DISSERTATION

RETURNS AND SPILLOVER OF COLORADO AGRICULTURAL RESEARCH-COMPUTABLE GENERAL EQUILIBRIUM MODEL FOR LIVESTOCK

SUBMITTED BY

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVSISION BY EIHAB MOHAMED FATHELRAHMAN ENTITLED RETURNS AND SPILLOVER OF COLORADO AGRICULTURAL RESEARCH- COMPUTABLE GENERAL EQUILIBRIUM MODEL FOR LIVESTOCK BE ACCEPTED AS FULFILLING IN PART OF REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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Abstract of Dissertation

RETURNS AND SPILLOVER OF COLORADO AGRICULTURAL RESEARCH-COMPUTABLE GENERAL EQUILIBRIUM MODEL FOR LIVESTOCK

Objectives of this dissertation include study of the implication of investment and returns to livestock research in Colorado as case studies for the Northern Plains Region, description of the components of Colorado regional CGE model of livestock production to analyze direct, indirect and induced impact of investment in livestock research and development of investment recommendations regarding implications of estimation of returns to investment in livestock research in Colorado case study to the regional livestock research policy in the Northern Plains.

Starting from initial rate of return of 20%, the estimated ROR was found to be 16%, all direct benefits to the beef as well as all agricultural and non-agricultural sectors included the ROR rises to 25%. When indirect benefits are included, the ROR is estimated to be 28%. When induced effects also added to the benefits of research ROR rise to 35%. Then the CGE model used to simulate 40% ROR to (beef and diary). When all direct benefits (targeted and non-targeted) are included ROR rise to 64%. However, when Indirect benefits included the ROR is estimated to be 76%. When induced effects also added to the benefits of research ROR rise to 104%. Starting from initial rate of return of a 60% ROR to all livestock research the estimated ROR found to be 57%. When all direct benefits (targeted and non-targeted) to the livestock sector as well as all agricultural and non-agricultural sectors are included the ROR rise to 73%. When indirect

benefits included the ROR is estimated to be 86%. When induced effects also added to the benefits of research ROR rise to 117%.

Investment in livestock research affect returns to factors of production and households income significantly. At 40% ROR to livestock R&D there is about 1% increase in returns to factors of production. The basic livestock research clearly contributes to higher returns to factors of production, and higher income to all household categories. The middle-income group witnesses a slightly higher impact than the low and high-income categories.

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DEDICATION

I dedicate this work to my family , my parents Mohammed and Omsalama, my wife Sihma and my beloved sons Mazin and Mouaz and daughter Shaza

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Chapter One: Introduction

1.1 Introduction

Investment in R&D affects farmers income when new technologies enable them to produce more output using the same amount of input or producing the same amount of output using lower amounts of inputs. The circulation of cash generated from livestock activities in the economy creates new jobs, encourages entrepreneurship, and increases investment in capital stock in the region. The impact also spills out to the neighboring states through inter-state trading and may provide products in lower prices. For these reasons, estimates of rates of return to investment in R&D should include an investigation of all productivity, demand side effects and business impacts.

Recently Hoag and Fathelrahman (2000) summarized a building literature regarding returns to agricultural research. Although most studies showed significant and positive returns to investments in research, they found that many characteristics of investments were not fully considered, includes indirect and induced impacts of research and development, the spillovers across vertical linkages (e.g. inputs and food processing sectors) and across geographical boundaries and the lagged effect of agricultural research.

The business impacts include an impact from direct cash investment, a second round of cash flow when businesses buy from each other, and the impact of the investment on the society by creating more jobs and increasing income levels of households. This research focus is to trace livestock research impacts in the region. Not only direct impact, assessed by previous studies, but also indirect and induced impacts.

Investment in livestock basic knowledge, applied research and technology transfer in the region has a large multiplicative impact because of the big share of the region nationally and because of the large number and volume of other businesses which support backward and forward services of the livestock sector (e.g. feed grains, prepared feeds and hay sectors as backward linkages and meatpacking plants, poultry processing and other food processing sectors as a forward linkages).

A region may invest in specific research only to have it spillover (either through pecuniary or technological effects) to other regions without paying back the original investment. For example, McCunn and Huffman (2000) found that a strong positive interstate spillover implies that independent state planning of agricultural research is inefficient and cooperation across states boundaries, including establishment of new political jurisdictions for financing public agricultural research, may enhance efficiency. A few studies also have analyzed spillovers at the regional level and fewer considered the pecuniary spillover impact. Araji (1995) found that, while total returns to investments in potato research were 79 percent, about 31 percent of return to investment accrues to states conducting the research and the spillover effects account for 69 percent.

The results of agricultural research can have two major types of spatial spillovers. New knowledge or technologies produced in or targeted for one country, region or state can spillover into other countries, regions or states. Also, new technology can affect prices (pecuniary effect). Alston et al. (1995) show that these spillovers influence both the size and distribution of research benefits and should be considered when research priorities are set. Pecuniary spillovers are particularly important in smaller geographical units, such as individual states. White and Havlicek (1979) found that a failure to take into account the geographical spillovers from U.S. regional agricultural research inflated the estimated rate of return to research and extension in the Southern region by more than 25 percent. This may explain higher returns to livestock than crop research estimated by Norton and Davis (1981), as they did not consider research spillover from other regions to the Southern states. Taking into consideration spill in and spill out of livestock research benefits is crucial to research priority setting and policies.

There are difficulties in modeling costs and benefits of research and development because of the time lag between research initiation and benefits accrue to end users. Modelers of R&D found difficulties associated with including variables representing research and development, infrastructure, spillovers (spill in and spill out), and extension services in the production function model because research affects agricultural production neither directly nor instantaneously. Data on such variables are usually not available for long enough periods that incorporate the time different between research and development investment and benefits reaching consumers and producers.

1.2 Research Goal

The goal of my dissertation is:

> *To estimate the full range of benefits from agricultural research in Colorado, including direct, indirect and induced effects as they translate into benefits and costs throughout the Colorado economy and the region. In addition, to include spill in and spill out, benefit lags and tax deadweight loss improvements over previous literature.*

This research will be applied to livestock in Colorado. In this dissertation, the tool deployed is Computable General Equilibrium (CGE) methods that consider interaction of

R&D with economic sectors, which is more robust compared to the productivity measure used by McCunn and Huffman (2000) and others. The modeling approach can be the most influential cause of over or underestimation of agricultural research returns (Alston et al. 1995).

CGE is a set of equations that describes the economic activities of consumers, producers, traders, and the government in the markets for factors of production, output, and net imports. The model states that the supply and demand in each of these markets is equilibrated by a market-clearing price. The case study in this research will use Colorado CGE models to trace rates of return to investment in livestock, input-output and price spillover impacts to the other sectors in Colorado, and the price spillover impact to other states and rest of the world. A static Colorado CGE model will provide a benchmark equilibrium that can be used to simulate the results of the structural change in livestock research in the state and among different scenarios of livestock research (e.g. basic versus applied research).

1.3 Research Objectives

To reach the stated goal, the objectives of this research are:

Objective (1): Describe the initial components of regional SAM models of livestock production in Colorado and other selected states in the Northern Plains region to analyze the direct, indirect and induced impact of investment in livestock research.

Objective (2): Assess the implication of investment and returns to livestock research in Colorado as a case study for the Northern Plains Region and discuss the opportunity cost of livestock R&D in the region.

Objective (3): Develop a CGE model of Colorado to describe both livestock research input-output and price spillover impacts to the agricultural and non-agricultural sectors in Colorado (vertical and pecuniary spillover) and the price spillover impacts to regions outside Colorado (horizontal pecuniary spillover). Vertical spill over includes impacts to backward sectors (feed grains, prepared feed, hay and pasture) and forward sectors (meatpacking, poultry processing, and other food processing).

Objective (4): Develop investment recommendations regarding the implications of estimation of returns to investment in livestock research in Colorado and the pecuniary spillover case study to the regional livestock research policy.

1.4 Procedures

There are four major steps needed to reach my research objectives:

Step 1: Summarize both previous studies and data on costs and benefits of public and private livestock research, rates of return to investment in livestock research, livestock research spillovers and lags of agricultural research among different types of livestock research in the U.S and the selected region to learn as much as possible about the subject being researched

Step 2: Determine characteristics of livestock research in the U.S. and selected Northern Plain States (Colorado, Kansas, Nebraska, and South Dakota).

Step 3: Use IMPLAN data sets to build Social Accounting Matrices (SAM) for Colorado. The IMPLAN data is needed to apply the results of the SAM multipliers to the economic characteristics of the state of Colorado in terms of the state capacity to multiply effects of investment and the opportunity cost of livestock research. The purpose of the multiplier estimation is to allow a desegregation of benefits from livestock research obtained from the CGE modeling into direct, indirect and induced impacts. The other advantage of the CGE modeling is the ability to determine the opportunity cost of investment used in conducting livestock research, otherwise invested in non-livestock sectors research.

