ELISA-based assay test designed specifically to detect sulfamethazine residues of up to 0.1 ppm. It requires no special training or special equipment to perform this test; the diluted sample is placed on a card that has been impregnated with sulfamethazine antibodies, if the sample does not turn purplish in color, then sulfamethazine is assumed to be present. Like the SOS test, it was designed to screen urine samples but can be used to detect sulfamethazine in drinking water, feedstuffs, flush water, and manure when appropriate steps are taken to prepare the samples. The simplicity and ease of using the E-Z Screen makes it ideal for producers to use in screening animals prior to shipment, and to use in conjunction with a quality assurance type program in controlling environmental contamination.

CHAPTER IV. STRATEGIES FOR REDUCING SULFONAMIDE RESIDUES

Proposed strategies for reducing sulfonamide residues in pork must involve action by three groups; regulatory agencies of the government, pork processors, and pork producers either working alone or in concert with each other. Since sulfamethazine is the most widely used of the sulfonamides and has the highest violation rates, it will be the focal point for most of the suggested strategies. Actions or strategies currently developed for reducing sulfamethazine residues may be useful in the future for devising strategies for the other sulfonamides or for any compounds used in food animal production.

Regulatory Agencies

There are two agencies within the U.S. government that are of primary importance in regulating the safety and quality of the food supply. These agencies are the Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA). The two sections within the USDA that would be involved in the issue of reducing sulfonamide residues would be the Animal and Plant Health Inspection Service (APHIS) and the Food Safety Inspection Service (FSIS).

While these governmental agencies can not directly reduce residues, they do have the power to indirectly influence the actions of the producers through such things as changes in testing levels, testing procedures, penalties for violations, restrictions in antibiotic usage, etc.

Food and Drug Administration (FDA)

The FDA was formed in 1927 by the U.S. Congress to inspect, test, approve, and set safety standards for foods, food additives, drugs, chemicals, cosmetics, and household and medical devices. The FDA is involved in such diverse areas as milk sanitation programs, testing of microwave ovens for radiation leakage, and labeling of food products. This agency has the power to remove a product from the market or limit its use if evidence emerges that a given product poses a threat to human health.

The FDA is responsible for the regulations concerning the use of antimicrobials in livestock production including the medication of feeds. Dosages, withdrawal periods, and tolerance levels for residues in meat are all subject to FDA approval prior to the introduction of any new product. A major focus of the FDA is protecting and enhancing the quality of the food supply. One recent focus has been further reductions of sulfamethazine residues in pork. Alternative actions that the FDA has considered with regards to attempting to effect this reduction of sulfa residue violations are; declare sulfamethazine an imminent hazard, issue a notice of opportunity for hearing, and develop a program of residue reduction. These alternatives are described in more detail below.

Declare sulfamethazine an imminent hazard The FDA has the power to recommend that the Secretary of Health and Human

Services declare a drug an imminent hazard to the public. If given such a recommendation, the Secretary would most likely move to suspend the New Animal Drug Application (NADA) approval. This action would in effect create an immediate ban of that compound. In 1988, the FDA held a public hearing on current findings about sulfamethazine to determine whether or not it should be declared an imminent hazard. The conclusion at that time was that no imminent hazard existed. This conclusion was based on two things; first, sulfamethazine residues had been reduced to near acceptable levels through a joint governmental/industry education program and second, the pharmaceutical industry had shown that while sulfamethazine is connected with tumors of the thyroid in laboratory mice, the connection is by way of a secondary mechanism. Unless new evidence emerges that sulfamethazine is in fact a human carcinogen, it is unlikely that the FDA will declare this compound an imminent hazard.

Issue a notice of opportunity for hearing By using the hearing process, the FDA can develop a public record of facts and opinions on a given issue which it then uses to develop and defend a decision on that issue. This approach is a longer process than the imminent hazard declaration but could still ultimately result in a ban of sulfamethazine use depending on the information obtained through these hearings. In the early part of 1991 the FDA formed a committee to develop a notice of opportunity for hearing but as of this writing the notice has not been published.

On the basis of information obtained in such a hearing, the FDA could choose to:

1) Do nothing. Allow sulfamethazine use to continue as it is currently.

2) Ban the use of sulfonamides in producing food animals. This ban would mostly likely be put into effect gradually by prohibiting any further production and sale of sulfamethazine for livestock production. However, sulfamethazine already in the marketplace could still be used until inventories were depleted.

3) Reduce the acceptable tolerance level for sulfamethazine residues from the current 0.1 ppm level to 0.025 ppm. This proposal would increase the measure of safety of the food supply but at the same time allow continued use of sulfamethazine.

Develop a program of residue reduction The FDA could also choose to assist in the development of a comprehensive, voluntary program to reduce the occurrence of residues. This program could possibly be similar to the NPPC's Quality Assurance program with added monitoring and enforcement polices administered by the FDA.

U.S. Department of Agriculture (USDA)

The USDA is an executive department of the U.S. government that is directed by the Secretary of Agriculture. The basic function of this department is to aid agriculture in producing and distributing high quality food and fiber commodities. The activities that the USDA carries out include; inspection of meat and other food products for quality and wholesomeness, regulations of pesticides, combating animal diseases and pests, administration of school lunch and food stamp programs, and distribution of food to the needy of the world.

There are two departments within the USDA that would be most closely involved in the issue of reducing sulfonamide residues in pork, the Animal and Plant Health Inspection Service and the Food Safety Inspection Service.

Animal and Plant Health Inspection Service (APHIS)

APHIS is that part of the USDA that is involved in disease control programs for the U.S. plant and animal populations at the production level. They also oversee various eradication programs for specific diseases and would be the agency most likely to be responsible for overseeing any of the traceback/-identification programs that have been proposed. Such programs would allow the USDA and the FDA to better identify residue violators. Currently, about 16% of the hogs that have been found to have violative sulfamethazine residues cannot be traced back to their farm of origin (Augsburg, 1989). While improving the ability to identify individual animals is not, by itself, a strategy for the reduction of residues; it can be a component of several of the other strategies that have been suggested.

Food Safety Inspection Service (FSIS) The FSIS is responsible for administrating the residue monitoring and surveillance programs at meat processing facilities across the U.S. The FSIS general policy for monitoring the occurrence of residue violations is to devise a plan of random sampling that provides a 95 percent confidence interval of detecting a violation if one percent of the population is violative. FSIS has the option to set up a more rigorous surveillance program if violations are a problem in a given species and they have done so with regards to sulfamethazine in swine. Currently the FSIS requires that six hogs per shift per day at each of the 100 largest hog processing facilities be screened for sulfa residues using the SOS test. The FSIS has proposed increasing the required number of animals selected for testing even further if violations continue to occur. By testing more hogs each day, the probability that a residue violation will be detected is increased. Increasing the probability of detection linked with an improved producer identification system would increase the likelihood that a detected violation could be traced back to the farm. This combination joined with a sufficiently severe penalty for a residue violation would encourage producers to take direct action to reduce residues at the point of production.

Pork Processors

Pork processing facilities are also concerned about the occurrence of sulfa residues. When a carcass is condemned for residue violations, the packing plant incurs a loss in terms of the actual price paid to the seller plus the cost of slaughtering that animal. In addition to these costs, the processor runs the risk of further losses if residues are discovered in pork that is slated to be exported. Countries such as Japan have expressed increasing concern over the incidence of sulfa residue violations in pork carcasses. In an effort to avoid or reduce these risks/costs, pork processors are looking at three strategies; increased testing, "bill back" provisions, and a concept of selected suppliers.

Increased testing

The 100 largest hog processing facilities are currently using the SOS test to screen for sulfa residues on the kill floor. They are required to assist the FSIS in randomly testing six hogs/shift/day/plant for residue violations. However, the processor could chose to test more carcasses in an effort to reduce violations. The rationale behind such testing is the same as was described above for the increased FSIS testing; the more testing that is done, the greater the probability that a violation will be detected. This increased risk of detection of even accidental residue violations would act as a deterrent/motivator to encourage the producer to take steps to reduce the chance of residue violations occurring. Increasing this post-slaughter testing would also decrease the risk that a residue violation will be undetected at the plant.

Screening tests such as the SOS test can also be used to check for residues pre-slaughter. It is possible that the packing plant could institute a plan where hogs are tested prior to being slaughtered. Under this strategy, hogs that test positive for sulfonamide residues would then be placed in a sulfa-free holding area with feed and water until they no longer have violative residues. It has been shown that hogs with violative residues might have to be held in such an area for more than five days (McKean, 1992, personal communication).

"Bill back" provisions

Under this proposal once a carcass is condemned for residue violations, the processing plant would have the right to charge the seller for the cost of the condemned carcass plus possibly some associated expenses such as legal fees. Under a California law passed in 1991, any livestock seller can be liable to the buyer (processor, etc.) for three times the selling price of the violative animal plus attorney's fees. This strategy has the effect of shifting the loss incurred due to the residue violation from the processing plant back to the seller. Problems with implementing such a strategy include; the lack of an efficient traceback/identification system for identifying the point origin of the violative animals, and the inability to adequately identify the source of sulfa contamination in many cases.

Selected supplier concept

In an effort to insure that hogs being bought by the packing plant contain no residues, some packers such as Monfort and Indiana Packers have instituted selected supplier programs. This strategy entails requiring producers to meet specific quality criteria before the packing plant will accept hogs for processing. Under the Monfort program, producers would be subject to biannual testing of their hogs/facilities and routine monitoring procedures. Both programs would shun producers that have repeated residue violations.

This type of program would mesh well with the NPPC's Pork Quality Assurance Program described below. In fact, under the Indiana Packers program, producers are currently being paid $1/cwt. more for their hogs once they have received their Level III verification and have met other requirements involving medication records.

Pork Producers

Realistically, direct action to reduce sulfonamide residues can take place only on the farm. The producer has the ultimate control over how and when sulfonamides are used and the responsibility to comply with withdrawal procedures. However, there are some different approaches and management strategies that a producer could employ to effect a fixed reduction of the risk of a residue violation occurring.

Output testing

Under this strategy hogs would be tested as they are ready for market using the E-Z Screen or the SOS test. This testing could either be of randomly selected animals or of all hogs leaving the farm. Positive animals would have to be held for a minimum of five days to insure that they were no longer in violation of the residue limits.

Input testing

Since residue violations most often occur as a result of contamination of the feed and/or the environment during the drug withdrawal period, a hazard analysis type approach might be of some benefit. In this type of strategy, the inputs such as feeds and the environmental factors such flush water would be routinely tested for sulfonamide content. This strategy allows the producer to identify problem areas and take steps to correct any possible contamination that might lead to a violation of residue limits.

Combination testing

A combination of the above approaches would create a form of quality assurance program for the individual production unit. This approach could possibly lead to the development of farm certification for branded product marketing. This strategy could also be incorporated as a check of management safeguards implemented in conjunction with the NPPC's Pork Quality Assurance Program.

Pork Quality Assurance Program

This educational program administered by the National Pork Producers Council is currently in use and focuses on using production strategies to help reduce the incidence of sulfa residues. It involves a three level process by which producers are instructed about withdrawal times, sequencing of mixing feed, environmental contamination points and other residue avoidance techniques. The two initial levels of the program are designed as a home study course while completion of the third level of the program must be verified by a designated individual such as a veterinarian, extension worker, or agricultural educator.

CHAPTER V. DISCUSSION

Introduction

Implementation of any of the strategies mentioned in the previous section will increase costs for the producer. These increased costs may be due to elevated levels of disease incidence which leads to slower, less efficient animal growth and increased death losses. Costs may also be increased by the necessity of changing management practices to meet the criteria of a given strategy or by implementing testing procedures in the production process. Since the change in costs will vary depending on the strategy implemented, the costs associated with individual strategies will be discussed separately.

A potential benefit common to all of the proposed strategies is the possibility of impacting consumer demand by increasing consumer confidence in the safety of pork products. There are other benefits that may occur such as reducing the risk that a pork producer will incur the costs associated with a residue violation. These benefits will also be discussed separately for each respective area.

Finally, an attempt will be made to evaluate which of the suggested strategies appears to be the most cost effective in achieving a long term reduction in sulfa residues.

Effects of Actions Taken by the FDA

Impact on supply

FDA actions will ultimately result in further restrictions on the use of sulfa in pork production. Such restrictions would increase producer costs in several ways. Increased mortality rates for animal health problems such as respiratory ailments would lead to higher costs per animal marketed. Morbidity rates would rise for such diseases as atrophic rhinitis, resulting in less efficient feed efficiency and in decreased growth rates by afflicted animals (Straw and Ralston, 1987). Zimmerman (1986) points out that even healthy pigs could be expected to show some loss of feed efficiency and slower growth rates. While there are some compounds that could be used in place of sulfamethazine, most are less effective and more expensive than sulfa so that they would not totally alleviate the increase in producer costs.

Even small changes in the production costs can have dramatic impacts on a competitive market such as pork production if the changes are widespread (i.e. occur for most production units) and persistent. Increased production costs will lead to an increase in the short run marginal cost curve (MC) and average cost curve (AC) of the individual producer as illustrated in Figure 3a. Since in a competitive market the industry supply curve is the sum of the short-run, individual marginal cost curves, this would result in a left-ward shift of the industry supply curve for pork. The magnitude of this shift would depend on how pervasive these increased costs are across the industry. If there is a fairly consistent increase in costs throughout the industry, a shift such as depicted in Figure 3b could occur. Such a shift would result in a decrease in the equilibrium quantity from Q_1 to Q_2 and an increase in the equilibrium pork price from P_1 to P_2.