Step 4: Develop the Computable General Equilibrium Model (CGE) of Colorado as a case study of the Northern Plains region to determine economic direct, indirect and induced effects of investment in livestock when relative prices effects are included.

Step 5: Use the Colorado CGE model to analyze 20%, 40%, and 60% initial rates of returns to investment in beef and livestock research (reproduction of previous studies RORs). These simulations are intended to investigate impacts of commodity-specific livestock research (20%) against broader types of livestock research (e.g. basic research (60%)) direct and pecuniary impacts.

Step 6: Determine direct effects to the beef and livestock sectors (targeted sector) from the CGE model, the direct effects to other agricultural and non-agricultural sectors (non-targeted sectors), along with the indirect and induced effects, that permit estimating adjusted rates of return.

Step7: Determine possibilities of pecuniary spillovers of research to the other sectors in Colorado and to the rest of the world.

Step 8: Discuss the policy implications of changes in the states' prices, economic and social indicators related to each simulation and the policy implication of investment in livestock research in each case.

1.5 Organization

Following this introduction, chapter two will explore the lessons learned from previous studies and explore the methods used to assess the effects of investment in agricultural research including productivity, production function, and the consumer and producer surplus approaches. Chapter three will focus on the description and components of the Computable General Equilibrium model for studying the economic and social impacts of investment in R&D and spillover of agricultural research. Chapter four will study the public and private sector costs of livestock research, with an emphasis on costs of performing animal research in the Northern Plains region. Chapter five will identify productivity gains in each of the four selected states over the period 1960 – 1996, discuss the implication of productivity gains, and link productivity changes to possible spillover of livestock research. Chapter six describes the Social Accounting Matrices (SAM) for each of the four selected states, portrays the economic characteristics in each state and reports the direct, indirect, and induced multiplier for each sector in the selected Northern Plains states. Chapter seven will include the simulations' results of returns and pecuniary spillover economic and social indicators of investment in livestock research in Colorado as a case study. Chapter eight will discuss the conclusions and policy implications of different assumptions related to rates of return and spillover of livestock research.

1.6 Data Sources

This research will rely on four basic data sources: The IMPLAN database for the regional input-output technical coefficients; the Inventory of Agricultural Research publications for the past and current investment in livestock research; Northern Plains Agricultural Experiment Stations' annual reports for the livestock research priority setting followed in each state, and the USDA publications on agricultural and livestock productivity.

1.6.1 IMPLAN

IMPLAN databases, combined with IMPLAN Software, allows the user to develop state-level input-output models that can be used to estimate the economic impact of policy and regulation changes, tax increases or decreases, and new firms moving into an area. The software allows a user to develop a complete set of Social Accounting Matrices (SAM's), create a specific multiplier table, change components (includes of production functions, trade flows, and/or database parameters), create custom impact analyses for entering final demand changes, and obtain reports to examine the models' assumptions and calculations.

1.6.2 Inventory of Agricultural Research for Physical years 1990-2000

Each year the Cooperative State Research, Education and Extension Service (CSREES) of the USDA publishes a report derived from the Current Research Information System (CRIS), which classifies public spending of agricultural research by commodity or resource, research problem area, and by research program group on the regional and state levels. These reports provide a valuable source for the data needed on the cost side of agricultural research to build the simulation.

Having the data in separate categories in the CRIS system is significant in terms of the type of research classification. However the state of Colorado is considered a part of the Western region, together with Alaska, Arizona, California, Idaho, Nevada, Oregon, New Mexico, Utah, Washington, Wyoming, and other Western States. The region for this study will include only Northern Plains states (Kansas, Nebraska, and South Dakota), which are part of the CRIS North Central region. This will necessitate a new set calculations for totals of the Northern Plains states in order to perform the analysis.

1.6.3 Northern Plains States Agricultural Experiment Stations Annual Reports and Publications

These published reports include an important data on investment in livestock research and other related subjects beside indicators on priority setting between these subjects. The information obtained from these reports will serve as a guideline for model simulation for past investment in livestock research. Information from personal contacts with Colorado Agricultural Experiment Station officials will determine the basic CGE assumptions.

Chapter Two: Literature Review

2.1 Introduction

The rate of return to investment in agricultural research has been estimated using a wide range of methods, varying from a very simple index of productivity or a consumer producer surplus method to very complex production or supply functions. The following is a literature review on the productivity measure, production function, and economic surplus approaches, including a discussion about some of the experiments used to adjust the rate of return to account for under or overestimates of the rate of return. These adjustment factors include lagged research effects, depreciation and maintenance spending, spill in and spill out, and tax deadweight loss.

2.2 Productivity Measures and Production Function Models

Through technology, the United States has developed the most efficient food and fiber system in the world. In fact, it is because of the advanced agricultural technology that the average American spends only 12 percent of their disposable income on food down from 15-18 percent 20 years ago (Hees, 1991). Initial agricultural research focused on improving productivity by using better agricultural practices and new varieties. Ironically, the very success of that research created the potential for production to exceed demand, thus depressing prices below the level of profitability. Animal agricultural industries in the United States have experienced remarkable productivity growth since the end of World War II. One of the most important factors behind this growth has been investment, both public and private, in animal research. These investments have provided farmers with a steady stream of technologies that have significantly increased productivity. For this reason a large number of studies focused on using productivity measures or a production function to estimate the rate of return to investment in agricultural research.

It is very challenging to present a brief literature review of all studies related to returns to agricultural research and extension, as this area of research is expanding rapidly. Agricultural research is an investment aimed at improving the well being of farmers and consumers by reducing costs, increasing output, improving product quality, and/or introducing new crops or methods of farming. Recognizing the importance of this investment, federal and state governments have made a sizable investment in agricultural research. Since the late 1950's, over sixty studies have examined the economic benefits of investments in agricultural research (Araji, 1995).

Aggregate evaluations of the impacts of investments in agricultural research in the United States have been conducted by Peterson (1969), Lu et al. (1978), Evenson et al. (1979), White, Havlicek and Otto-Davis (1979), White and Havlicek (1979), Braha and Tweeten (1986) used production approaches to assess benefits of all agricultural research. Most of these studies showed more than a 40% return to investment in agricultural research. Evenson (1967) argued that a more useful approach is to measure research productivity for a particular commodity or a particular agricultural experiment station.

Rates of return are the compounded financial yield from an initial investment outlay that generates a series of multiyear benefits. It is much like the yield on a bond. Fuglie, et al. (1996) summarized the results of these studies and estimated the core range of results by research and extension area as shown below (Table 2.1).

The majority of studies (1964-1993) showed an average 40-60 percent return to investment in public agricultural research. Basic research earned the greatest rates at 60-90 percent, and extension earned less than 30 percent. Basic research has the greatest return, which drives up the average return for public research compared to private research. Only about 15 percent of private research is basic, compared to 41 percent in the public sector, which partially explains why private research has generated a lower rate of return than the public sector. There has been a general pattern of increasing rates of return from agricultural research over time. A possible explanation is the lag of agricultural research benefits, which can take up to 30 years to be fully realized. In the 1990s, much of the agricultural research benefits were due to research conducted in the 1960s and the 1970s.

Table (2-1) Rate of Return to Investment in Agricultural Research

Type of Research/Outreach	Full Range	Core Range
Public Research	0-100	40-60
Public Basic Research	57-110	60-90
Private Research	26-90	30-45
Extension	Negative-110	23-35
Farmer's Schooling	15-83	30-45

Source: Adopted from and Fuglie et al. (1996), and Fuglie et al. (1995)

2.3 The Rate of Return to Investment in Animal Research Using Productivity Measures or Production Function Method

Many studies have estimated the specific returns of different commodities. Most commodities show high rates of return, but estimates of individual commodities vary widely among studies. There is a great variation across these studies' time periods and approaches, which makes them difficult to compare. However, there is a noticeable difference between the rate of return to livestock research and crop research. Livestock returns are lower, and even negative in recent studies. It is thought that research on livestock has a larger lag than research on plants due to more sophisticated characteristics and physiologies of the animals compared to plants (Fuglie et al. 2000)

The studies that focus on an investigated rate of return to investment in animal research are summarized in Table (2-2). These studies offer a wide range of estimates that varies between "negative" to 86 percent depending on animal product and/or period of study (Fuglie et al. 1996). Most of these studies used a production function or the productivity measure to estimate return to investment in animal research.