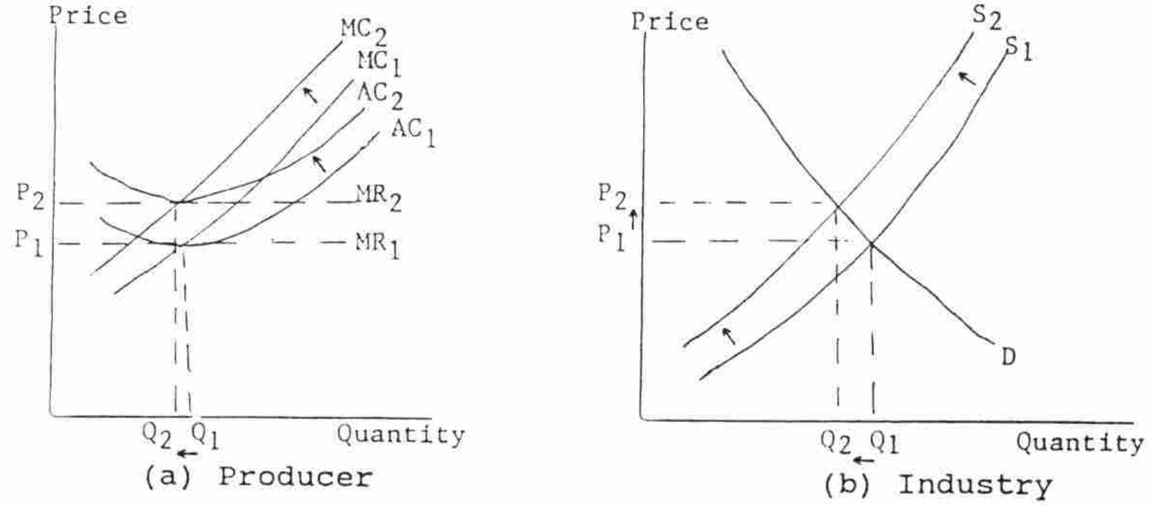

Figure 3. Effects of increased production costs on the individual pork producer and the pork industry

In addition, those producers who now have average costs that are greater than the market price will leave the market in the long-run. This reduction in the number of producers would result in a further left-ward shift of the industry supply curve and lead to an even smaller equilibrium quantity and greater equilibrium price.

It has been shown that agricultural products are relatively price inelastic, i.e. a one percent change in quantity results in a greater than one percent change in price. Therefore, even a slight left-ward shift of the industry supply curve would have a significant impact (increase) on the price of pork. This increase in price could entice other producers to enter the market or to expand existing operations in the long-run, shifting the supply back to the right to some extent. However, if the assumption is made that the rise in production costs is pervasive and permanent, the new industry supply curve would remain to the left of the original curve. This is due to the fact that optimal output in a competitive market is determined by setting average cost equal to marginal cost which equals industry price. With the assumptions given, marginal costs remain higher than in the original market resulting in a permanent, left-ward shift in industry supply.

The overall effect of any increase in production costs is; a reduced pork supply, higher prices received by producers, and higher retail prices paid by consumers. This assumes that there are no other changes taking place in the market and that there are no substitutes available to reduce production costs to the original level.

The FAPRI model

The macroeconomic (industry) effects of further restrictions on sulfa use were modelled using the Food and Agricultural Policy Research Institute's (FAPRI) model of the pork sector. The FAPRI model of the pork sector is part of a dynamic econometric supply-demand simulation model of U.S. agriculture. The use of this model also allowed some conclusions to be drawn about the magnitude of the changes that would occur in the pork industry sulfa use was further restricted.

Production lags in agriculture often delay industry response to changes in the production environment. Once sows have been bred, production decisions are more limited. Therefore, in the short run, pork supply is determined by the breeding herd inventory. For periods longer than one year (the accepted lag time for pork production), variables such as feed costs, production efficiency, prices of market and breeding hogs, will impact on the decision-making process of the pork producer. Equations (1)-(7) show the key biological and economic variables and relationships of the supply side of the FAPRI model in a reduced form. Figure 4 shows how the components interact to determine U.S. pork supply.

The market clearing price in the model is determined at the retail level, through consumer demand. In the short run, the model assumes that supply is fixed. However, in the longer run, equilibrium price and quantity adjust to reflect changes in supply and/or demand. The reduced form equations for use in estimating demand and determining price in the FAPRI model are shown in Equations (8)-(10) while the components of price determination for the pork industry are illustrated in Figure 5.

(1) PKSOWFAR = F(PKHOGNBR$_{t-1}$, PKGLTADD)

(2) PKPIGCRP = PKSOWFAR * PKPIGLIT

(3) PKHOGFRM = F(PKHOGFRM$_{t-1}$, PKPIGCRP, PKBAGKSD)

(4) PKBAGKSD = F(PKPIGCRP, PKHOGFRM$_{t-1}$)

(5) PKSOWKS = F(PKHOGNBR, SLHGR, CPPKF, CPPKX)

(6) PKPROD = F(PKSOWKS, PKBAGDSD)

(7) PKSUPP = F(PKPROD, PKSTK$_{t-1}$)

(8) PKPCCW = F(PKRETP, BFCKRETP, PCIUW, ZCENFABW)

(9) PKSTK = F(PKRETP, PKPROD)

(10) PKCDIS = F(PKSUPP, PKSTK)

where,
PKSOWFAR = sows farrowed
PKGLTADD = gilts added to the breeding herd
PKHOGNBR = breeding hogs on farms, Dec 1.
CPPKF = cost of production, feed (grain and supplements)
SLHGR = slaughter hog receipts
PKSOWKS = sow slaughter
PKPIGCRP = U.S. pig crop
PKPIGLIT = pigs per litter
CPPKX = cost of production, expenses other than feed
PKBAGKSD = barrow & gilt domestic slaughter
PKHOGFRM = market hogs on farms, Dec. 1
PKSUPP = pork supply
PKPCCW = per capita pork consumption
BFCKRETP = retail prices for beef and chicken
PKRETP = retail price for pork
PCIUW = consumer price index
ZCENFABW = personal consumption expenditure
PKSTK = pork ending stocks
PKCDIS = civilian disappearance of pork supplies
(Brown, 1992)

It is difficult to predict the impact that restricting sulfa use will have on production levels in the pork industry. The available data on the benefits that accrue to pork producers from the use of sulfas vary quite widely, but a reasonable

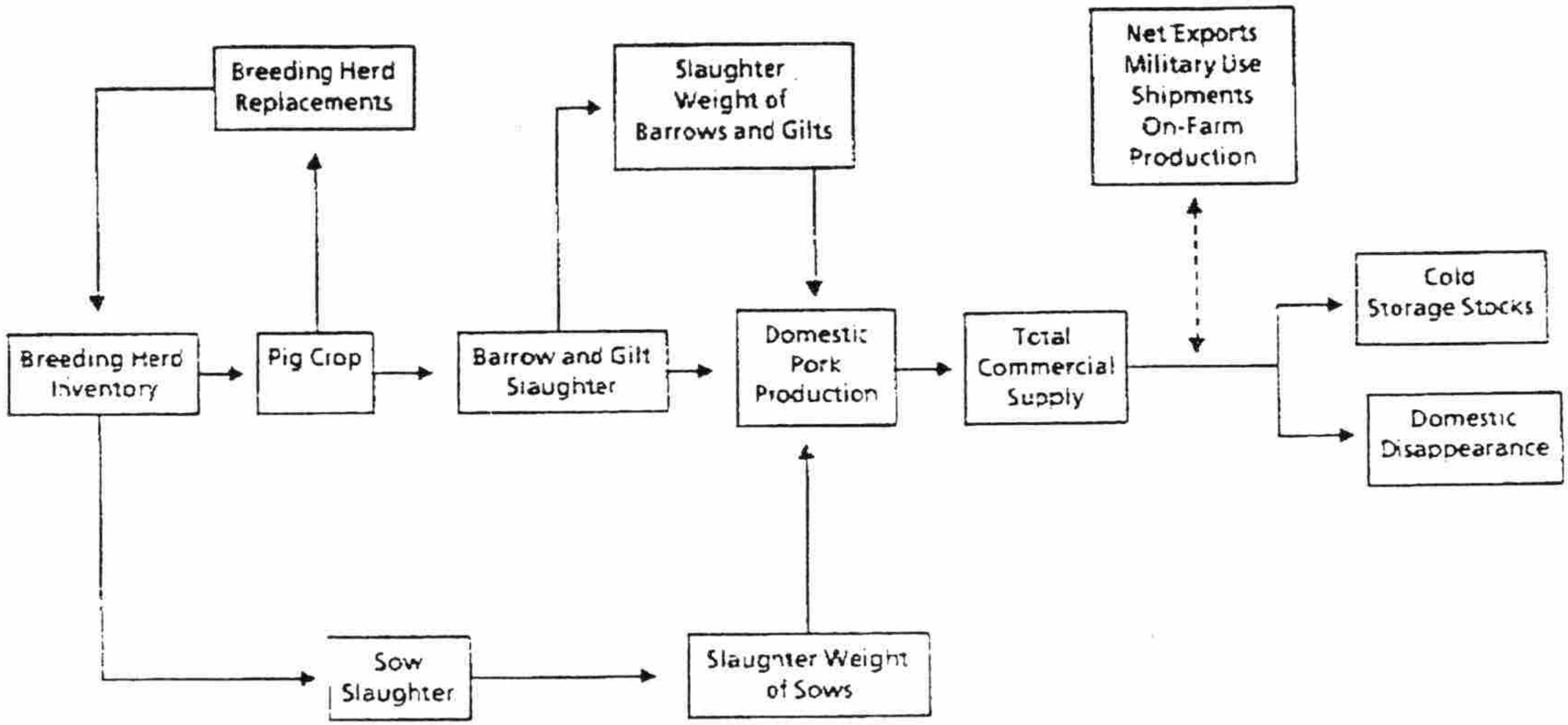

Figure 4. Supply components of the FAPRI pork model

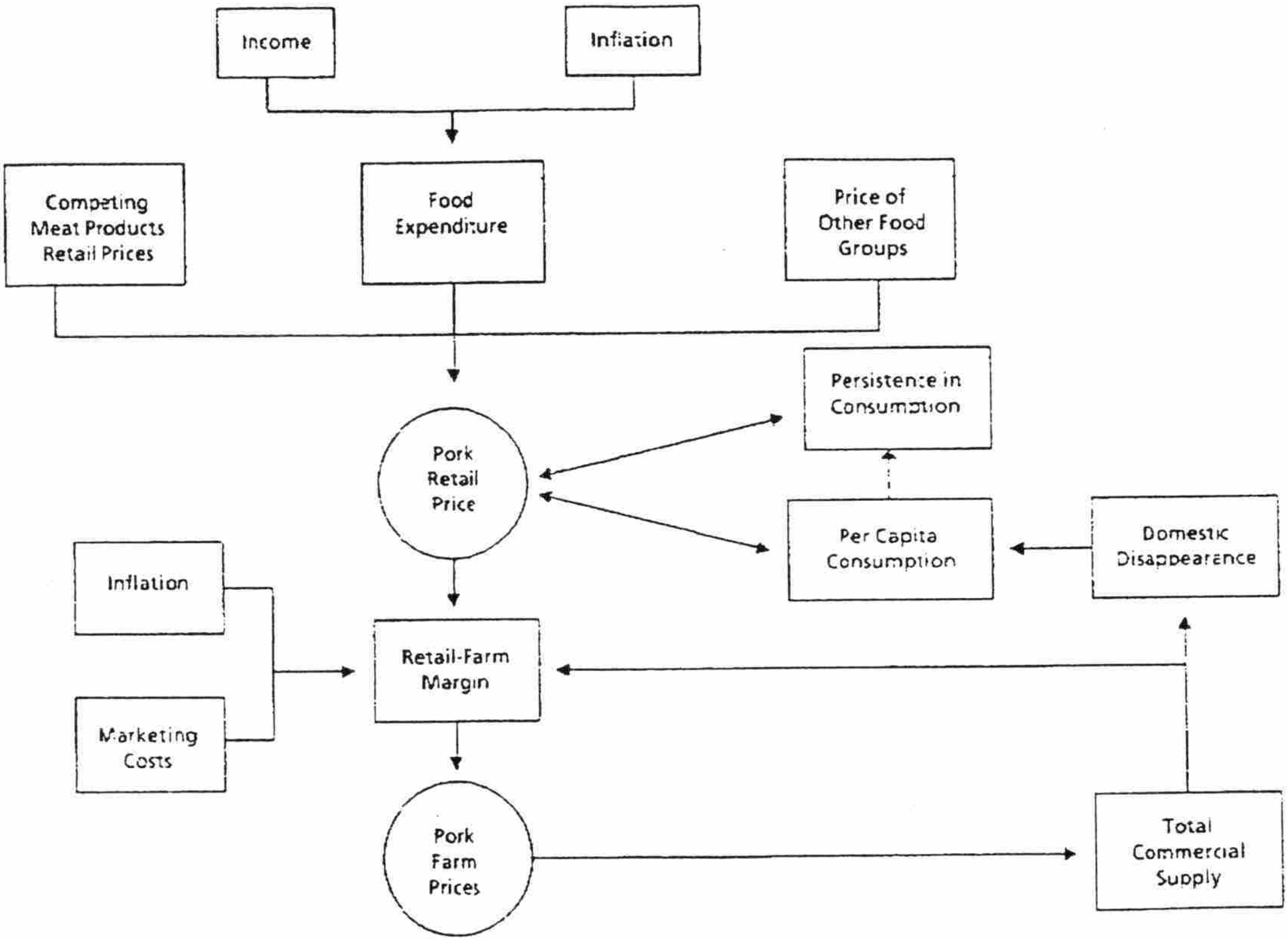

Figure 5. Price determination of the FAPRI pork model

assumption seems to be an average increase in daily gain of 11 percent, and an increase in feed efficiency of about 4 percent (Zimmerman, 1986). However, it is currently believed that anywhere from 30 to 50 percent of pork producers have suspended sulfa use in the past few years due to the recent publicity about sulfa residues (McKean, 1992). Using this information, an assumption was made that approximately two-thirds of the pork industry would be affected by a ban of sulfamethazine. It was also determined that a 10 percent reduction in pork production efficiency across the industry would represent an upper bound of the possible impact following a ban on sulfamethazine. The assumption that substitutes for sulfa are not available implies that this must be an upper bound.

Incorporating this assumption about the reduction in production efficiency into the FAPRI pork model provided an evaluation of the impact a total ban on the use of sulfa would have on the pork industry. Additional assumptions made for the purpose of this study include; the ban would be evenly implemented over a period of three years and no substitute compounds would be available. Results of this model are shown in Tables 5 through 8 and illustrated by Figures 6 through 9.

As seen in Table 5 and Figure 6, pork production is projected to decrease 2.31 percent over non sulfa ban levels (baseline) by the end of the third year following the ban. Pork production would remain persistently less than the baseline for the ten years of the projection. Producer prices for pork show a significant increase of almost 7 percent by the second year (Table 6, Figure 7) with an increase of more than 4 percent sustained even after 10 years.

Pork consumption is projected to decrease by slightly more than 2 percent by the third year and to remain 1 to 2 percent lower over the ten year period (Table 7, Figure 8). This decrease in quantity demanded is the result of the persistently higher retail prices. There is a fairly dramatic increase in retail prices by the second and third year followed by a slight readjustment in years four and five (Table 8, Figure 9). However, prices again increase compared to the baseline projection and continue to be more than 2.5 per cent higher throughout the period modelled.

Impact on demand

There exists a potential secondary change in the pork market which would follow a FDA ban on the use of sulfa in pork production. If the consuming public perceives that this strategy results in a more wholesome, safer food supply then consumer demand could increase. This would result in the demand curve shifting to the right, leading to an increase in the quantity of pork demanded and higher industry prices as depicted in Figure 10.

Table 5. Changes in pork production following restrictions in sulfa use (million pounds)

Year	Baseline	with Restrictions	Percent Change
0	15733	15733	0%
1	16601	16483	-.71%
2	16320	15969	-2.15%
3	15776	15412	-2.31%
4	15279	15018	-1.70%
5	15934	15702	-1.46%
6	16405	16096	-1.89%
7	16993	16681	-1.83%
8	16638	16372	-1.60%
9	16079	15840	-1.48%
10	16995	16752	-1.43%

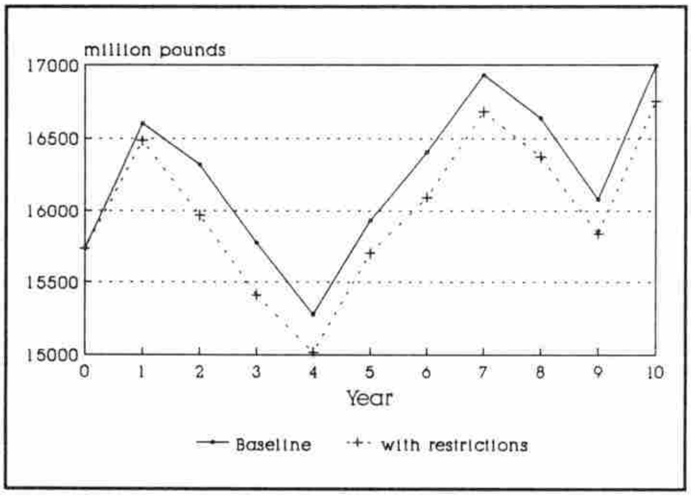

Figure 6. Changes in pork production following restrictions in sulfa use (million pounds)

Table 6. Changes in farm prices for barrows and gilts following restrictions in sulfa use ($/cwt)

Year	Baseline	with Restrictions	Percent Change
0	$48.41	$48.41	0%
1	$41.34	$42.26	2.21%
2	$46.20	$49.36	6.83%
3	$52.53	$56.09	6.76%
4	$56.57	$59.25	4.74%
5	$52.75	$54.59	4.06%
6	$51.24	$54.09	5.57%
7	$49.01	$51.78	5.66%
8	$53.23	$55.86	4.94%
9	$57.75	$60.45	4.66%
10	$46.17	$48.47	4.96%

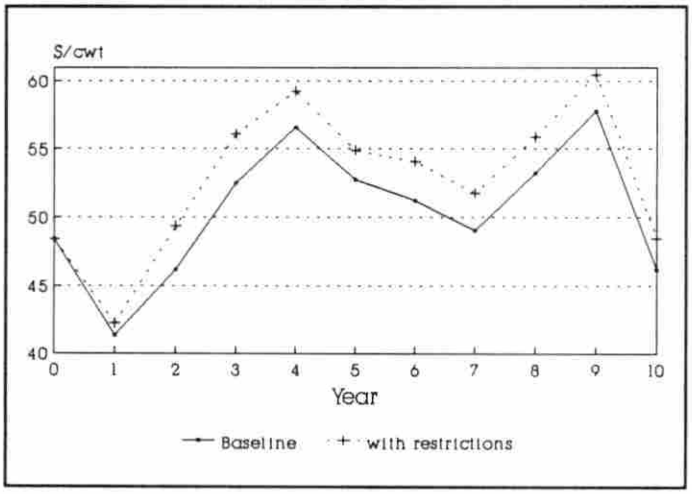

Figure 7. Changes in farm prices for barrows and gilts following restrictions in sulfa use ($/cwt)

Table 7. Changes in pork consumption following restrictions in sulfa use (million pounds)

Year	Baseline	with Restrictions	Percent Change
0	16685	16685	0%
1	17532	17418	-.65%
2	17297	16952	-2.00%
3	16851	16488	-2.16%
4	16413	16150	-1.60%
5	16903	16669	-1.38%
6	17229	16921	-1.79%
7	17652	17340	-1.76%
8	17285	17018	-1.55%
9	16736	16497	-1.43%
10	17931	17688	-1.38%

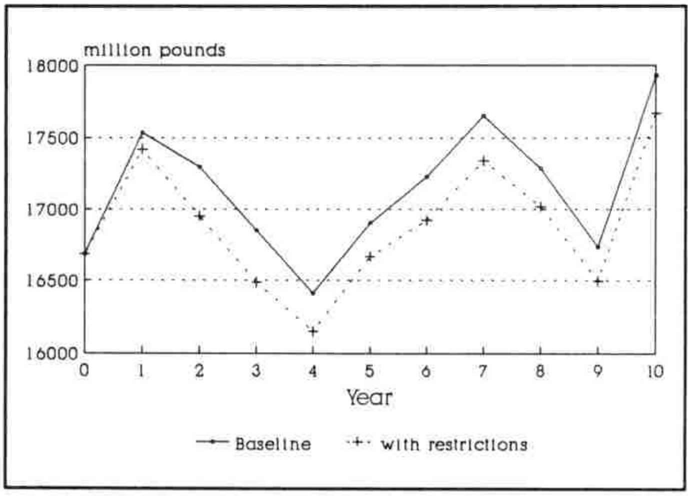

Figure 8. Changes in pork consumption following restrictions in sulfa use (million pounds)

Table 8. Changes in retail pork prices following restrictions in sulfa use ($/pound)

Year	Baseline	with Restrictions	Percent Change
0	$2.01	$2.01	0%
1	$1.93	$1.95	.97%
2	$1.97	$2.03	3.07%
3	$2.08	$2.15	3.15%
4	$2.12	$2.17	2.17%
5	$2.11	$2.15	1.80%
6	$2.09	$2.14	2.70%
7	$2.07	$2.13	2.81%
8	$2.10	$2.15	2.64%
9	$2.20	$2.26	2.61%
10	$2.06	$2.12	2.74%

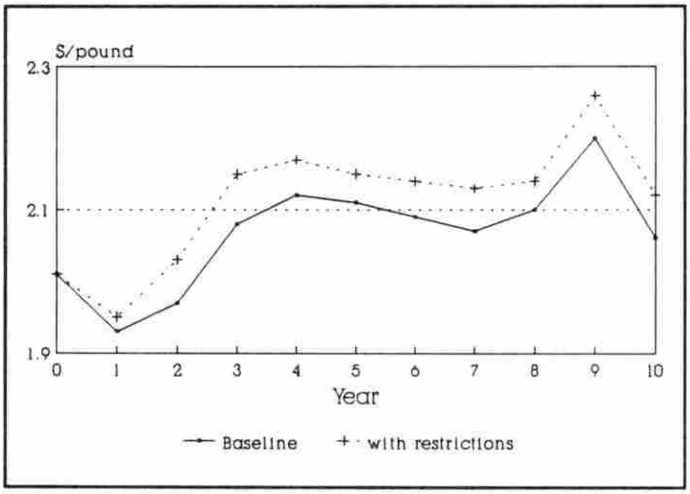

Figure 9. Changes in retail pork prices following restrictions in sulfa use ($/pound)

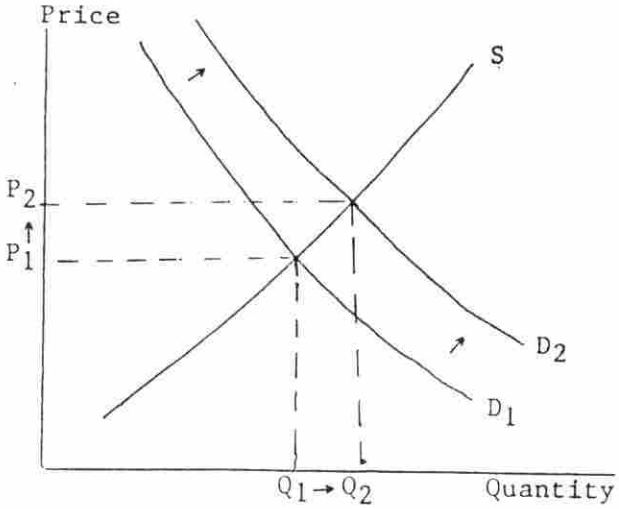

Figure 10. The effects of a shift in consumer demand on the pork industry

What is the likelihood that a significant shift in demand would occur? Generally consumers appear to assume that the food supply is safe until specific information arises about a potential problem. While there has been information published about possible concerns relating to antibiotic use in livestock and poultry production, there has been little evidence that consumers have become alarmed about this issue. For example, when asked to make an unassisted list of their concerns about the food supply, approximately one percent of the respondents indicated that they were concerned about the use of antibiotics in livestock and poultry production (Food Marketing Institute, 1989). However, when directly asked if they felt that antibiotic and hormone use in poultry and livestock production was a serious hazard to human health, 61 percent of consumers answered affirmatively (Food Marketing Institute, 1989). In another study, 88 percent of those polled were willing to pay at least 5 percent more for "residue-free" beef (Henderson, 1989).

The question of how much consumers are willing to pay for the assurance of residue-free meat is one that needs further research. For the sake of determining the potential benefits of the strategies being analyzed in this project, two demand shift scenarios were examined using the FAPRI model. In the first, it was assumed that consumers would be willing to pay one percent more for a safer pork product and in the second, a 5 percent increase in willingness-to-pay was assumed.

It has already been shown that action by the FDA would lead to increased production costs which would shift the supply curve to the left and result in decreased pork production. If the FDA's actions also lead to increased consumer confidence and thus increased consumer demand, then the demand curve for pork would shift to the right as seen in Figure 11. The combined effect of these shifts is difficult to forecast. Depending on the magnitude of each shift, the new equilibrium quantity could be less than, greater than, or equal to the equilibrium that had been established prior to action by the FDA. The equilibrium price would be expected to be higher in

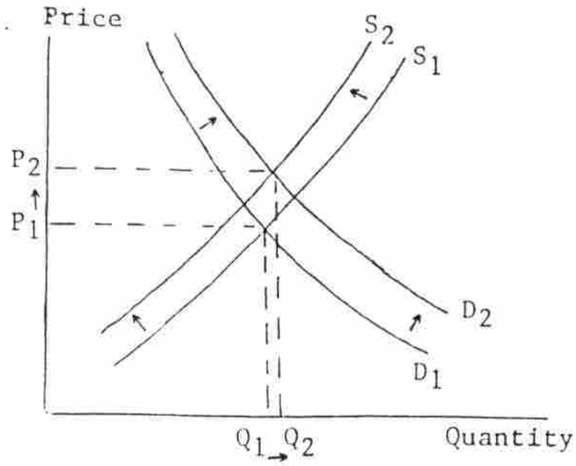

Figure 11. The effects of a combined shift in pork supply and consumer demand on the pork industry

all cases. In an effort to determine the possible impacts on the pork industry following a combined shift of the supply and demand curves, the two demand shift scenarios were each combined with the production scenario described above and modelled using the FAPRI pork model as de cribed previously. The results of this second model are presented in Tables 9 through 12, and illustrated in Figures 12 through 15.

For both demand shift scenarios, pork production remained less than the amount projected for the ten year baseline model (Table 9, Figure 12). However, if consumer willingness-to-pay is increased by 5 percent, the change in demand almost compensates for the reduction in quantity caused by the movement of the supply curve. The overall reduction in pork production in this case did not exceed one percent and was approaching the projected baseline by the end of 10 years.