Table (2-2) Rate of Return to Animal Research in the United States

Investigator	Year Published	Commodity	Period of Study	Rate of Return
Peterson	1967	Poultry	1915-60	21
Bredahl and Peterson	1976	Poultry, Dairy, Beef, Swine and Sheep	1969	37-47
Evenson and Welch	1979	Livestock	1964	55-60
Norton	1981	Dairy, Beef, Swine and Sheep	1974	33-66
Smith, Norton, and Havlicek Jr.	1983	Poultry, Dairy, Beef, Swine and Sheep	1978	22-61
Evenson	1989	Livestock	1952-1982	11
Evenson	1991	Applied Livestock	1952-1982	11
Norton and Ortiz	1992	Poultry, Beef, Swine and Sheep	1950-82	46-55
Huffman and Evenson	1993	Public Livestock Research and Extension	1950-82	Negative
		Public Basic Livestock Research	1950-82	83
		Private Livestock Research	1950-82	86

Sources: Townsend and Thirtle (2001), Fuglie et al. (2000) and Fuglie et al. (1996)

The limitation of these studies is that they may ignore or underestimate the importance of technology spillover across regions. Interstate research spillovers can be significant because improved animal technology is often directly transferable across geographical boundaries (Fuglie et al. 1996).

Most of the difficulties associated with including variables representing research and extension in the production function model arise because research affects agricultural production neither directly nor instantaneously. Alston et al. (1995) explained research lag and absoluteness as follows:

> *"There are considerable time lags between investment in research and generation of usable technologies, and there are lengthy lags in the uptake of technologies. As new technologies depreciate or become obsolete, their output enhancing or cost saving effects may eventually wane".*

Social and economic research benefits are not easy to estimate for a specific region because, as stated above, research spills out and spills in across geographical boundaries.

Productivity measures might hide other causes of increased productivity rather than show returns to investment in research. For example table (2-3) shows that growth in animal yield between 1955 and 1995 was greatest for dairy and showed steady improvements for all major animal commodities. The relatively smaller growth in beef may be even lower than it looks. Beef yield increased due to a decline in veal slaughter. In other words, the productivity increased due to increases in the proportion of beef grown to maturity rather than from improvements in technology (Fuglie et al. 2000).

Table (2-3) Changes in U.S. Livestock and Poultry Productivity 1955-95

Year	Beef Cattle (lb beef/cow)[1]	Hogs (lb pork/sow)[2]	Dairy (lb milk/cow)	Broilers (lb/bird)	Layers (eggs/layer/year)
1955	590	788	5,842	3.07	192
1965	591	1,022	8,304	3.48	218
1975	546	1,167	10,360	3.76	232
1985	680	1,310	12,994	4.21	247
1995	723	1,503	16,451	4.67	253

[1]Beef cattle yield: pounds of beef produced divided by the number of cows and heifers that have calved

[2]Hog yield: pounds of pork produced divided by the number of farrowing sows

Source: Fuglie et al. 2000 P. 118

2.4 The Rate of Return to Investment in Animal Research Using Consumer and Producer Surplus Approach

Research may result in a consumer surplus by introducing more utility gain from product consumption. In addition, a technology may enable a producer to reduce production costs and therefore increase net benefits. In both cases there is a welfare change that can be measured. If benefits from research exceed costs and gainers from technological change could, in principle, compensate losers then society is said to be better off.

Estimates of social rates of return to agricultural research now have high credibility and, with appropriate understanding, are meaningful to use in making decisions about future support of agricultural research. The social rate of return to investment in agricultural research includes total economic benefits of new technology to the society, benefits to farmers, agribusiness and consumers (Fuglie et al. 1996). The concept of economic surplus underlies most of the methods used by economists to estimate the benefits and costs of agricultural research. The following selected papers did not estimate rate of return to investment in animal research, however they were related to this research subject area.

Freebairn et al. (1982) used the consumer and producer surpluses approach, in a multistage analysis of input suppliers, farmers, marketers, and consumers, to measure distribution of research benefits among these beneficiaries. They concluded that the total cost reduction value is the same whether it occurs at an input supply point, farm, or marketing sector. The relative distribution between these sectors depends on the elasticity of retail demand and supply elasticities of value added at each stage of production. In general the more inelastic a sector's supply is relative to the other sectors, the greater will be the share of research gains going to that sector.

Norton et al. (1987) examined the benefits of agricultural research and extension in a consumer-producer surplus framework for five commodities in Peru. Norton considered the effects of demand shifts over both time and government pricing policies on research and extension benefits. Data for the analysis included the results of research and extension questionnaires administered at seven sites in Peru. The projected rates of return to research and extension indicate substantial returns to public investments.

Fuglie (1995) measured the welfare effect from reduction in potato storage losses in Tunisia as a result of improved pest control technology. Potato consumer and producer interests are in conflict, as consumers would prefer more research that reduces post-harvest marketing losses, particularly for food staples, while producers would prefer research that lowers the cost of inputs of potato storage (pest control research). This research concluded that research that reduces input costs is more socially optimal than reducing marketing losses.

The consumer and producer surplus approach has been criticized from several perspectives. Alston et al. (1995) summarized these perspectives as: this approach relies on what should be rather than what is (normativeness); accuracy of measurement of consumer and producer surpluses; and the validity of the partial welfare analysis, which ignores complex relationships with the other market factors in the economy. Examples of these factors are transaction costs and existence of externalities.

The literature shows that both the production function approach and economic surplus approach have been used heavily to assess returns to investment in agricultural research. Many of the studies that used these two major methods lack consideration for other important factors, such as the lagged effect of the stock of agricultural knowledge, the depreciation of agricultural research, the burden of tax collection loss, the geographical spill out and spill in, which causes under or over estimate of agricultural research, and/or exclusion of the private sector contribution from total estimated benefits and expenditures of agricultural research. These limitations are discussed below.

2.5 Lags of Agricultural Research

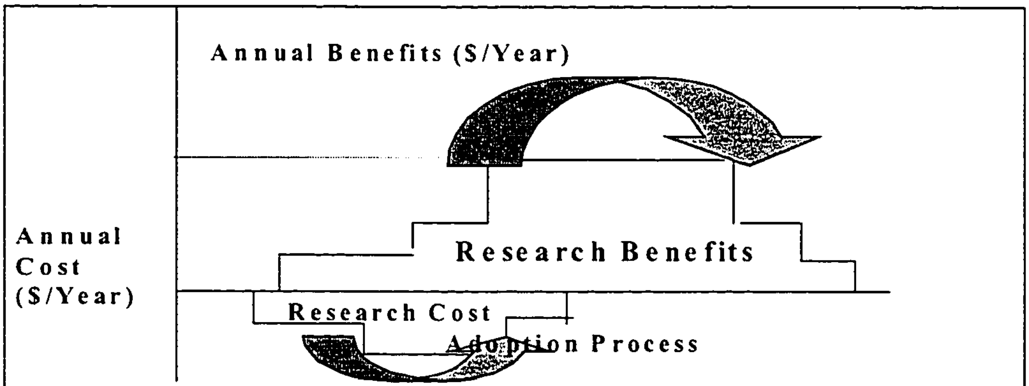
Previous studies showed that there are long, variable, and uncertain time lags in the term between implementing research activities and producing knowledge, and therefore between generating new technology and the adoption of this technology. Beyond that, when research causes an increase in the supply of knowledge or an enhancement in available technology, that increase in knowledge or improvement in technology yields a stream of future benefits that continues until the knowledge or new technology becomes extinct (Alston et al. 1995).

The complete evaluation of a particular research investment must therefore take into account the dynamic relationships between investments in research that lead after some, possibly long, lags to a sustained change in the stock of productive capital and thus to a stream of future benefits. The lag structure of benefits of research and development expenditures is important because the sooner the research benefits are received and the longer they last, the higher the rate of return to research.

Alston et al. (1995) described phases of research benefits as follows:

> *"Annual flow of net benefits from the adoption of new technology starts positive. In some cases the flow of benefits may continue indefinitely; but in many cases benefits will eventually decline. This is because the technology that embodies the results is progressively abandoned as it becomes obsolete and newer and later technologies evolve; because results depreciate, as for example when pests develop resistance to particular pesticide; or if results become uneconomic for some other reason, such as changes in market prices of inputs or outputs".*

Alston et al. (1995) also showed the hypothetical relationship between the adoption of new technology and the time after the initial investment in research. He includes a research lag (shown as five years) between the initiation of the research and the generation of pre-technology knowledge, followed by a development lag (shown as a further four years). During this time the results from pre-technology research are incorporated into useful agricultural technology, followed by an adoption lag (say a further six years) between the release of the agricultural technology and maximum adoption by producers. Adoption of new technology usually continues between ten to fifteen years until a new technology arises and the old technology starts to deteriorate in another lag of five years. The total time period of lagged research between initial investments of agricultural research until the point where old technology is fully substituted with a new one is estimated to be about thirty years (Alston et al. 1995).