Table 9. Changes in pork production following restrictions on sulfa use and with increases in consumer demand

Year	Baseline	1% Increase in Demand	Percent Change	5% Increase in Demand	Percent Change
0	15733	15733	0%	15733	0%
1	16601	16481	-.072%	16471	-.78%
2	16320	16029	-1.79%	16268	-.32%
3	15776	15477	-1.89%	15735	-.26%
4	15279	15057	-1.45%	15207	-.47%
5	15934	15742	-1.20%	15902	-.20%
6	16405	16145	-1.59%	16338	-.41%
7	16993	16728	-1.56%	16910	-.48%
8	16638	16418	-1.33%	16596	-.25%
9	16079	15886	-1.20%	16065	-.09%
10	16995	16796	-1.16%	16979	-.09%

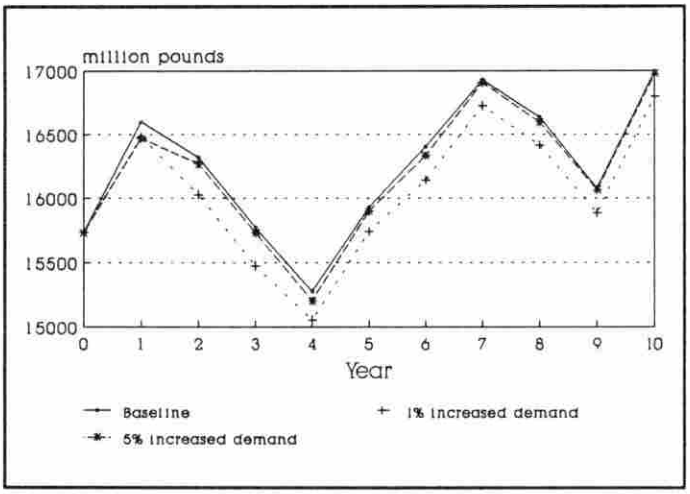

Figure 12. Changes in pork production following restrictions on sulfa use and with increases in consumer demand

Table 10. Changes in farm price for barrows and gilts following restrictions on sulfa use and with increases in consumer demand

Year	Baseline	1% Increase in Demand	Percent Change	5% Increase in Demand	Percent Change
0	$48.41	$48.41	0%	$48.41	0%
1	$41.34	$42.79	3.50%	$44.92	8.66%
2	$46.20	$49.36	6.83%	$49.32	6.75%
3	$52.53	$55.97	6.55%	$55.53	5.71%
4	$56.57	$59.40	5.00%	$59.97	6.01%
5	$52.75	$55.02	4.30%	$55.51	5.23%
6	$51.24	$54.13	5.64%	$54.28	5.93%
7	$49.01	$51.86	5.81%	$52.15	6.41%
8	$53.23	$55.95	5.10%	$56.28	5.73%
9	$57.75	$60.53	4.81%	$60.86	5.37%
10	$46.17	$48.58	5.21%	$49.04	6.20%

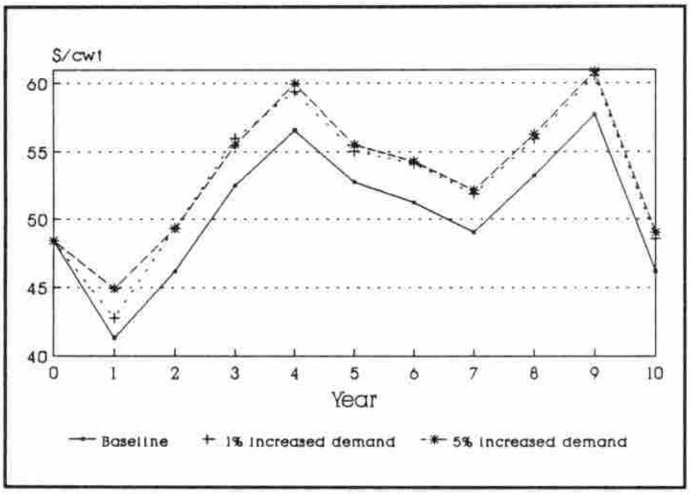

Figure 13. Changes in farm price for barrows and gilts following restrictions on sulfa use and with increases in consumer demand

Table 11. Changes in pork consumption following restrictions on sulfa use and with increases in consumer demand

Year	Baseline	1% Increase in Demand	Percent Change	5% Increase in Demand	Percent Change
0	16685	16685	0%	16685	0%
1	17532	17415	-.67%	17407	-.72%
2	17297	17010	-1.66%	17243	-.31%
3	16851	16553	-1.77%	16810	-.25%
4	16413	16189	-1.36%	16343	-.43%
5	16903	16710	-1.14%	16870	-.20%
6	17229	16970	-1.50%	17163	-.38%
7	17652	17387	-1.50%	17570	-.46%
8	17285	17063	-1.28%	17241	-.25%
9	16736	16542	-1.16%	16721	-.09%
10	17931	17734	-1.10%	17915	-.09%

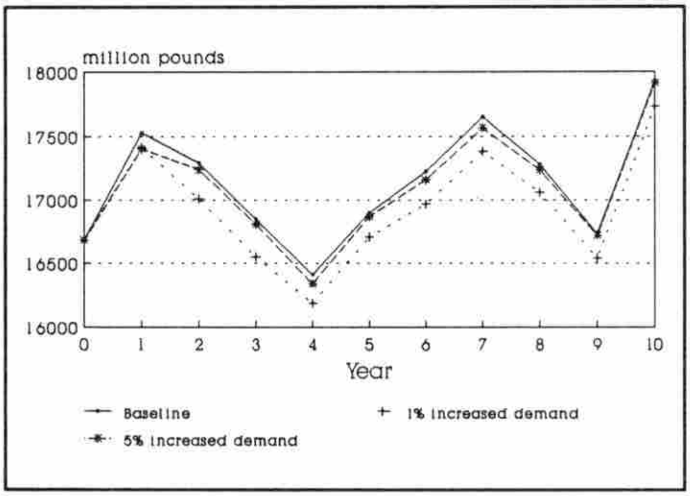

Figure 14. Changes in pork consumption following restrictions on sulfa use and with increases in consumer demand

Table 12. Changes in retail pork price following restrictions on sulfa use and with increases in consumer demand

Year	Baseline	1% Increase in Demand	Percent Change	5% Increase in Demand	Percent Change
0	$2.01	$2.01	0%	$2.01	0%
1	$1.93	$1.97	2.25%	$2.07	7.43%
2	$1.97	$2.05	3.75%	$2.10	6.43%
3	$2.08	$2.16	3.70%	$2.21	5.89%
4	$2.12	$2.18	2.94%	$2.25	5.98%
5	$2.11	$2.16	2.55%	$2.22	5.50%
6	$2.09	$2.16	3.35%	$2.21	5.96%
7	$2.07	$2.14	3.52%	$2.20	6.32%
8	$2.10	$2.17	3.36%	$2.23	6.20%
9	$2.20	$2.27	3.33%	$2.34	6.16%
10	$2.06	$2.13	3.53%	$2.20	6.67%

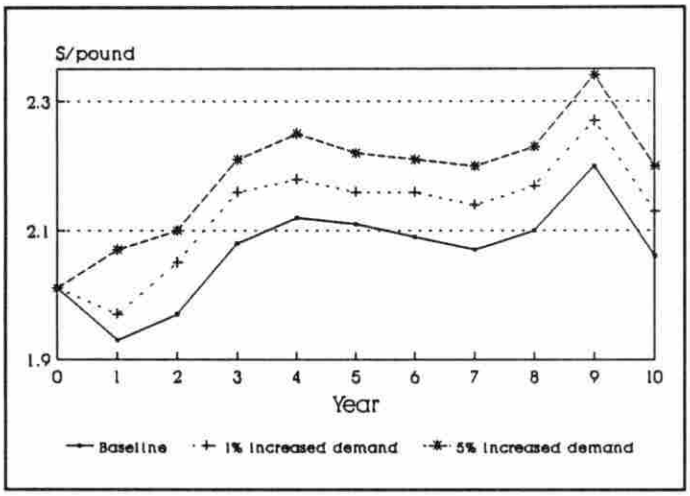

Figure 15. Changes in retail pork price following restrictions on sulfa use and with increases in consumer demand

Farm prices in this model are substantially higher as seen in Table 10 and Figure 13. Both demand scenarios show a sustained increase in farm prices over the period modelled. In the one percent willingness-to-pay scenario, prices were 5.2 percent higher after 10 years while the farm prices were 6.2 percent higher at the end (year 10) of the 5 percent willingness-to-pay scenario.

The changes in consumption and retail prices are similar to the changes in production and farm prices (Tables 11 and 12, Figures 14 and 15). Consumption is lower over the entire period for both scenarios modelled. However, if demand increases by 5 percent, consumption gravitates to close to the baseline level by years nine and ten. Retail prices increase and are sustained at the higher level over the entire period for both cases.

Summary

If the FDA establishes new restrictions on the use of sulfas in pork production, the quantity of pork produced and consumed can be expected to decrease and prices at both the retail and farm level will rise. The magnitude of the change that occurs will be determined by the response of consumers to the assurance of a safer food supply as well as the availability of substitutes for sulfa. If this strategy does affect the consumption pattern of consumers, the change in industry demand may compensate to some extent for the shift in the supply curve caused by increased production costs. However, the general direction of the changes in the industry equilibrium price will be upward and the equilibrium quantity will be downward. The levels of adjustment will be determined by the amount of change in consumer perception of food wholesomeness and by the availability of sulfa substitutes.

The ultimate cost of this strategy will fall upon consumers. Less pork will be consumed at a higher price, reducing consumer welfare. Those producers who can adjust to the increase in production costs will remain in the market and as an industry will sell less pork at a higher price. Currently, it is unknown if these higher farm prices will be enough to offset the increased production costs therefore conclusions about producer welfare are uncertain.

Effects of Increased Testing by the FSIS

A primary strategy that the FSIS might implement to reduce sulfa residue violations is to increase the testing level of pork carcasses for sulfa residues. The theory behind increasing the level of testing is that by increasing the producer's risk that a residue violation will be detected, producers would be induced to take the necessary steps to reduce the possibility of a residue violation occurring. Of course, for the producer who is not using sulfas there would be no individual action needed and therefore no additional costs to consider. Those producers who are currently using sulfas would have several options that range from ceasing to use sulfas to small changes in management practices. As discussed before, eliminating the use of sulfas from a production unit would increase costs due to increased disease levels and reduced animal productivity. Changes in management practices resulting from reduced sulfa availability would also increase production costs but the amount of the increase would depend on the actions taken by the individual producer and could vary substantially from one operation to the next. Those producers who are more flexible and better managers would have the advantage. The individualized nature of this situation makes it difficult if not impossible to estimate the impact these changes in management practices would have on the industry. For the purpose of this paper, it will be assumed that the changes implemented by the majority of the producers will have only small effects on the individual's cost of production and that the overall impact on industry supply will be negligible.

The cost of implementing this strategy would consist of the increase in those costs associated with the testing procedure. The FSIS is currently using the SOS test and would most likely continue to do so. While the cash outlay for the SOS test per animal is low, approximately $1.25 per animal, the labor costs incurred by increasing testing levels could be fairly substantial. Labor shortages are already a concern for the FSIS at some of the major processing facilities. This means that increasing the number of tests performed per day would mandate an increased work force. FSIS inspectors are government employees, classified as level G-11 or G-12 with an annual salary of from $30,000 to $50,000 plus benefits. The number of new employees needed would depend on the level of testing desired.

The benefit of implementing this strategy would be the potential for increasing consumer confidence in the safety of the pork supply. If consumer confidence is increased, the industry demand curve would shift to the right as discussed above and as illustrated in Figure 10. This would increase the equilibrium price and quantity in the market. This situation, where consumer demand could be expected to increase while production in the industry remains constant, was also modelled using the FAPRI livestock model.