Research Conducted By	*Technique Used*	*Lag*
Griliches, Zvi, 1963	Linear lag structure	6 year
Evenson, Robert	Imposed lag structure	10-20 years
Knutson and Tweeten, 1979-White and Havlicek,1982 - Pardey and Craig, 1989 - Alston et al. 1995	Different Approaches	30 years

Figure (2-1) Lags in Agricultural Research and Adoption

Alston and Pardey (2001) summarized results of previous studies on lags of agricultural research to be in the range between 13.2 and 38.0 years. Until recently, it was common to restrict the lag length to less than 20 years. More recent studies have tended to use more flexible, and longer lags (e.g Pardey and Craig used 30 years lag for crop research lags, Chavas and Cox also used 30 years lags in their studies). Thirty-five years lag of livestock research used in this study because most of livestock research deal with biological production function, which is expected to have a longer lag of benefits compared to crops.

2.6 Maintenance and Depreciation of Agricultural Research

As with any other type of capital, the economic contribution of the stock of knowledge erodes over time because of depreciation and obsolescence. Research–based information depreciates when circumstances change in a way that makes information less productive or becomes obsolete when it is gradually replaced with better information for the same conditions. Maintenance research is needed to compensate for inherent depreciation and obsoleteness of information, technology, and material. Examples of maintenance research are the animal health and plant protection research. These types of research do not introduce a new improvement or technology innovation, however in the absence of health and protection research there would be tremendous losses would have occurred.

The timing and extent of deprecation varies significantly among different types of agricultural research. Basic research tends to have a smaller depreciation rate compared to pre-technology and applied research (Alston et al, 1995). Ruttan (1982) speculated that the rate of knowledge decay is likely to increase, as agricultural production systems become more knowledge intensive so that a larger share of research resources are needed simply to maintain the existing knowledge stock. Townsend and Thirle (2001) argued that studies of rates of return to research have usually based on the assumption that if there were no research, then there would be neither growth nor decline in productivity. Maintenance research keeps productivity from declining and allow for growth to happened. The authors suggested that relatively lower rates of returns to investment in animal research in previous studies are a result of ignoring the losses that would have occurred in the absence of animal health research.

Oehmke et al. (2000) argued that current models in public agricultural research rely largely on models that fail to represent the changing nature of intellectual property protection, and the potential dynamic growth of biotechnology. In particular, their paper summarized the review provided by Alston et al (1995) and concluded that all previous models fail to recognize the dynamic pattern of product obsolescence and replacement that occur with increasing rapidity in agriculture.

Adusei and Norton (1990) concluded that a considerable percentage of agricultural research in the U.S. has been maintenance research. As a result, studies may have underestimated the initial effect of particular research investments but overestimated the longevity of this particular research. The current stock of usable knowledge is the result of previous investment in agricultural research. Current change of knowledge is a result of two opposing factors; new research investment and depreciation of old research. Utilization and dissemination of research results has a spatial dimension and a time extent. Fuglie (1996) indicated that 30% of U.S. agricultural research is needed to maintain previous research gains.

2.7 Tax Collection and Deadweight Losses

The economic inefficiencies created by tax collection are termed "deadweight losses". Fox (1985) argued that the costs of public expenditures on agricultural research have been underestimated by a failure to account for the marginal excess burden of the tax collection system. A tax on wages reduces labor supplied, and a tax on capital reduces capital investment. Deadweight losses refer to the value of foregone production resulting from the imposition of taxes in an economy and should be taken into account when the social rate of return of an investment in public research is to be estimated (Fuglie et al, 1996).

Yee (1992) estimated that extra tax collection costs reduced the effective rate of return on a dollar of public and private expenditure from 58 percent to 43 percent of deadweight loss estimates as the tax collection costs increases 1 cent. That means as tax deadweight loss accounted for in rate of returns estimation a reduction of 15 percent occurs when rate of returns to investment in agricultural research calculated. (Fuglie et al., 1996). Studies tend not to consider tax deadweight loss as a cost factor for research and overestimates rate of returns as a result.

Frisvold and Vogel (2000) used a computable general equilibrium (CGE) model of the U.S. economy to conduct a series of tax shift experiments to examine welfare, distributional and other economic effects of financing public agricultural R&D through commodity taxes rather than general taxation. The numerical simulation results indicated that funding research through commodity taxes rather than general taxation reduces the social cost of financing research by about 15 percent. This suggested approach of taxation would induce a reallocation of labor from lower-wage to higher-wage sectors, raising welfare by over $200 million. However financing commodity-specific research through commodity taxes would reduce farm income by about half the amount of revenues raised by taxes. The interpretation of this result is that if agricultural research were funded by a one percent commodity checkoff, half the cost would be borne by agriculture and the other half by the rest of the economy.

2.8 Spillover of Agricultural Research

The results of agricultural research can have two major types of spatial spillovers. First, new knowledge or technologies produced in or targeted for one country, region or state can spillover into other countries, regions or states. Second, new technology can affect prices (pecuniary effect). These spillovers influence both the size and distribution of research benefits and should be considered when research priorities are set (Alston et al, 1995).

Byerlee and Traxler (2001) discussed the role of technology spillovers and economies of size in the efficient design of agricultural research systems. They identify three types of spillovers: (1) knowledge-related spillovers refer to new knowledge generated elsewhere (for example, a new research method or discovery) that is applied to research process to enable more efficient generation of new technology. Evenson (1989) refers to these as pre-technology spillovers; (2) technology-related spillovers come about when a technology itself is transferred or adapted to a new environment; and (3) price-related spillovers derive from price reductions in the same or related industries (sometimes referred to as pecuniary spillovers). Byerlee and Traxler focused on the second type, technology spillovers, claiming:

> *"although considerable literature exists on spillovers, little attention has been paid to the role of economies of size and scope of agricultural R&D. The presence of economies of size in research implies that the unit cost of producing a given research product, such as new plant variety, decreases as the size of research efforts increases".*

This research applied the economic surplus approach and used country-level data on maize-breeding research in 44 developing countries, program-level data on wheat-breeding research at 63 research stations in 30 countries, and program-level data level on wheat-breeding research at 50 research stations in India. Spillover coefficients are econometrically estimated based on performance of varities of different origins in different environments in a supply function. Yield of technology in specific location, specific year, and specific environment is regressed against year of release of technology, set of dummy variables for environment origin, and another sets of dummy variables to remove location and year effects in panel data. The results of this research concluded that because spillovers tend to flow from large regions and from central research programs, the failure to include spillovers and spill-ins has inflated estimates of returns to research in the small regions and underestimated returns in larger programs. They found that intensity of research declines by about 0.5 percent for each 1 percent increase in the area targeted for the crop. The estimated spill-in elasticity is very small and not significant, which means that policymakers determine investment levels for reasons that are independent of potential to free-ride on spill-ins.

Geographical spillovers are particularly important in estimating returns to smaller geographical units, such as individual states. White and Havlicek (1979) found that failure to take into account the geographical spillovers from U.S. regional agricultural research inflated the estimated rate of return to research and extension in the Southern Region by more than 25 percent. Evenson (1989) reported substantial direct spillovers of research benefits between states, with larger direct spillovers for livestock than for crops. This may explain higher returns to livestock than crop research as found by Bredahl and Peterson (1976) and Norton (1981), because these two studies did not subtract the spill in effect of agricultural research from other states to the Southern Region. However Evenson showed that indirect spillover (via enhancement of invention potential of other states) is higher for crops compared to livestock. States are likely to be most interested in funding research where the benefits accrue to people in the state and thus may be more likely to fund crop research. Because the benefits of livestock research spillover widely, state funding for it may be comparably lower. This would drive up the marginal rate of return to livestock research and drive down the marginal rate of returns for crops if there are diminishing returns to research (Fuglie et al. 1996).

U.S. agricultural productivity may similarly benefit from spillovers of technology developed by foreign R&D expenditures. Thirtle et al. (1994) incorporate spillover between EC countries. They find that spillovers between the European research system and from the United States may be more important than the direct effects of the national agricultural systems. The authors conclude that failure to take into account spillovers may bias upward the rate of return to R&D in EC countries. These estimates suggest that an individual country could reduce some spending on research and take advantage of research from other countries. This research concluded that because of the public good nature of research it couldn't be contained by national borders (Fuglie et al., 1996).

Ouyang (1999), in a Ph.D. dissertation, studied public agricultural research and research spillover effects on the 48 U.S. states' agricultural productivity. One of his conclusions is that research spillover potentials between states with similar production characteristics are likely to be larger than states with widely different patterns of agricultural products. He argued that spillovers across U.S. states are larger when they produce the same commodities rather than across geographical boundaries. Two neighboring states might not interchange technology as much as two distant states producing the same agricultural products. Ouyang applied clustering procedures to group the states, computed productivity indexes for intertemporal (relative to productivity 1982), spatial (relative to the yearly national average) and temporal-spatial (relative to 1982 national average) comparisons to identify sources of productivity variations across states and/or over-time. The research identified five clusters: poultry/cotton, vegetable/fruit, livestock/crop, livestock, and diary. Spillover potential within the same cluster, and spillover potential between different clusters are defined as variables in the regression analysis. Agricultural research was found to be a complement to public extension, total research spillovers and spillovers from states in different clusters. Own-state public agricultural research was found to be a substitute for private agricultural research.