Pork production and consumption both showed a very slight decrease in the first year following an increase in consumer demand of either one or five percent (Tables 13 and 14, Figures 16 and 17). This decrease in production is due to producers retaining gilts to expand the breeding herd in response to the increased demand. The production lag from when gilts are retained until their offspring are marketed is approximately one year. During this process, pork supplies are tightened as fewer females are sold. Consumption also de

Table 13. Changes in pork production following increases in consumer demand

Year	Baseline	1% Increase in Demand	Percent Change	5% Increase in Demand	Percent Change
0	15733	15733	0%	15733	0%
1	16601	16598	-.01%	16588	-.07%
2	16320	16380	.37%	16622	1.85%
3	15776	15844	.43%	16110	2.12%
4	15279	15319	.26%	15475	1.29%
5	15934	15975	.25%	16133	1.25%
6	16405	16455	.30%	16651	1.50%
7	16993	17040	.28%	17228	1.39%
8	16638	16684	.28%	16865	1.36%
9	16079	16125	.29%	16305	1.41%
10	16995	17041	.27%	17225	1.35%

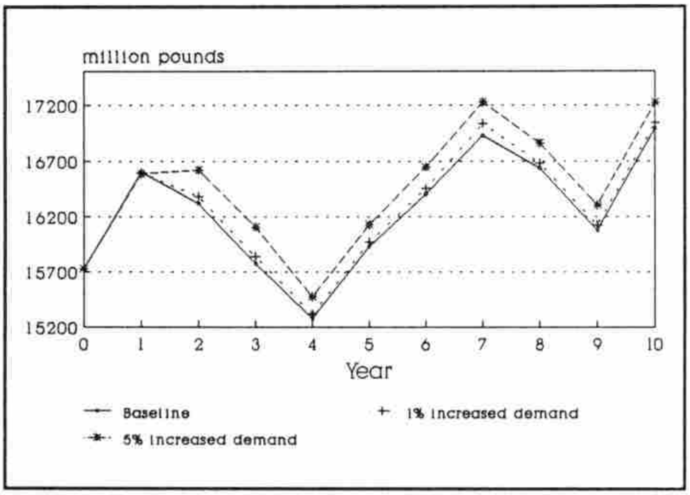

Figure 16. Changes in pork production following increases in consumer demand

Table 14. Changes in pork consumption following increases in consumer demand

Year	Baseline	1% Increase in Demand	Percent Change	5% Increase in Demand	Percent Change
0	16685	16685	0%	16685	0%
1	17532	17530	-.01%	17521	-.06%
2	17297	17356	.34%	17592	1.70%
3	16851	16919	.40%	17185	1.98%
4	16413	16454	.25%	16613	1.22%
5	16903	16943	.24%	17102	1.18%
6	17229	17279	.29%	17473	1.42%
7	17652	17700	.27%	17887	1.34%
8	17285	17331	.27%	17511	1.31%
9	16736	16782	.27%	16962	1.35%
10	17931	17997	.26%	18161	1.28%

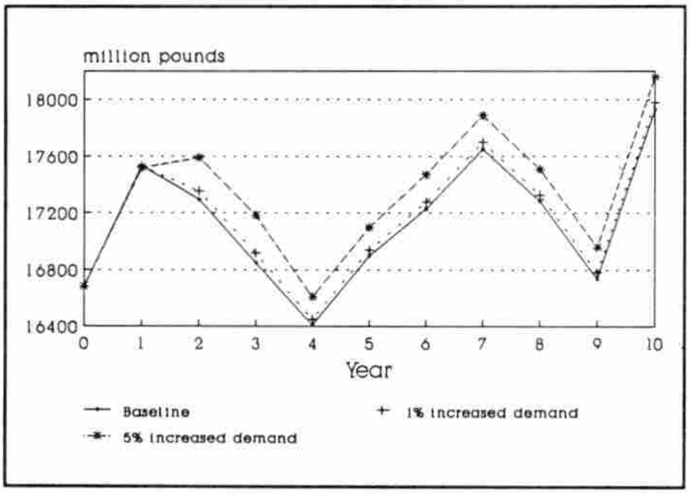

Figure 17. Changes in pork consumption following increases in consumer demand

Table 15. Changes in farm prices for barrows and gilts following increases in consumer demand

Year	Baseline	1% Increase in Demand	Percent Change	5% Increase in Demand	Percent Change
0	$48.27	$48.27	0%	$48.27	0%
1	$41.31	$41.83	1.27%	$43.92	6.32%
2	$46.85	$46.85	.01%	$46.84	-.02%
3	$53.33	$53.21	-.22%	$52.74	-1.09%
4	$57.72	$57.85	.22%	$58.36	1.10%
5	$55.98	$56.11	.23%	$56.62	1.15%
6	$55.06	$55.09	.06%	$55.22	.30%
7	$53.83	$53.90	.12%	$54.15	.60%
8	$60.65	$60.73	.14%	$61.05	.67%
9	$65.23	$65.31	.13%	$65.64	.62%

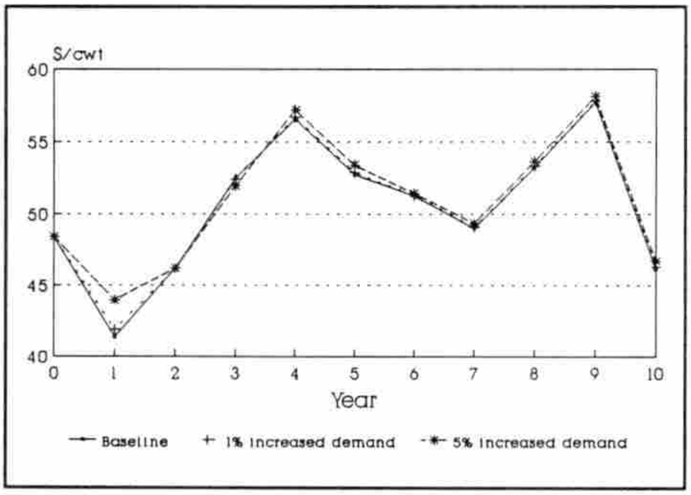

Figure 18. Changes in farm prices for barrows and gilts following increases in consumer demand

Table 16. Changes in retail pork prices following increases in consumer demand

Year	Baseline	1% Increase in Demand	Percent Change	5% Increase in Demand	Percent Change
0	$2.01	$2.01	0%	$2.01	0%
1	$1.93	$1.95	1.27%	$2.05	6.38%
2	$1.98	$1.99	.67%	$2.04	3.29%
3	$2.09	$2.10	.53%	$2.14	2.61%
4	$2.12	$2.14	.74%	$2.20	3.67%
5	$2.15	$2.16	.73%	$2.23	3.66%
6	$2.16	$2.17	.63%	$2.23	3.15%
7	$2.18	$2.19	.67%	$2.25	3.34%
8	$2.27	$2.29	.69%	$2.35	3.41%
9	$2.40	$2.42	.69%	$2.49	3.43%

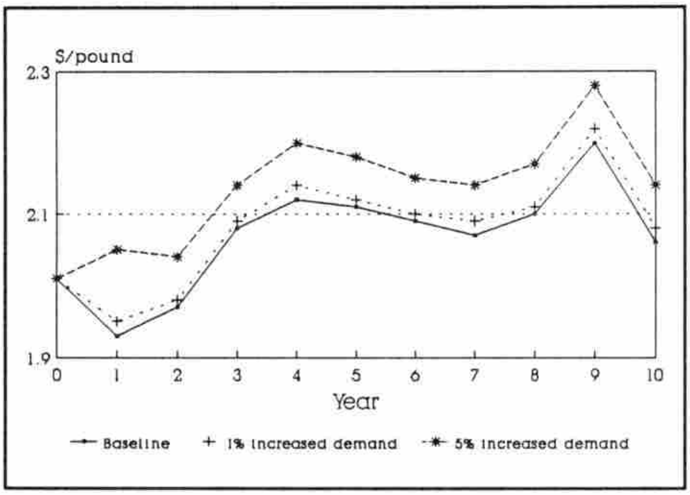

Figure 19. Changes in retail pork prices following increases in consumer demand

creases during this period, reflecting the reduced pork supplies.

Production reaches a peak in the third year of the model and remains persistently higher than the projected baseline throughout the period. Pork consumption follows the same path but with less deviation from the baseline.

Prices react immediately to the new demand with a rapid increase (Tables 15 and 16, Figures 18 and 19). The initial increase, particularly in retail prices, is due to the production lag in meeting this new demand. After the initial increase, farm prices drop rather dramatically, resulting from the initial over-response in production on the part of producers as they respond to higher market prices. Retail prices remain above the baseline projections and stabilize much faster than farm prices. Both farm and retail prices show a greater increase when demand shifts by 5 percent as is expected.

Summary

If this strategy is implemented, the cost will accrue solely to the consumer. Producers will be able to sell more pork at a higher price than previously. Consumers will not only be purchasing more pork products at a higher price but, since the FSIS is a governmental agency, the cost of the testing program will be paid for out of tax dollars.

Effects of Actions by Pork Processors

There are three proposed strategies that could be adopted by pork processors to reduce sulfa residues in pork. These are; increased testing either pre- or post-slaughter, the "bill back" plan, and the selected supplier concept. Implementation of any of these strategies would have at least one benefit in common, an increase in consumer confidence in the safety of pork products with the corresponding shift in consumer demand to the right. This is the same result that was discussed above for increasing FSIS testing and was illustrated in Figure 10. The result of this change in demand would be increased pork production and consumption, and higher prices at both the farm and retail level. The costs of implementing each of these strategies vary and they will be discussed individually below.

Increased testing

One strategy that pork processors could adopt is to institute testing procedures either pre- or post-slaughter. This testing would be in addition to the testing performed by the FSIS.

One problem of implementing such a testing program is defining the "population" to be tested. Violative animals entering the processing facility are not randomly distributed in a strict sense. The risk that market hogs are violative will vary between pork production units so that even while the producers selling to the processor are randomly distributed, the animals that are violative are not. The sampling of animals is also not random. There is a tendency on the part of regulatory personnel to test animals that are slaughtered early in the day or shift rather than randomly throughout the time period. Samples are chosen in this way so that testing may be completed during the course of that day or shift. For the purpose of this project, it will be assumed that the population can be defined as all animals slaughtered during a given day, that any violative animals are randomly distributed within that population, and that the sampling is random.

The next difficulty is in determining the minimum sample size to be tested in order to detect violative animals with a given degree of certainty. This was accomplished by employing two formulas that are used in epidemiology to calculate the testing rate needed to detect a disease problem. These equations are presented below as Equations 11 and 12. The prevalence rate was estimated to be one percent. Then these equations were used to estimate the necessary sample size to be tested out of a selected population given varying confidence intervals and acceptable margins of error.

Equation 11 establishes the sampling rate needed when testing an infinite population. The results from this calculation are then used in Equation 12 to determine the sample

$$n_{\infty}=\frac{(P)\times(1-P)\times Z^{2}}{(d)^{2}}\qquad \text{Equation (11)}$$

$$n_{fin}=\frac{(n_{\infty})}{1+\frac{(n_{\infty}-1)}{N}}\qquad \text{Equation (12)}$$

Where: n_{∞} = sample size for an infinite population
n_{fin} = sample size for a finite population
P = the estimated prevalence (as a decimal)
Z = the t value for infinite degrees of freedom for a given confidence level
d = the maximum acceptable difference between observed and true prevalence
N = the finite population being tested
(Ronald D. Smith, 1991, p. 131)

size need to detect violations when a finite population is being tested.

The sample size was calculated for daily slaughter numbers of 1,000; 3,000; 6,000; 10,000; and 15,000 head when the confidence interval desired was 95%, 98%, and 99%. The results when the acceptable margin of error (d) is equal to 0.01% is shown in Table 17, when d is equal to 0.1% in Table 18, and when d is equal to 1.0% in Table 19. For example (from Table 18), if the daily slaughter capacity is 6,000 head and you wish to be 95% confident that any violative animals will be detected, then 5,183 animals from that day's slaughter

Table 17. Sample size to be tested for various sized slaughter capacities and varying confidence intervals when the acceptable variation is +/- 0.01%

Hog slaughter per day	Sample Size		
	95% Confidence interval	98% Confidence interval	99% Confidence interval
1000 head	1000 head	1000 head	1000 head
3000 head	2998 head	2998 head	2999 head
6000 head	5991 head	5993 head	5995 head
10000 head	9974 head	9981 head	9985 head
15000 head	14941 head	14958 head	14966 head

Table 18. Sample size to be tested for various sized slaughter capacities and varying confidence intervals when the acceptable variation is +/- 0.1%

Hog slaughter per day	Sample Size		
	95% Confidence interval	98% Confidence interval	99% Confidence interval
1000 head	974 head	982 head	985 head
3000 head	2781 head	2841 head	2869 head
6000 head	5183 head	5396 head	5498 head
10000 head	7918 head	8427 head	8679 head
15000 head	10757 head	11718 head	12212 head

Table 19. Sample size to be tested for various sized slaughter capacities and varying confidence intervals when the acceptable variation is +/- 1.0%

Hog slaughter per day	Sample Size		
	95% Confidence interval	98% Confidence interval	99% Confidence interval
1000 head	276 head	349 head	397 head
3000 head	338 head	455 head	539 head
6000 head	358 head	492 head	592 head
10000 head	366 head	508 head	617 head
15000 head	371 head	517 head	629 head

must be tested (provided the true prevalence of residue violations is between 0.9% and 1.1%). If a margin of error of +/- 1.0% is acceptable, then only 358 hogs would need to be tested each day.

It is obvious that the degree of certainty desired has a dramatic effect on the number of animals that must be tested. It is likely that consumers will not accept a margin of error of +/- 1.0% in this situation. For the purpose of calculating the cost of testing at the processor level, it will be assumed that a confidence interval of 95% with a margin of error of +/- 0.1% will be acceptable to consumers.

The SOS test would be the most likely choice for any testing program implemented by the processors. It is easy and quick to perform and is relatively accurate for detecting sulfonamide residues. The cost would be approximately $1.25 per animal tested for the SOS test. The annual costs for sufficient SOS tests to achieve a 95% confidence interval with varying margins of error are shown in Table 20, a 98% confidence interval in Table 21, and a 99% confidence interval in Table 22.

Table 20. Annual costs (in thousands) of using the SOS test to obtain a 95% confidence interval[a]

	Daily slaughter capacity				
Margin of error	1000	3000	6000	10000	15000
0.01%	$313	$937	$1,872	$3,117	$4,699
0.1%	$304	$869	$1,617	$2,474	$3,362
1.0%	$86	$106	$112	$114	$116

[a]cost of the SOS test is assumed to be $1.25 per animal tested and it is assumed that the packing plant operates 5 days a week, 50 weeks per year

Table 21. Annual costs (in thousands) of using the SOS test to obtain a 98% confidence interval[a]

	Daily slaughter capacity				
Margin of error	1000	3000	6000	10000	15000
0.01%	$313	$937	$1,873	$3,119	$4,674
0.1%	$307	$888	$1,686	$2,633	$3,662
1.0%	$109	$142	$154	$159	$162

[a]cost of the SOS test is assumed to be $1.25 per animal tested and it is assumed that the packing plant operates 5 days a week, 50 weeks per year

Table 22. Annual costs (in thousands) of using the SOS test to obtain a 99% confidence interval[a]

	Daily slaughter capacity				
Margin of error	1000	3000	6000	10000	15000
0.01%	$313	$937	$1,873	$3,120	$4,677
0.1%	$308	$897	$1,718	$2,712	$3,816
1.0%	$124	$168	$185	$193	$197

[a]cost of the SOS test is assumed to be $1.25 per animal tested and it is assumed that the packing plant operates 5 days a week, 50 weeks per year

In addition to the cost of the test, additional personnel would have to be hired. The SOS test does not require any special skills or training so the expected cost of these additional labors would be expected to be from $15,000 to $20,000 annually plus benefits for each person hired. If it requires approximately a total of two minutes to obtain a urine sample from a carcass on the rail and to run the SOS test, then the smaller plants would need to hire four additional laborers and the larger plants up to 45 additional employees just to perform this testing. This would put the annual cost of testing at more than $364,000 for the smaller plants and in excess of $4 million for larger facilities. The estimated increases in operating costs per animal slaughtered is shown in Tables 23-25.