McCunn and Huffman (2000) used an agricultural Total Factor Productivity (TFP) measure for the period 1950-1982 to examine U.S. interstate research spillover. The researchers noticed that as the federal government shifts greater responsibility to states for carrying out agricultural research programs, many state governments are scrutinizing expenditures. Agricultural research administrators see potential changes and are weighing opportunities and options for future funding. The authors used a cross-sectional time series data of TFP and found that spill in are significant factors of the production function of knowledge in most of the 48 states. They concluded the presence of strong positive spill in and spill out between states that share similar geoclimatic characteristics. They implies that independent state planning of agricultural research is inefficient and cooperation across states boundaries can enhance returns to investment in agricultural research. The spillover effects of public agricultural research are important at the regional level rather than the national level. A criticism McCunn and Huffman paper may face is related to the total factor productivity measure rather than the model or procedure used, because the productivity measure and the production function approach lack reliability related to the exclusion of the other interacting elements of the agricultural sector and the rest of the economy's sectors. The paper also did not consider other factors stated above such the effect of tax collection deadweight loss and the effect of depreciated research.

In conclusion a more accurate estimation of rate of return to investment in agricultural research needs to correct for the drawbacks of the previous studies by adjusting for several biases. Biases may rise from one or more of the following: the methodology used to estimate benefits of research (partial versus general equilibrium method), using static model, which does not allow for lag of agricultural research effect, exclusion of the impact of maintenance research, which account for the losses that might occur in the absence of research, using prices not adjusted for tax deadweight loss, and when underestimating the welfare impact of research if only consumer or producer surplus measured but not both. Another drawback of previous studies is ignoring the spatial effect of research when technology itself adopted in other regions without paying for the research cost, and underestimation or omitting of the pecuniary effect when agricultural research causes prices to drop for importing consumers in the other regions.

In this study by using the general equilibrium model rather than partial equilibrium approach some of these drawbacks will be corrected because of the nature of the model. The general equilibrium model considers interaction between the economy's agents (sectors, households, factors of production, government and trade). This characteristic allows for tracing of the cost and benefits of the productivity changes not only within the agricultural sub-sectors, but also measuring the gains and losses to the other non-agricultural sectors, consumers, factors of production and the government. When gains and losses measured across all sectors, cost of productivity gains is calculated and the tax deadweight loss is counted for both consumers and producers. The focus of this research is to estimate the returns to Colorado livestock research when direct, indirect and induced impacts are counted for. These impacts include the direct investment impact to the targeted sector by research (e.g beef sector), direct impacts to the other agricultural and non-agricultural sectors because investment of livestock research uses resources from these sectors, indirect impacts when business buy products and services from each other, and induced impacts to all sectors when households income rises and returns to factors of production increases.

Simulating the general equilibrium model along the expected time path (35 years) of expected benefits of research allows counting the discounted future benefits against the initial cost of agricultural research solve the problem of lagged research benefits not counted in previous studies. Simulations of this research are designed to investigate different types of livestock research. Example of types of livestock research includes commodity specific research (e.g beef research) and a broader type when the research target is all livestock animals and feed grains rather than specific commodity or sector. To evaluate the spillover impact, this study will estimate the pecuniary effect of research gains and losses to the other agricultural and non-agricultural sectors in Colorado and highlight the possibility of pecuniary effects to outside from Colorado. This study focus on the welfare impact of research when it explore the cost and benefits from the livestock production research shock to backward linkages sectors (feed gains, hay and pasture prepared feed) and the forward linkages sectors (meatpacking, poultry processing and other food manufacturing)

Covering these measures in this study will leave the areas of direct technology spillover (when new technology itself adopted somewhere other than origin state) and the effects of maintenance research impact uncovered. Both direct spillover and effect of maintenance issues covered in previous studies and require exogenous sets of data out of scope of the data collected to build the Social Accounting Matrices (SAM) as a step to construct Colorado Computable General Equilibrium model.

Chapter Three: Methodology

3.1 Introduction

The literature review summarized above suggests the need for a more representative model of the economy in order to avoid the drawbacks of studies that investigated rates of return to investment in agricultural research. Figure (3-1) outlines areas covered by the different methods, which includes using production functions or consumer and producer surplus approaches to investigate returns to investment in agricultural research. All of the estimates of returns to investment in agricultural research have been addressed by using the production function approach and many have been addressed by using the economic surplus approach. Other sectors in the economy sectors interact with research and development in agriculture. Few studies provided empirical results on the usefulness of rate of returns estimation and how could it be used to assess the impact of investment in specific type of commodity research. This study provides empirical work that investigate returns and impact of investment in livestock research with consideration for both the commodity's demand when economy's sectors interact with each other and the spatial dimension when the state spill in and spill out to the neighbor states in the Northern Plains region.

This research will develop regional Social Accounting Matrices for Colorado and a Computable General Equilibrium Model (CGE) of Colorado as a case study for regional Northern Plains to study the effects of investment in livestock research. This research will use a CGE model as a tool, which will account for most of the disadvantages of methods summarized in the literature review above. Social Accounting Matrix (SAM) and the Computable General Equilibrium (CGE) Model are used to address issues related to the social cost of using public taxes to finance agricultural research (Frisvold and Vogel, 2000). SAM and CGE are more comprehensive and have the advantage of capturing the direct, indirect, and induced effects of investment in livestock research compared to the other methods because they include the livestock production sector as well as all economy's sector, households, governments, and interstate trade.

Approach	Lagged Research	Spill in and Spill out / Regional Application	Tax Deadweight Loss	Deprecation of Research	Regional Application	Commodity Specific Research
Production Function or Productivity Measure	X	X	X	X	X	X
Economic Surplus Approach	X		X	X		X
CGE			X*			

Figure (3-1) Areas of Research Uncovered by Literature Review in Rate of Returns to Investment in Agricultural Research

*Frisvold and Vogel (2000) Used CGE to study the welfare, distributional, and economic effects of financing public R&D through commodity taxes rather than general taxation.

3.2 Computable General Equilibrium (CGE) Model

The CGE system uses a non-linear production function that includes a variable for agricultural knowledge. Using changes of supply and demand functions in this model, the model can be used to study economic as well as welfare impact of the benefits and costs of new technology adoption. This research will use the advantages of the CGE model to consider the depreciation of research as the livestock technology decays over time.

Fortunately, the CGE model has been used extensively to evaluate different scenarios that simulate the impact of government tax policy, which will ease the estimates of tax collection deadweight loss of livestock research made here. However, the private sector share of technology expenditures and benefits must be estimated as a major part of the livestock research model here.

A CGE model is a multi-sectoral, economy-wide mathematical model with analytical, and theoretical structure. The CGE describes the economy in terms of optimal behavior of individual and representative economic agents. The structure of the CGE includes in its components producers making intermediate and final outputs to maximize profits and maximize returns to factors of production. Consumers receive returns by using their labor and spending their income on consumption and savings to maximize their utility. The government, at both federal and state levels, collects taxes and spends this revenue on government consumption.

The regional application, by using the Northern Plains region as a case study, will add the privilege of investigation of research spill in and spill out across geographical boundaries. Many economic scholars (e.g. Huffman and Evenson) called for research that focused in on specific commodities to introduce a pilot method that can be used by policy-makers for research priority setting among different commodities research. The reason behind this call is the argument about using a commodity-oriented tax system for research funds rather than the general fund, especially with increasing involvement of the private sector due to the progress and development of the patent system in the U.S.

P. Berck et al. (1996) derived the following description of the CGE model components from the Dynamic Revenue Analysis Model (DRAM) for California. DRAM is based on a CGE structure and has been used for a number of models at Colorado State University and other places, to simulate growth and planning. The model was well documented, and was handy to use by researchers. The description below is taken directly from DRAM, and is applied to the research problem. Some of the components, which are not applicable to this research problem, are not included in the description.

Figure (3-2) shows the components of the CGE model. In a CGE model, the economy is known better because all agents are represented, trade in and out flows to the other states and rest of the world is also present, and supply and demand equilibrium determine prices of final goods. Prices of final output are different than intermediate goods, which allow for margins measurement. Producers in the Research and Development (R&D) sector, choose a combination of the two primary inputs, giving the existing stock of knowledge to produce new technology. This new technology can spill out across the states embodied in inputs, intermediate goods and the final goods as the states trade inputs and commodities.