Table 23. Testing costs per animal slaughtered annually to obtain a 95% confidence interval (including cost of test and estimated cost of additional labor)[a]

	Daily slaughter capacity				
Margin of error	1000	3000	6000	10000	15000
0.01%	$1.49	$1.50	$1.50	$1.50	$1.50
0.1%	$1.46	$1.39	$1.29	$1.19	$1.08
1.0%	$0.40	$0.16	$0.09	$0.06	$0.04

[a]cost of SOS testing taken from Table 20 and labor cost set at $15,000 annually per additional employee needed to complete the required number of daily tests

Table 24. Testing costs per animal slaughtered annually to obtain a 98% confidence interval (including cost of test and estimated cost of additional labor)[a]

	Daily slaughter capacity				
Margin of error	1000	3000	6000	10000	15000
0.01%	$1.49	$1.50	$1.50	$1.50	$1.50
0.1%	$1.47	$1.41	$1.35	$1.26	$1.17
1.0%	$0.53	$0.23	$0.12	$0.08	$0.05

[a]cost of SOS testing taken from Table 21 and labor cost set at $15,000 annually per additional employee needed to complete the required number of daily tests

Table 25. Testing costs per animal slaughtered annually to obtain a 99% confidence interval (including cost of test and estimated cost of additional labor)[a]

	Daily slaughter capacity				
Margin of error	1000	3000	6000	10000	15000
0.01%	$1.49	$1.50	$1.50	$1.50	$1.50
0.1%	$1.47	$1.44	$1.38	$1.30	$1.21
1.0%	$0.59	$0.26	$0.15	$0.09	$0.06

[a]cost of SOS testing taken from Table 22 and labor cost set at $15,000 annually per additional employee needed to complete the required number of daily tests

The costs discussed above represent the total cost for post-slaughter testing. If a strategy of pre-slaughter testing at the packing plant was implemented, there would be other costs in addition to those discussed. Hogs that have been transported generally have voided their bladders and it could take several hours to collect urine samples from these animals. This would require that there be holding areas of sufficient capacity to hold those animal selected for testing for several hours until a sample could be obtained. In addition, there would have to be facilities to house and feed those animals that tested positive for residues. On average, it would be expected that an animal with sulfa residues would have to be held for six days for the residues to be excreted from the tissue. There would also be additional labor costs for animal care and the re-testing of these animals before slaughter. It is possible that these additional costs for holding hogs until they are residue free could be billed to the production unit where the violative hogs originated. However, it is unlikely that processors will be willing to accept the burden of holding the live animals or to accept the disruption of the systematic operation of the plant by having to hold hogs for testing or residue excretion. Therefore, this strategy does not seem to be a viable option.

Summary If increased testing is implemented by pork processors, it will almost certainly be conducted post-slaughter as mentioned above. The actual increase in production costs for the processor will be divided between pork producers and food retailers with the producers receiving slightly less for each hog sold and the retailers paying a slightly higher price for pork products. The higher price paid by the retailers will in turn be at least partially passed on to the consumers. The portion of the costs that will accrue to each sector will depend on the elasticity of the demand and supply curves in the market.

In terms of the macroeconomic adjustments in the industry, consumers would pay a higher price for pork products due to the outward shift of the demand curve resulting from a perceived increase in wholesomeness of pork products. This increase in price would be in addition to the higher prices passed on by the retailer. The producer would be able to sell hogs at a higher price due to the demand shift but it is unknown if this price increase will be off-set by the lower price offered by the processor as discussed above.

There may be some additional benefits that accrue to processors in the form of increased access to export markets and the possibility of marketing a "branded" product that is certified to be residue free. This is an area that will require further research before these potential benefits can be quantified.

"Bill back" provisions

There have been proposals made to implement a nation-wide "bill back" law so that processors can assess the producer for costs associated with a carcass condemned for residue violation. It will be assumed that the recently passed California law is a prototype for what could be implemented at the federal level.

A 1991 California law makes the seller of animals with violative residue levels liable for three times the selling price of the animal plus any associated costs. For example, if the average weight of a market hog is 240 pounds, and the market is $40/cwt., then the seller could be liable for $288/animal plus attorney's fees (not to exceed $100) and any penalty imposed by state and federal regulatory agencies.

Summary It is generally accepted to be only fair that the cost of a negative externality be assessed to whoever received the benefit of the process causing the externality. However, implementing this type of plan is an over-simplification of the problem. It is often difficult to pinpoint where in the production process the sulfa contamination occurred. Is the hog producer to be held liable for the contamination even if it occurred in a way that was outside of his control? What effect does a program such as this have on the open market relationship between producers and processors? Sixteen percent of animals that are in violation of residue limits cannot be traced back to the point of origin (Augsburg, 1989). Who will bear the cost of these animals or the cost of establishing a identification/traceback system where by the producer of a given animal could be identified more readily? These questions are beyond the scope of this project but must be addressed before a bill back type proposal is implemented nation-wide.

The majority of the cost of this strategy will accrue directly to the individual producer, affecting his/her cost structure. The main benefit of this proposal is that it would offer incentive for producers to take the necessary steps to avoid residue violations. Effects on the pork industry as a whole would be expected to be negligible.

It is doubtful that this strategy will have a measurable impact on consumer demand as it offers little in the way of concrete assurances that residue violations would, in fact, be decreased by its implementation.

Selected supplier concept

This strategy offers a combination of penalties and incentives to induce pork producers to market residue free animals. Processors would have specific quality criteria that producers would have to meet before marketing their animals. Producers who have repeated residue violations would be barred from marketing their animals with that particular processor while those who meet certain criteria may collect a premium on the price received for animals marketed under this program.

The costs to implement this strategy would consist mostly of administrative expenditures and the cost of monitoring the producer's operation. Realistically, the producer would probably have to bear most of the cost of the monitoring program in terms of veterinary charges, periodic testing of both animals and environment, etc. However, this may be a small cost to bear in order to retain a processor as a marketing option.

If a producer has repeated violations and is shunned by the processor, the resulting costs to the producer could be very significant. Industry experts suggest that a producer could have to transport animals up to an additional 75 miles further to reach a secondary market. The cost for actual transport would be about 40 cents per hog if the cost of transport is 22 cents per hundredweight per 100 miles (USDA, 1991). An additional cost would be incurred through shrinkage of the animals during transport. Studies have shown that a 2.75 percent shrinkage could be expected from hauling hogs an additional 75 miles (McCoy, 1979). If the current hog price is $40/cwt., this would amount to a cost of about $2.64 per animal for hogs weighing 240 pounds when they left the farm. Therefore the total cost to the producer would be $3.04 per hog marketed. For producers marketing 50 hogs every two weeks, this would be an additional cost of almost $4,000 annually. This cost would persist over time unless some provision could be made whereby the processor would re-evaluate the decision to shun the producer if certain criteria were met.

Summary The majority of the cost of this strategy would be borne by the individual producer. The effects on the hog industry would depend on the number of processors instituting such a plan. If this program was to become widespread, it is expected that a relatively slight, left-ward shift of the supply curve would occur due to an industry-wide increase in costs. This would lead to decreased production, higher farm and retail prices, and decreased consumption, similar to the initial results discussed under the section on actions by the FDA but of less magnitude.

It is doubtful that this strategy would have much impact on consumer demand. It would require a massive advertising campaign to convince consumers that such a strategy has increased the safety of pork product consumption.

Effects of Actions by Producers

There are three suggested strategies for pork producers; output testing, input testing, or a strategy combining these two types of testing. The cost of implementing each of these strategies varies to some extent and they will be discussed individually below. The benefit common to all of these is the possibility of shifting the consumer demand curve to the right. Whether or not such a shift would occur and the magnitude of such a shift would depend on the number of producers that participate in residue reduction and the confidence consumers have that producers are accomplishing their goals. As discussed previously, a shift in consumer demand would increase pork production and consumption as well as increase prices at the farm and retail level.

An additional benefit of action by pork producers is the reduction of the risk of a producer incurring the costs associated with a residue violation. If a producer is identified as having marketed a hog with violative residues, he/she will incur costs in addition to the penalties imposed by the regulatory agencies. Once a hog has tested positive (suspect) for residues at the processing plant with the SOS test, the carcass is held while further tests of organ and muscle tissue are run at the FSIS laboratories. While these tests are run, the producer is not allowed to sell any other market hogs. The amount of time for the results of the conformation testing can be from 2 to 3 weeks.

Since most producers market small groups of hogs on a regular basis, such an embargo can lead to increased costs. If it is assumed that the average producer is marketing hogs every two weeks, then an embargoed producer will have to hold one group of hogs past the normal marketing time. This will result in increased costs in the form of docks for overweight and lower grade animals, increased feed, labor, and interest costs, and indirect costs in the form of bottlenecks in the production process for the producer. Table 26 illustrates a sample budget comparing the revenues and costs for marketing hogs at 230 pounds as opposed to 260 pounds.

As indicated above, when the hogs are marketed following an embargo for residue violations, the producers hogs will likely be docked due to overweight and possibly a lower grade. If it is assumed that these animals will go to the processor 2 weeks later than anticipated, then it can be expected that they will weigh between 250 and 270 pounds, and be of grade 1 to 3. If they had been marketed when at the optimum time, they would have weighed from 230 to 250 pounds and graded from 1 to 2. The difference in price can be from $1 to $4 per hundredweight depending on market conditions. In the example in

Table 26. Sample budget showing difference in net revenue between marketing hogs at 230 pounds and 260 pounds

Weight when marketed	230 lbs.		260 lbs.	
Revenue received:				
Price = $45/cwt	$103.50		$117.00	
Less $2.50 dock	- 0.00		- 6.50	
Gross revenue	$103.50		$110.50	
Variable costs:				
Feeder pig	$43.00		$43.00	
Interest @ 10%	1.37	(115 days)	1.54	(129 days)
Feed:				
Corn @ 2.20/bu	22.88	(10.4 bu)	27.06	(12.3 bu)
Protein @ $.14/lb	15.40	(110 lb)	18.76	(134 lb)
Other costs:				
Veterinary	1.50		1.50	
Fuel, utilities	2.00		2.00	
Marketing, misc.	2.00		2.00	
Interest @ 10% (on feed and other)	0.73	(60 days)	1.05	(74 days)
Labor	4.20	(.7 hr)	4.80	(.8 hr)
Total variable costs	$ 92.35		$101.71	
Fixed costs	9.23		9.23	
Total all costs	$101.58		$110.94	
Net Revenue	$ 1.92		-$ 0.44	

adapted from Iowa State University Extension Service, Livestock Budgets for Iowa-1992

Table 26, the amount the producer is docked for overweight hogs is assumed to be $2.50 per hundredweight. In this example, the producer is actually better off for selling heavier hogs in terms of gross revenue.

However, keeping hogs past the optimum marketing time also means increased feed costs, higher labor costs, and increased interest expense for the producer. Table 26 shows that feed costs are $7.54 higher per animal if hogs are marketed at a heavier weight. Interest on the feeder pig expense and feed costs are also 49 cents higher for the 260 pound hog and labor costs were 60 cents higher. With the figures used here, being forced to market hogs at a heavier weight means losing money when all costs are taken into account. If the size of the marketing group is 50 head, the total loss in this example would be -$22 as opposed to a profit of $96 if the producer had been able to market these hogs at the optimum time.

The indirect costs of a marketing embargo also need to be addressed. Most pork producers today, in an effort to be as efficient as possible, have their operations highly synchronized. If hogs cannot be marketed in a timely fashion, then bottlenecks start to occur. Since hogs have not moved out of the finishing unit and freed up the necessary space, pigs must remain in the nursery longer than planned. Because the nursery has not been emptied and cleaned, pigs are weaned at a later date than normal. This creates problems in the farrowing house as the next batch of sows begins to farrow and there is no room for them. Attempting to deal with problems such as this could lead to problems with overcrowding of animals which in turn leads to stress and disease problems that cannot be easily quantified. It is to the producer's benefit to look at some of the possible strategies that could be adopted to avoid such problems.

Output testing

One of the strategies that producers could adopt would be to set up a testing program to screen hogs for residues as they are marketed. However, producers tend to market small groups on a frequent basis. To reliably detect residue violations within relatively small groups, the testing rate must be extremely high. To determine the minimum sample size need to detect a one percent violation rate given different confidence intervals, Equations 11 and 12, presented previously, were again employed. The estimated prevalence rate was again set at one percent.

The sample size that would need to be tested was calculated for marketing groups of 25, 50, 200, 500, and 1000 head when confidence intervals were 95, 98, and 99 percent. The results when the acceptable margin of error (d) is 1.0% are shown in Table 27 and when d is equal to 0.1% in Table 28.