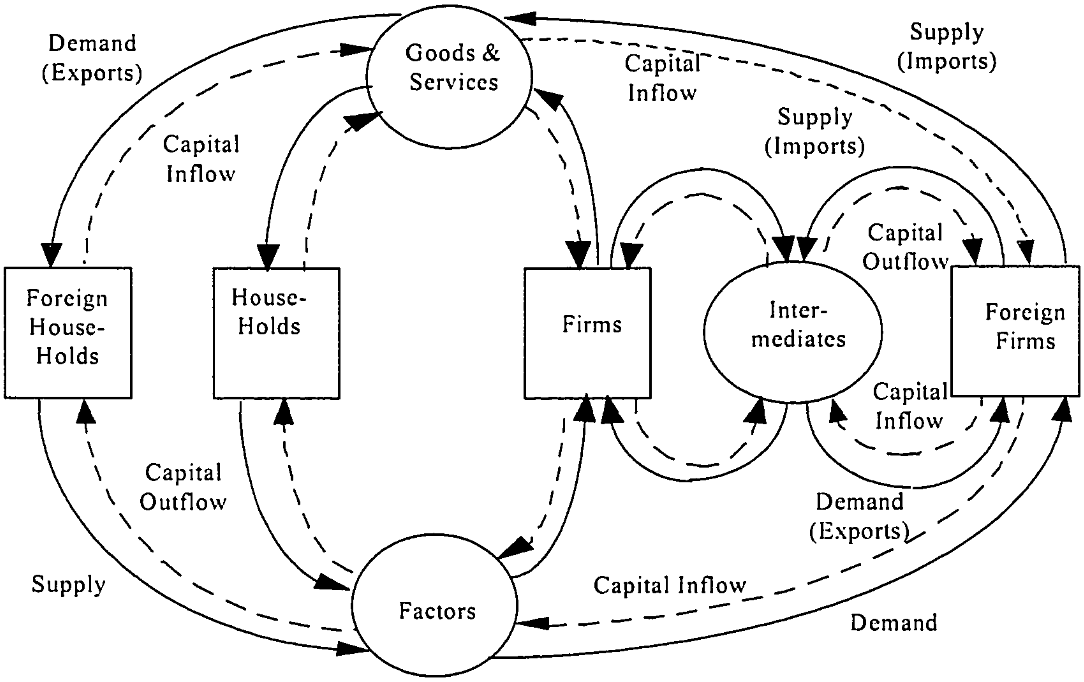


Figure (3-2) Computable General Equilibrium Model Components

Source: Berck P. et. al (1996)

3.2.1 Producers

Producers are a large number of identically behaving firms, which at the beginning of each year rent primary inputs labor and products from consumers, a set of differentiated capital from the capital good sector, and technology from the R&D sector. Producers are assumed to maximize profit. In other words, the fundamental behavioral assumption of the corporate sector is that firms strive to maximize the value of the outstanding stock of the shares. As a result of the profit maximization assumption in aggregate, each sector chooses the inputs, capital, labor, intermediate goods, and technologies that lead to the output that makes the most possible money. This choice is a function of the prices of outputs and inputs (Schreiner 1998). Inputs of the production for the purpose of measuring productivity impact is different than the commonly known production function because it should included an embodied technological change.

Yee and Huffman (2001) assumed a single, output aggregate production function with embodied technical change as follow:

$$Q = AF(K, L, M)(OWNRD)^{\delta_1}(EXT)^{\delta_2}(SPILLIN)^{\delta_3}(HIWAY)^{\delta_4}$$

Where Q is the aggregated output into one index of output, A is a constant. F(●) is a well behaved function, K is physical capital input, L is labor input, M is material input , OWNRD is the state's own public research stock, SPILLIN is the public research stock from other states, EXT is extension stock, and HIWAY is highway stock. The authors then defined the Total Factor Productivity (P) as

$$P \equiv \frac{Q}{F(K, L, M)} = A(OWNRD)^{\delta_1}(EXT)^{\delta_2}(SPILLIN)^{\delta 3}(HIWAY)^{\delta 4}$$

This format of the production function fits the framework of the CGE model is both the output value and factors of production are a major components of the data. Total Factor Productivity change is attributed to research and development, extension services, spill in to the states from outside, and infrastructure. The direct, indirect and induced effects of investment in livestock research could be estimated at various levels of returns to the investment by changing parameters of the production function and using the SAM multipliers.

3.2.2 Consumers

The second component of the CGE is households, who receive income from firms and buy products from domestic or foreign firms. The CGE model incorporates the economic theory that the consumers' choice of goods is made within their budget constraint. The solution to the consumer problem is the demand curve for each marketed good, and their supply of labor. The model is called general, rather than partial equilibrium because the income of consumers is determined within the model.

Household Gross Incomes

$$y_h = \sum \frac{\alpha_{hf} a_h^w}{\sum \alpha_{hf} a_h^w} y_f \left(1 + \sum \tau^h\right)$$

Where: y_h = household income, y_f =factor income, α_{hf} = initial shares of consumption, a_h^w = Number of working households τ^h = tax paid by households

Household gross income is a function of payments to factors supplied by each household group, and is apportioned to households on a fixed scale of shares per household type.

3.2.3 The Government

Government is exogenous to the model. It chooses a set of policies to allocate available funds among specified number of priorities.

Government Income

Government income is the sum of sales taxes collected from domestic consumption (intermediates, imports, household consumption, investment and governments), plus taxes on factor payments, plus taxes collected from households (income taxes and per household taxes). All tax rates were derived from IMPLAN ratios.

3.2.4 The Foreign Sector

Agents outside the modeled region, called foreign, even though it would include U.S. states outside of as well as other countries in this model, are taken as having a known demand curve for each good and service. Net demand is a device that captures exports and imports in the same equation.

Export Demand

Export demand for domestic production is a simple function of observed exports and the relationship between domestic and world prices. As domestic prices rise in relation to world prices, exports fall. However, they do not drop to zero the instant that domestic prices rise beyond world ones. Current exports were drawn from IMPLAN data.

Import Demand

Imports are simply the share of domestic consumption that is not supplied by domestic sources.

$$m_i = (1 - d_i)x_i$$

Where m_i sectoral import demand, di = share of domestic consumption, X_i = domestic demand.

3.2.5 Aggregated Prices

Average prices faced by domestic households for goods and by firms for intermediate goods are calculated by multiplying the domestic share times the domestic price and adding this to the import share (one minus the domestic share) times the world price. All prices (domestic and foreign) are in relation to current ones, i.e. are set to unity prior to solving the model.

3.2.6 Value Added Prices

Value added is defined as the summation payments to workers, taxes, and profits. The value added prices are different than the aggregate prices. One of the advantages of the CGE models the ability to show the impact of growth or any other policy changes on value added prices. Value added prices are calculated as follow:

$$p_i^{va} = p_i^d - \sum_{i' \in I} \alpha_{i'i} p_i \left(1 + \sum_{g \in GS} \tau_{gi'}^v\right)$$

Where: P_i^{va} = value added price, P_i^d = domestic producer price, $\alpha_{i'i}$ = domestic input-output coefficients, P_i = aggregate price, and τ_{gi}^v = intermediate good sales and excise tax rates.

Since intermediate goods are in fixed proportion to output, their shares of costs do not form a direct part of the profit maximizing use of various intermediates, i.e. there is no substitution between intermediate goods, or between intermediates and factors.

3.2.7 Number of Non-working Households

The number of non-working households is simply the count of that household's population, less those with jobs.

In brief the CGE model is a general equilibrium model that implements the text book definition of an economy. There are utility maximizing consumers whose decisions determine the demand for goods and supply of labor. There are profit-maximizing producers whose decision determines the supply of goods and demand for primary factors and intermediate inputs. There is regional and international trade. There are governments who collect taxes and tariffs, may set exchange rates, and provide transfers of subsidies and services. Finally there are market-clearing conditions specifying supply-demand balance, which will determine equilibrium prices. The model is "general equilibrium" because all domestic supplies, demands, prices, and incomes are determined simultaneously within the model. It is "computable" because the model solves empirically for all endogenous variables in a highly nonlinear system of simultaneous equations (Berck et al. 1990).

3.3 Computable General Equilibrium (CGE) Model Assumptions

Kazaran (1997) described the CGE model structure and stated many of the CGE model assumptions, but only some of them apply to this research. This study will use a static CGE model to investigate the direct, indirect and induced effects of investment in livestock research and the spill over of agricultural research. Tax collection deadweight loss is considered within the CGE framework, which makes it more valid tool to assess the economic and social effects of livestock R&D investment.

General Equilibrium Model Assumptions are: Markets clears, agents behave optimally, functional representations of consumer preferences and producer technology is feasible, technologies are constant return to scale, no excess demand exists for any good, every producer earns zero profit, no consumer exceeds her budget, preferences are identical and homothetic, and the utility function is additively separable.

3.4 Computable General Equilibrium Model and Growth

Many applied general equilibrium models tend to be either based on single period optimization assumptions or to use the CGE structure in a discrete sequential manner to model dynamic processes. Computable General equilibrium models have been applied by; Davarajan and Go (1998) Gunter (1993), Ho (1989), Jorgenson and Wilcoxen (1990), Keuschnigg and Kohler (1994, 1995), McKibbin and Warwick (1993), Mercenier (1993, 1995), Nordhaus and Zili (1996) and Ronald (1999), where the discipline of steady state dynamic via exogenous specification of the rate of growth is imposed. Diao et al. (1996) cited the models prior to 1996 recognizing that they resolve the inconsistency problems of intra and inter-temporal optimization, however they rely on the exogenous specification of technological change and other effects that can affect the rate of economic growth. Consequently, they fall short of providing a link between economic structure and policy effects on growth rate.

The growth-accounting literature investigates the contribution of different factors of production to macroeconomic growth by starting from the following production function $Y_t = f(A_t, K_t, L_t)$, where: A_t K_t, and L_t are the stock of knowledge, capital, and amount of employed labor at time t, respectively. Since the measurement of the stock of knowledge is problematic (Griliches (1973)), its contribution is calculated as the residual of growth rate, remaining after the impact of capital and labor accumulation has been taken into account. Based on assumptions about the form of the production function, one can estimate the contribution of capital and labor to aggregate growth. The remaining fraction of growth is then attributed to technological change (Solow-residual). Almost all studies use the following underlying assumption with respect to the production function: constant return-to-scale, neutrality of technological change, and profit maximization in perfectly competitive markets. The measured impact of technological change varies considerably between these studies.

3.5 Regional Computable General Equilibrium (CGE) Models

Regional CGE models are similar in design to the national and international models, but exhibit major differences. Berck et al. (1996) summarized these differences as follows: first, regional models do not require the regional savings to be equal to regional investment, when Coloradoans save more than consumption Colorado investors want to use, excess savings flow out of the state; second, regional economies trade a large share of their output, therefore trade is more important in the regional setting; the third difference is that regional economies face larger volatile immigration flows than nations. Hence, migration is a major factor in economic growth of the state's economy model compared to the national model. A fourth difference is that regional economies have no control over monetary policy. As a result, in regional models taxes are interdependent through deductibility from income constrained by local regularities.

Partridge and Rickman (1998) surveyed the literature related to regional CGE models, discussed the contribution of such modeling techniques toward economic analysis, and outlined the regional modeling technique. The paper listed over 30 regional studies and summarized production inputs, mobility of capital, labor, and energy and the status of labor market closure in each study (between market clearing wage setting, exogenous wage rate, or scenarios for both). The study explored the regional CGE models' published applications strengths and weaknesses in different areas of interest such as regional effects to changes in final demand, tariffs and federal fiscal policies, agricultural and environmental policies, regional fiscal policies, and transportation policies. The paper then suggested future directions of research in regional CGE modeling. These suggestions include using flexible functional forms (FFF) such as the Translog or Generalized Leontif alternatively to CES functional forms, as the FFF have the advantage of allowing substitutability between factors of production, beside a degree of complement between some other factors such as energy.

Goodman (2000) developed a CGE model of the Southeastern Colorado economy. The model was used to study the economic impacts of proposed increase in reservoir storage as an alternative to temporary water transfers in the Arkansas River Basin. This regional model was set up with four factors of production: land, labor, capital, and water. The IMPLAN 528 production sectors' data were aggregated into three sectors: agricultural, commercial, and industrial. The CGE model was benchmarked to the 1995 base year data; it was then simulated in the economy for the 2000-2040 period, based on projected water data obtained from the Southern Colorado Water Conservancy District. The study classified the economy into two regions, urban and rural. Both consumption and production functions were modeled as nested CES functions. The research concluded that while increase in the reservoir storage would provide both urban and rural areas with their needs, water temporary transfers alternative is much lower economic and environment cost. This analysis illustrates how CGE model provides a more realistic portrayal of the impact of policy changes than input-output analysis by allowing substitution in response to economic conditions.

Chapter Four: Cost of Animal Research

4.1 Introduction

Using both public and private research funding instruments, policy-makers influence the type of research to be performed. In the past, sources of funding played a major role in the direction and end use of this funding. Public research tends to focus on basic research, while private research is more technology and applications-oriented.

Total U.S. public (federal and state) research funds were estimated to be \$3.1 billion dollars in 1997. Of the total amount of research funds (\$3.1 billion), state governments provided about \$1.1 billion, representing about one third of total public research funding, while the remaining two-thirds are provided by the USDA and other federal agencies (Figure 4.1).

Alston (1999) showed that the USDA, as a major source of public federal agricultural research, provided more than \$1.2 billion in 1997, leaving less than \$1 billion to other non-federal sources to fund federal research. Public research is either performed through the State Agricultural Experiment Stations (SAES) and related institutions or in-house by the USDA agencies. In 1997, research performed at SAES cost over \$2.3 billion dollars representing about 75% of the total public research while the rest (25%) was funded to perform in-house research (Figure 4.1). This shows how important it is to investigate allocation of SAES among different subjects and issues as

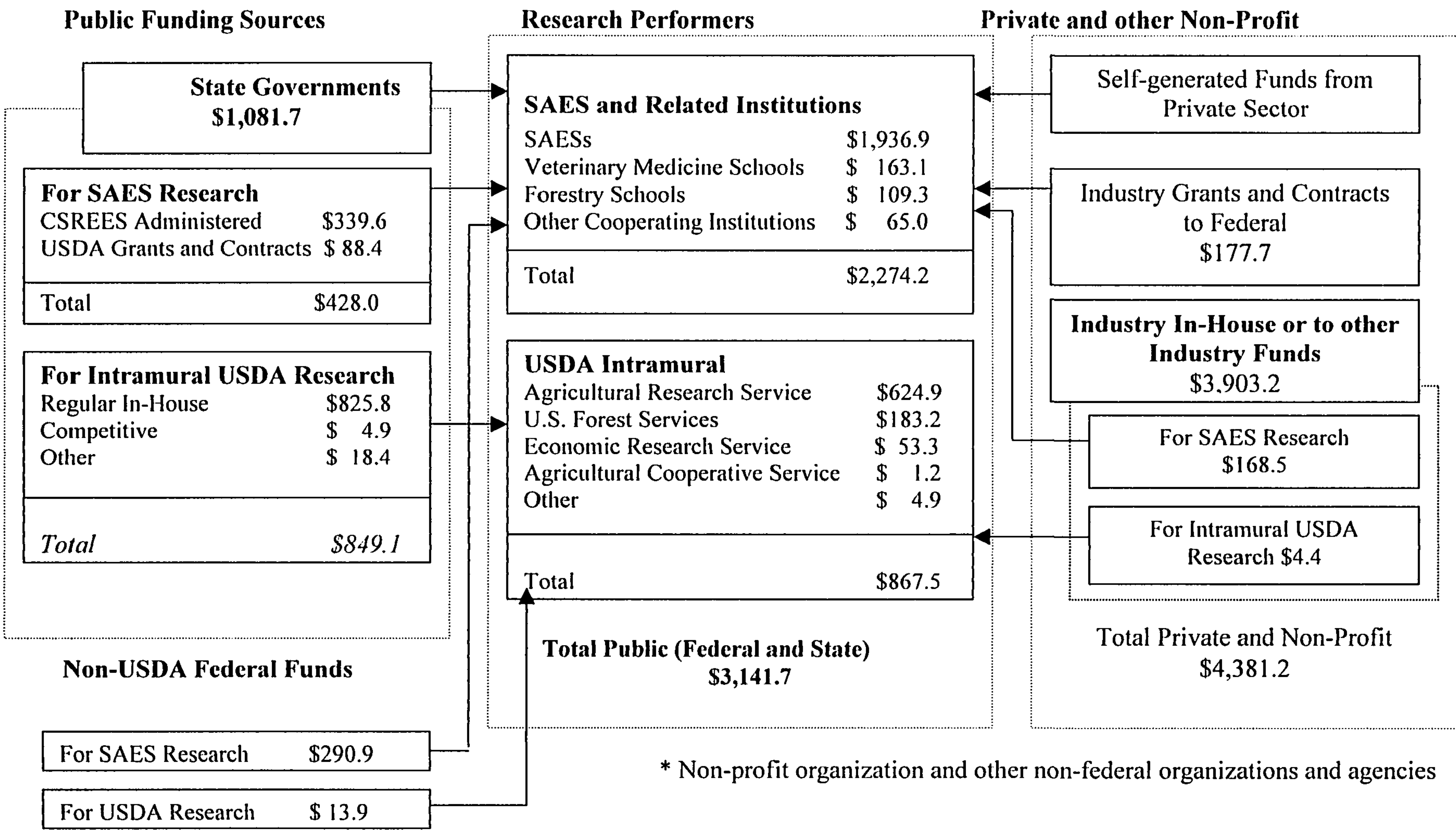


Figure (4-1) Public and Private Agricultural R&D Funding Sources and Uses in $ Million 1997

Source: Adapted from Alston et al., p. 86 (1999)

SAES plays the bigger role in carrying both crop and animal research objectives to maintain national goals behind funding agricultural R&D.