Again we see that the number of animals that need to be tested increases dramatically as the margin of error is reduced. If the acceptable margin of error is further decreased to +/- 0.01%, then virtually all animals that are marketed must be tested.

Table 27. Sample size to be tested for various sized marketing groups and varying confidence intervals when the acceptable margin of error is +/- 1.0%

Size of Marketing Group	Sample Size		
	95% Confidence interval	98% Confidence interval	99% Confidence interval
25 head	25 head	25 head	25 head
50 head	50 head	50 head	50 head
200 head	199 head	199 head	199 head
500 head	494 head	495 head	496 head
1000 head	974 head	982 head	985 head

Table 28. Sample size to be tested for various sized marketing groups and varying confidence intervals when the acceptable variation is +/- 1.00%

Size of Marketing Group	Sample Size		
	95% Confidence interval	98% Confidence interval	99% Confidence interval
25 head	24 head	24 head	24 head
50 head	44 head	46 head	47 head
200 head	131 head	146 head	154 head
500 head	216 head	259 head	284 head
1000 head	276 head	349 head	397 head

Estimating the cost of output testing again presents some difficulties. The amount of time that it would take to collect a sample can be highly variable; from 2 minutes for one random sample to several hours to sample the majority of the pigs in a pen. If it is assumed that it would take approximately 10 minutes to collect a sample from a given animal and 3 minutes to complete the screening test, then testing would cost approximately $1.70 per animal when labor is valued at $8/hour. Given that the cost of either the SOS test or the E-Z screen is about $1.25 per animal, this puts the total estimated cost at $2.95 per animal tested. This estimated cost could vary widely due to the difficulties inherent in obtaining a urine sample from a particular animal.

If it is assumed that producers ship hogs to market every two weeks in groups of 25, 50, 200, 500, or 1000 head; and that they wish to be 95 percent confident that a violation will be detected within a +/- 1.00% margin of error, the annual costs would be as shown in Table 29 for a wide range of testing costs. In Table 30, we see this cost broken down to cost per pig marketed. As we have seen before, increasing the confidence interval to 98% or 99% and/or decreasing the acceptable margin of error will increase the costs. Table 31 shows how the annual costs change when the confidence interval is set at 99% and the desired margin of error is +/-0.01%. As was stateed before, with the margin of error set at +/-0.01%, all animals are tested so the cost per pig marketed equals the cost of testing.

Table 29. Annual cost for testing various sized marketing groups when the acceptable margin of error is +/- 1.00%

Cost of testing[b]	Size of Market Group[a]				
	25	50	200	500	1000
$7.00	$4280	$8061	$23,896	$39,359	$50,183
$6.00	$3669	$6910	$20,483	$33,736	$43,014
$5.00	$3057	$5758	$17,069	$28,113	$34,845
$4.00	$2446	$4607	$13,655	$22,491	$28,676
$3.00	$1834	$3455	$10,241	$16,868	$21,507
$2.00	$1223	$2303	$6828	$11,245	$14,338

[a] When a confidence interval of 95% is desired.
[b] When the cost of the SOS test is assumed to be $1.25 but cost of labor varies.

Table 30. Cost per hog marketed for testing various sized marketing groups when the acceptable margin of error is +/- 1.00%

Cost of testing[a]	Size of Market Group				
	25	50	200	500	1000
$7.00	$6.33	$6.20	$4.60	$3.03	$1.93
$6.00	$5.43	$5.31	$3.94	$2.60	$1.65
$5.00	$4.52	$4.43	$3.28	$2.16	$1.34
$4.00	$3.62	$3.54	$2.63	$1.73	$1.10
$3.00	$2.71	$2.66	$1.97	$1.30	$0.82
$2.00	$1.81	$1.77	$1.31	$0.87	$0.55

[a]When the cost of the SOS test is assumed to be $1.25 but cost of labor varies.

Table 31. Annual cost for testing various sized marketing groups when the acceptable margin of error is +/- 0.01%

Cost of testing[b]	Size of Market Group[a]				
	25	50	200	500	1000
$7.00	$4550	$9100	$36,400	$91,000	$182,000
$6.00	$3900	$7800	$31,200	$78,000	$156,000
$5.00	$3250	$6500	$26,000	$65,000	$130,000
$4.00	$2600	$5200	$20,800	$52,000	$104,000
$3.00	$1950	$3900	$15,600	$39,000	$78,000
$2.00	$1300	$2600	$10,400	$26,000	$52,000

[a] When a confidence interval of 99% is desired.
[b] When the cost of the SOS test is assumed to be $1.25 but cost of labor varies.

Summary As discussed before, the major benefit from this strategy for the individual producer is the reduction of the risk that he/she will incur a residue violation or penalty. The impact on the pork industry as a whole would depend on the level of participation by producers. The more producers that participate, the higher the consumer confidence level in the safety of the food supply and the greater the possibility of a substantial shift in consumer demand. The costs of this plan will be borne entirely by the producers. This will affect the individual's cost structure and marginal cost curve but the effect on the industry will again depend on the number of producers participating in such a program. If the numbers are substantial enough to cause a shift in the supply curve and to influence demand, then a situation may develop as discussed previously in the section on effects of FDA action. That is, the pork supply will decrease, farm and retail prices will increase, and consumption will decrease. This amount of participation by producers is doubtful due to a lack of incentive other than the individual's desire to reduce risk.

Input testing

This strategy involves a routine checking of the inputs used in the swine production process and waste generated. Samples of feed, manure, flush water, and drinking water are taken at regular intervals and checked for residue levels. Testing frequency would depend on the individual producer and his/her level of risk aversion. The costs would be $1.25 for the test plus the labor for collecting samples and running the test. Total costs would depend upon the type of sampling program initiated which in turn would vary between individual operations.

An example of a input testing program might be to test, on a two week interval, samples of the manure pack from each pen containing hogs that will be marketed within the next two weeks, random feed samples from the feeders in these pens, and a sample of the flush water. For a small producer, this might entail testing 10 samples per month while a larger producer might be examining 50 samples monthly. If it takes 2 to 3 minutes to complete a test with an additional 10 to 30 minutes to gather the samples to be tested, labor costs would be from $4.00 to $20.00 per month. Actual costs of tests performed would be $12.50 to $62.50 per month. Annual costs for this example would be from $200 to $1000 per year.

Summary As before, the cost of this strategy will be incurred by the individual producer. Any changes in the industry supply curve or in consumer demand will be a function of the level of participation by individual producers. This is a less expensive alternative than output testing but still lacks any incentive for producers to participate other than their own desire to reduce the risk of a residue violation.

Combination testing

Combination testing involves a program that includes both input and output testing. It would lend its self well to an individual operation quality assurance type program and might work well in conjunction with the NPPC's Quality Assurance Program.

Ideally, a strategy such as this would have the producer putting together a plan of management strategies to reduce the risk of sulfa contamination in the finishing phase of his/her operation. The producer would then use input and output testing as a check to assure that the management plan was functioning as it was intended to. The actual testing costs would be less as fewer tests would be performed annually but there could be additional costs in the form of management changes to make a workable plan. Due to the highly individualized nature of such plans, it is virtually impossible to estimate the cost of this type of strategy.

This type of strategy may offer an additional benefit over the other producer strategies. It might be possible to work this strategy into a branded product that is certified to be residue-free, thus tapping into a niche market and increasing revenue. Combination testing would also fit well with the selected supplier concept discussed earlier.

CHAPTER VI. SUMMARY AND CONCLUSIONS

It has been shown that, while sulfonamides are important to the swine producer, there are some valid concerns about the frequency with which sulfa residues occur. In this paper, an attempt was made to identify that point in the pork product chain that would be the most cost effective and efficient place to intervene to reduce the incidence of sulfa residues.

In addition to examining the basic economic principles concerning the anticipated supply and demand shifts that would occur at each of the selected points, the FAPRI model of the pork sector was employed. This model was used in an attempt to quantify the predicted changes in pork production, consumption, farm level prices and retail prices. Using this model, several scenarios were examined within two extreme points:

1. A supply only shift resulting from a total ban on the use of sulfa in pork production with the assumption that no substitutes would be available to off-set the resulting increase in production costs.

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.

Several testing strategies were presented and discussed. The alternatives that were evaluated are:

1. A ban on sulfa use by the FDA.

2. Increased testing by the FSIS.

3. Implementation of testing programs by the pork processors, both pre- and post-slaughter.

4. Implementation of a "bill back" law that would allow processors to 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.

Benefits and costs for each of these strategies were presented as accurately and as objectively as possible, however many assumptions had to be made thus making some of the conclusions suspect. The results that were obtained are presented below.

If the FDA bans sulfa use in pork production, the overall result is that consumers would face higher prices and reduced supplies. Producers would receive higher prices for their hogs than before but it cannot be determined if these increased prices would be enough to offset the increased production costs incurred by the loss of sulfa from the production process. In addition, some pork producers would be forced out of the market due to increased production costs.

The FSIS strategy of increased testing also leads to higher retail and farm prices but results in increased pork supplies. In addition, the additional funds necessary to institute this testing would come from tax dollars since FSIS is a governmental agency. This would have the effect of increasing the overall cost of this strategy to consumers.

If processors institute a testing program either pre- or post-slaughter, consumers can expect to face higher prices. This increase in prices is not only due to the macro effects in the industry but also due in part to the processors passing on their increased production costs. Pork producers will be faced with lower prices being offered by the processors but it is unknown if this will offset the increase in prices resulting from the macro effects in the industry.

The "bill back" proposal has some merit in that it attempts to assign the costs directly to the producer who sold the violative animal and that it would offer an incentive to producers to reduce the risk of incurring a residue violation. However, there are many questions as to the impact that such a proposal will have on the open market relationship between producer and processor, the ability to correctly identify violators, etc. that need to be addressed before this proposal would be considered an acceptable solution. It is expected that the effects on the pork industry supply and demand would be negligible.

If the selected supplier concept was to become widespread, it is expected that a left-ward shift of the supply curve would occur due to an industry-wide increase in costs.

This would result in decreased pork supplies and higher prices at both the farm and retail level. The majority of the cost of the selected supplier strategy would be borne by the individual producer. This strategy has the advantage of offering an incentive for the producer to take individual action to reduce the risk of a residue violation. However, the plan must be implemented with care so that the processors do not gain excessive power of the producer through this program.

The impact of the three strategies to be implemented at the producer level (output testing, input testing, and a combination of these two) would depend on the level of producer participation. If sufficient numbers of producers participate, consumers may perceive that pork has become more wholesome and thus consumer demand may shift. As before, a shift in demand will result in decreased pork supplies and increased prices at both the farm and retail level. The main drawback of these strategies is that they lack any incentive for the producer to participate.

If sulfa residues are treated as a negative externality of a production process, then those who benefit from the production process should incur the cost of dealing with the externality. The use of sulfa in the production of pork allows for producers to reduce their production costs but the primary beneficiary of these reduced costs are consumers since low production costs lead to lower retail prices. If the suggested strategies are evaluated based on this criteria, then the recommended actions would be one of the following: the FDA ban of sulfa, the FSIS increased testing program, or testing by the pork processor. Further research is needed to determine which of these alternatives is the least cost approach.

However, in the opinion of this researcher, it is more efficient to deal with the occurrence of residues at the source, that is at the production level. Therefore, the conclusion of this researcher is that the optimal solution would be to institute a program of combination testing and management safeguards at the producer level. It may be necessary to combine such a program with increased penalties from the regulatory agencies or controls such those within the selected supplier concept to give producers the incentive to participate. However, this combination of strategies appears to be the most efficient in effecting control over residue violations at the point of origin with the least cost to any given group.

Further research ideas

As with much research, this report raised more questions that it likely answered. Information about the cost of making management changes to avoid residues is non-existent, as is information about the possible impact on consumer demand following a permanent reduction in the incidence of residue violations. Much of the data on the production benefits of using sulfa in pork production is more than ten years old, raising the question on the accuracy of data used in this study. None-the-less, it is the best available. It is known that continuing residue violations threaten some export markets, especially the Japanese market. Work needs to be done on the possible increase in export markets obtained by an added assurance of reduced residues. The area of food residues and violative levels is an important one that needs further investigation so that responsible policy decisions can be made in the future.

Additionally, this research points to the apparent cost effectiveness of on-farm testing and management safeguards. Further research and analysis is needed of specific on-farm management strategies to identify industry direction and methods of cost effectively reducing food residues to lower levels.

BIBLIOGRAPHY

"The Antibiotic Controversy: The Science." Animal Nutrition and Health, Feb., 1985, pp 24-25.

Absher, C.W. and T.H. Blosser. "Better Meat, Eggs, and Milk for Our Tables." 1981 Yearbook of Agriculture: Will There Be Enough Food? Ed. Jack Hays. Washington, D.C.: USDA, 1981, pp 92-115.

Ashworth, R.B., R.L. Epstein, M.H. Thomas and L.T. Frobbish. "Sulfamethazine Blood/Tissue Correlation Study in Swine", American Journal of Veterinary Research, 47, No. 12 (1986), pp 2596-2603.

Augsburg, John K. "Sulfa Residues in Pork: An Update." Journal of Animal Science, 67, No. 10 (1989), pp 2817-2821.

Beran, George W., Ph.D, DVM, L.H.D. "Use of Drugs in Animals, an Epidemiologic Perspective," from Proceedings of the Symposium on Animal Drug Use-Dollars and Sense, Ed. Gary E. Stefan. Rockville, MD: FDA-Center for Veterinary Medicine, 1987, pp 3-27.

Bevill, Richard R. "Sulfonamides." CRC Handbook Series in Zoonoses, Section D: Antibiotics, Sulfonamides, and Public Health Section editors: Thomas H. Jukes, Herbert L. DuPont, and Lester M. Crawford. Boca Raton, FL: CRC Press Inc., 1984, pp 355-365.

Bird, Jackie. "Antimicrobials-An Uncertain Future." Animal Pharm, 4 May, 1990, p 12.

Braude, R., H.D. Wallace, and T.J. Cunha. "The Value of Antibiotics in the Nutrition of Swine: A Review", Antibiotics and Chemotherapy, 3, No. 3 (1953), pp 271-291.

Brown, Scott. FAPRI Pork Model, Columbia, MO: Food and Agricultural Policy Research Institute, October, 1992.

Burbee, Clarke. "Feeding Antibiotics to Farm Animals-Benefits, Risks, and Alternatives." in National Food Review, Fall 1980, Washington, D.C.: USDA-ERS, pp 21-23.

Burbee, Clark R., Robert Green, and Masao Matsumoto. "Antibiotics in Animal Feeds: Risks and Costs." American Journal of Agricultural Economics, 67, No. 5 (1985), pp 966-970.

Burbee, Clarke R. and Carol S. Kramer. "Food Safety Issues for the Eighties." National Food Review, Spring, 1986, Washington D.C.: USDA-ERS, pp 17-20.

Cordle, M.K. "Sulfonamide Residues in Pork: Past, Present, and Future", Journal of Animal Science, 67, No. 10 (1989): pp 2810-2816.

Council for Agricultural Science and Technology. "Antibiotics in Animal Feeds." Ames, IA, Report No. 88, March 1981.

Cromwell, Gary. "Antibiotics for Growth Promotion in Swine." Animal Nutrition and Health, July-Aug 1983, pp 18-23,31.

Fagerberg, D.J. "Salmonella Incidence and Antimicrobial Resistance in Fecal and Feed Samples of Production Broilers, Beef Cattle and Swine and Swine at Slaughter Plants in the United States-A Four Year Study", Journal of Animal Science, 62, Supplement 3 (1986), pp 33-42.

Fischer, Lawrence, Mary Zabik, Andy Thulin, and Kena Chapman. "Effects of Cooking on Antibiotic Residues in Meat: Sulfamethazine in Pork", presented at the International Conference on Issues in Food Safety and Toxicology, Michigan State University, East Lansing, MI, May 29-June 2, 1990.

Food Marketing Institute. Trends 1989: Consumer Attitudes and the Supermarket, 1989, Washington, D.C.: Food Marketing Institute.

Frapaolo, Philip J. "Risks to Human Health from the Use of Antibiotics in Animal Feeds." Agricultural Uses of Antibiotics, Ed. William A. Moats, Washington, D.C.: American Chemical Society, 1986, pp 100-111.

Hays, Virgil W. "Benefits and Risks of Antibiotics Use in Agriculture." Agricultural Uses of Antibiotics, Ed. William A. Moats, Washington, D.C.: American Chemical Society, 1986, pp 74-87.

Henderson, Pam Cole. "Food for Thought." Beef Today, 5, No. 10 (1989), pp 12-15.

Hilley, Harvey D., Barbara Kott, Gary D. Dial. "Chronic Resiratory Disease in the Pig." Current Veterinary Therapy-Food Animal Practice 2, Ed. Jimmy L. Howard. Philadelphia: W.B. Saunders, 1986, pp 681-684.

Hog Farm Management. Hog Farm Management 1988 Market Profile Study. Minnetonka, MN: Miller Publishing Co.

Iowa State University Extension Service. "Iowa Swine Enterprise Record", Iowa State University: Ames, IA, various years.

Institute of Medicine, Human Health Risks with the Subtherapeutic Use of Penicillin or Tetracyclines in Animal Feed. Washington, D.C.: National Academy Press, 1989.

Jukes, Thomas H. "Effects of Low Levels of Antibiotics in Livestock Feeds." Agricultural Uses of Antibiotics, Ed. William A. Moats, Washington, D.C.: American Chemical Society, 1986, pp 122-126.

Kramer, Carol S. and Karen P. Penner. "Food Safety: Consumers Report Their Concerns". National Food Review, Spring 1986, Washington, D.C.: USDA-ERS, pp 21-24.

Landefeld, J. Steven and Eugene P. Seskin. "The Economic Value of Life: Linking Theory to Practice." American Journal of Public Health, 72, No. 6 (1982), pp 555-565.

Liss, Robert H. and F. Ralph Batchelor, "Economic Evaluations of Antibiotic Use and Resistance-A Perspective: Report of Task Force 6". Reviews of Infectious Diseases, 9, Supplement 3 (1987), pp S297-S312.

McCoy, John H. Livestock and Meat Marketing, 2nd. ed., Westport,CN: AVI Publishing, 1979.

McKean, James. "Swine Rhinitis." Current Veterinary Therapy-Food Animal Practice 2, Ed. Jimmy L. Howard. Philadelphia: W.B. Saunders, 1986, pp 587-589.

McKean, James, R. Klostermann, D. Dewitt, M. Honeyman. "Evaluation of Field Diagnostic Tests for Sulfamethazine Residues in Swine." Proceedings of the 10th International Pig Veterinary Society Meeting, Aug. 14-17, 1988, Rio de Janerio, Brazil. p 410.

Mathur, Vandana. "Illegal Drug Residue Incidence Continues to Fall", Feedstuffs, 63, No. 28 (15 July, 1991), p 7.

National Academy of Sciences. The Effects on Human Health of Subtherapeutic use of Antimicrobials in Animal Feeds, Washington, D.C.: National Academy Press, 1980.

Prescott, John F. and J. Desmond Baggot. Antimicrobial Therapy in Veterinary Medicine. Boston: Blackwell Scientific Publications, 1988.

Preston, R.L. "The Role of Animal Drugs in Food Animal Production." Proceedings of the Symposium on Animal Drug Use-Dollars and Sense. Ed. Gary E. Stefan, Rockville, MD: FDA Center for Veterinary Medicine, 1987, pp 127-134.

Randecker, V.W., J.S. Reagan, R.E. Engel, D.L. Soderberg, and J.E. McNeal. "Serum and Urine as Predictors of Sulfamethazine Levels in Swine Muscle." Journal of Food Protection, 50 (1987), p 115.

Raynaud, J.P., J. MacKinnon, G. Kemp, R. Beukers, and K. Metzger. "Establishing Tolerance Levels of Antimicrobials in Human Food", Rationale View of Antimicrobials Residues, Berlin: Paul Parey, pp 40-55.

Roberts, Tanya and E. van Ravenswaay, "The Economics of Safeguarding the U.S. Food Supply." USDA-ERS Agricultue information Bulletin 566, Washington D.C., 1989.

Roberts, Tanya. "Human Illness Costs of Foodborne Bacteria." American Journal of Agricultural Economics, 71, No. 2 (1989), pp 468-474.

Roberts, Tanya. "Salmonellosis Control: Estimated Economic Costs." Poultry Science, 67, No. 6 (1988) pp 936-943.

Samuelson, G., D.M. Whipple, D.H. Showalter, W.C. Jacobson, G.E. Heath. "Elimination of Sulfamethazine Residues from Swine." Journal of the American Veterinary Medical Asssocieation, 175, No. 5 (1979), pp 449-452.

Shapouri, Hosein, Russell Bowe, Terry Crawford, and Warren Jessee. Costs of Producing U.S. Livestock 1972-1987. USDA-ERS Agricultural Economic Report #632, April, 1990.

Smith, Rod. "Drug Violation Could 'Jeopardize' Future Pork Trade". Feedstuffs, 62, No. 32 (30 July, 1990), pp 1,27.

Smith, Ronald D. Veterinary Clinical Epidemiology: A Problem-Oriented Approach, Boston: Butterworth-Heineman, 1991.

Somogyi, A. "The Objective of the Legislator Safety Evaluation of Veterinary Drug Residues", Rationale View of Antimicrobials Residues, Berlin: Paul Pery, 1989 pp 7-17.

Straw, B. and N. Ralston. "Comparative Costs and Methods for assessing Production Impact of Common Swine Diseases." Economics of Animal Diseases, University of Michigan, 1987, pp 165-180.

Steele, James H. and George Beran, eds. CRC Handbook Series in Zoonoses, Section D: Antibiotics, Sulfonamides, and Public Health, Section editors; Thomas H. Jukes, Herbert L. DuPont, and Lester M. Crawford. Boca Raton, FL: CRC Press Inc., 1984.

Stevermer, Emmett. "Efficacy of Feed Additives in Swine," presented at the conference, Drug Use by the Practitioner, Nov. 15-16, 1976, Iowa State University, Ames, IA.

"Sweden: Ban Complicates Pig Production", Large Animal Veterinarian, 44, No. 1 (1989), pp 14-16.

USDA, "Economic Effects of a Prohibition on the Use of Selected Animal Drugs." Washington D.C.: Nov. 1978.

USDA, "Livestock and Poultry Situation and Outlook." Washington, D.C., July, 1991.

"U.S. Sales Show Larges Growth for Three Years", Animal Pharm, 229 (June 7, 1991), p 12.

Zimmerman, Dean R. "Role of Subtherapeutic Levels of Antimicrobials in Pig Production", Journal of Animal Science, 62, Supplement 3 (1986), pp 6-17.

APPPENDIX: CALCULATIONS OF THE COSTS OF *SALMONELLA* MORBIDITY AND MORTALITY ATTRIBUTABLE TO FEEDING SUBTHERAPEUTIC ANTIBIOITCS

A summary of estimates of mortality rates due to *Salmonella* as done by the NRDC from the Holmberg paper published in Science in 1984:

1. The First Estimate:

   a. Approximately 40,000 cases of salmonellosis are reported each year (CDC data base).

   b. 20-30% of *Salmonella* isolated from humans are resistant to one or more antibiotics (CDC data base).

   40,000 * 20% = 8,000 cases caused by resistant *Salmonella*/year

   c. The death rate from resistant *Salmonella* is 4.2% (from Holmberg et al.).

   8,000 * 4.2% = 336 deaths/year from resistant *Salmonella*

   d. 69% of reported outbreaks due to resistant *Salmonella* are traceable to animal sources (from Holmberg et al.).

   336 * 69% = 232 deaths/year from animal origin, resistant *Salmonella*

   e. 50% of the resistant strains are a result of using subtherapeutic antibiotics (NDRC estimate).

   232 * 50% = 116 deaths/year from the use of subtherapeutic antibiotics

2. The Second Estimate:

   a. 1,000 to 1,500 deaths/year are associated with *Salmonella* outbreaks (CDC).

   b. 76.5% of fatal cases are associated with resistant *Salmonella* (calculated by NRDC from Holmberg et al.).

   1,000 * 76.5% = 765 deaths/year from resistant *Salmonella*

c. 69% of reported outbreaks due to resistant *Salmonella* are traceable to animal sources (from Holmberg et al.).

   765 * 69% = 528 deaths/year traceable to animal sources

d. 50% of the resistant strains are a result of using subtherapeutic antibiotics (NDRC estimate).

   528 * 50% = 264 deaths/year from the use of subtherapeutic antibiotics

3. The Third Estimate:
   (From figures presented by the Institute of Medicine, 1988 report)

   a. Approximately 50,000 cases of salmonellosis reported each year.

   b. 15% of these cases are resistant to penicillin/ampicillin or the tetracyclines.

      50,000 * 15% = 7500 cases/year from resistant *Salmonella*

   c. Death rate among cases with drug-resistant *Salmonella* is 1%.

      7500 * 1% = 75 deaths/year from resistant *Salmonella*

   d. 70% of these deaths are traceable to animal sources.

      75 * 70% = 53 deaths/year traceable to animal sources

   e. 90% of the resistant *Salmonella* from animal sources are due to the feeding of subtherapeutic antibiotics.

      53 * 90% = 48 deaths/year from the use of subtherapeutic antibiotics

The morbidity estimate:

1. As calculated by the NRDC from Holmberg et al.:
   a. Approximately 40,000 cases of salmonellosis are reported each year (CDC data base).

   b. 20-30% of *Salmonella* isolated from humans are resistant to one or more antibiotics (CDC data base).

      40,000 * 20% = 8,000 cases caused by resistant *Salmonella*/year

   c. 69% of reported outbreaks due to resistant *Salmonella* are traceable to animal sources (from Holmberg et al.).

      8,000 * 69% = 5,520 cases reported/year attributable to animal sources

   d. 50% of the resistant strains are a result of using subtherapeutic antibiotics (NDRC estimate).

      5,520 * 50% = 2,760 cases/year attributed to the use of subtherapeutic antibiotics

   e. 1 % of all cases of *Salmonella* infections are reported (CDC).

      2,760 * 1% = 276,000 cases of non-fatal salmonellosis that are associated with the feeding of subtherapeutic antibiotics

2. An estimate from figures presented by the Institute of Medicine, 1988 report:

   a. Approximately 50,000 cases of salmonellosis reported each year.

   b. 15% of these cases are resistant to penicillin/ampicillin or the tetracyclines.

      50,000 * 15% = 7500 cases/year from resistant *Salmonella*

c. 70% of these cases are traceable to animal sources.

7500 * 70% = 5250 cases/year traceable to animal sources

d. 90% of the resistant *Salmonella* from animal sources are due to the feeding of subtherapeutic antibiotics.

5250 * 90% = 4725 cases/year from the use of subtherapeutic antibiotics

e. 1% of all cases of *Salmonella* infections are reported (from CDC in Beran).

4725 * 100 = 472,000 cases of non-fatal salmonellosis that are associated with the feeding of subtherapeutic antibiotics