Data on private investment in animal research is rare and incomplete compared to public expenditure in research. The first to report an aggregate estimate of private investment in animal research was Moschini and Lapan (1997), where they showed that private animal health research is very close to plant breeding research expenditure from 1960-1980. However recently (during the last two decades) plant breeding private research expenditures exceeded animal health. (They did not report animal breeding research (Table 4-1). In general adding together animal health and animal breeding research expenditures shows the significance of the animal research share in the total agricultural research expenditure.

Table (4-1) Public and private agricultural R&D in Millions of Current dollars

	Private R&D							
Year	**Plant Breeding**	**Agricultural Chemicals**	**Farm Machinery**	**Animal Health**	**Food and Kindred Products**	**Total Private**	**Total Public**	**Total Private and Public**
1960	6	27	75	6	92	206	216	422
1970	26	98	89	45	206	464	448	912
1980	97	395	363	111	488	1454	1214	2668
1990	314	1127	360	245	965	3011	2380	5391
1992	400	1279	394	306	1038	3417	2605	6022

Source: Moschini and Lapan, 1997

Total public and private funding for animal research was estimated to be $1.2 billion in 1996. As shown in the figure (4.2), on average in the United States, the federal government provided 27 percent of funding for animal research, state and local governments cover 23 percent, and other non-governmental public entities account for up to 12 percent, leaving the remaining 38 percent for the private sector. It is not the same picture for total agricultural research, where the private sector outspends the federal and state governments combined. This indicates that the private sector invests more in crop and other agricultural products and inputs compared to livestock research and technologies.

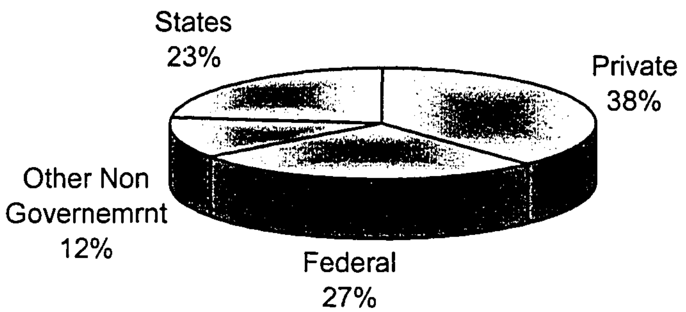


Figure (4-2) Sources of Funds for Animal Public and Private Research 1996

Fuglie et al. (2000) provided a summary of animal, public and private research investment with allocations to different technology areas, Table (4.2). Both public and private sectors allocate most research dollars for animal research into two major categories, animal breeding and animal health technologies. Public and private sector spent together over 1.2 billion dollars in animal research, with the public sector contribution of $666.7 million and the private sector spending $453.2 million in 1996. The public sector allocated over 40 percent of animal research funds to research related to animal breeding and biological efficiency because of the long-term and public nature of animal breeding research. The private sector finds it unprofitable to allocate funds to animal breeding, as it is not clear how to capture benefits of such technology development. The private sector allocates about half of its research dollars to animal health and protection, as firms are usually able to capture more benefits of R&D in this area because of the short-term nature and high necessity for new innovation in the animal health sector (Table 4.2).

Table (4-2) Summary of Allocation of Public and Private Animal Research in the United States in 1996

Technology Area	Public	Private	Total
Breeding and Biological Efficiency	284	118.4	402.4
Health and Protection	310	252.8	562.8
Feed, Nutrition, and Maintenance		48.5	48.5
Machinery	0.7	33.5	34.2
Management and Economics	36		36
Externality (Pollution Control and Food Safety)	36		0
Total	**666.7**	**453.2**	**1,159**

Sources: Fuglie et al. (2000)

4.2 U.S. Public Animal Research

Table (4-3) below shows that total public animal research was estimated to be about $743 million in 1996. On average, the federal government provided 44% of the animal research expenditure and states provided 37%, leaving about 19% for non-governmental sources. Federal contributions toward each of the five categories of animal commodities were reported to be between 38% for dairy cattle to 48% for sheep research. State contributions range between 35% for sheep research to 40% for poultry.

As expected, private research is more demand and market-oriented when it comes to allocation of investment in animal research. As an example, the private sector invested about 68% of its animal breeding research budget, which is estimated to be around $118 million dollars in 1996, on poultry breeding, responding to the market demand for increasing consumption of poultry products in recent decades (Fuglie et al. 2000).

Table (4-3) U.S. Public Sector Animal Research By Sources of Fund and Animal Commodity 1996

Commodity	Federal	State	Non-Government	Total	Federal	State	Non-Government	Total
	(Thousands of 1996 Dollars)				(Percentage)			
Beef	74,677	68,505	37,198	180,380	41.40%	37.98%	20.62%	100.00%
Dairy	55,642	57,048	33,108	145,798	38.16%	39.13%	22.71%	100.00%
Swine	45,895	38,532	16,418	100,845	45.51%	38.21%	16.28%	100.00%
Poultry	47,472	40,125	12,299	99,896	47.52%	40.17%	12.31%	100.00%
Sheep	21,632	15,674	7,325	44,631	48.47%	35.12%	16.41%	100.00%
Other	77,687	56,151	37,485	171,323	45.35%	32.77%	21.88%	100.00%
Total	**323,005**	**276,035**	**143,833**	**742,873**	**43.48%**	**37.16%**	**19.36%**	**100.00%**

Source: Adopted from Fuglie (2000)

Fuglie et al. (2000) used research intensity as a measure of congruence between research on a given product and its value of production. Research intensity is an index measures the relationship between value of investment in research to the gross value of production in a specific year for a specific sector or commodity (research intensity = ($ of research/ $ of production) X 100 %). The authors explained that this relationship could be used as evidence to suggest that as research support has become more constrained, the orientation towards commodity research becomes greater. They also believe that this phenomenon is at work in commodity groups' lobbying for public research support, as well as to the private sector's own support of research through commodity check-off funds. Research intensity in swine tripled between 1970 and 1996, while beef research intensity doubled for the same period. The research intensity for dairy and poultry grew relatively smaller, indicating a stronger position for the beef and swine industry group as compared to the dairy and poultry in getting support from both public and private sectors.

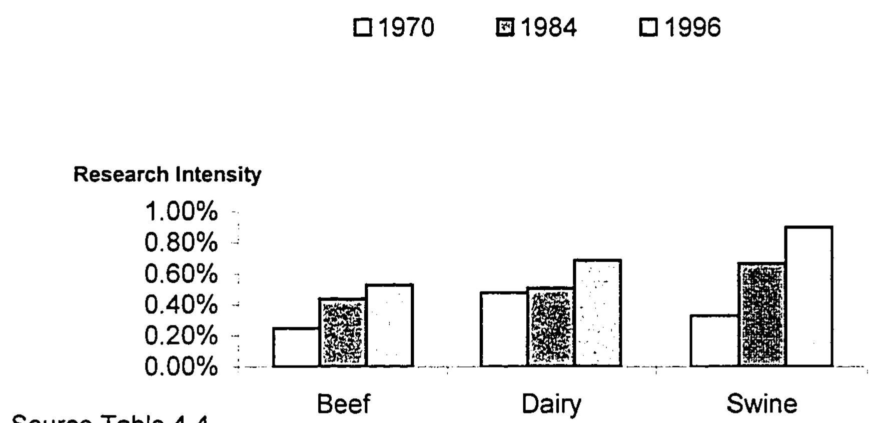
Table (4-4) shows a comparison of the intensity of animal research in the U.S. among different commodities for the years 1970, 1984, and 1996. Research intensity is an index relates the dollar amount spent in specific commodity's research to value of production of that commodity in a specific year. Beef research intensity doubled between 1970 and 1996. Swine research intensity nearly tripled across the same period of time while dairy research intensity increased gradually (figure 4.3). The sheep and goats research intensity did not follow a specific pattern but it changed significantly during the last three decades. However poultry research intensity was relatively very stable. Research intensity indicator implies that beef and swine research smoothly follows a pattern of increases in the value of production, which may indicate other factor affect research expenditures, such as the consumer demand side and external trade of these commodities.

Public scientist-years funded to perform animal research is another measure that indicates how much the public allocates human resources to this subject of science. The number of scientists conducting animal research did not change as much as the intensity of research changed. However in recent years, and especially by the late 1990s, the total number of scientist-years in livestock research had decreased by more than 200 scientists compared to early 1980's (about 9%). The larger decrease of public scientists is seen clearly in both beef and dairy projects. The reason could be a shift of research interest to swine research, which was not substituted by new research in beef and dairy (Table 4-4).

Table (4-4) U.S. Public-Sector Animal Research Relative to the Commodity Value in 1970, 1984, and 1996

Year / Commodity	Scientist-years	Research Expenditure	Production	Research Intensity
				($ Of Research/ $ of Production) X 100%
1970		($ Thousands)	($ Million)	
Beef	510.9	33,840	13,730	0.25%
Dairy	515.8	31,345	6,512	0.48%
Swine	197.8	14,593	4,444	0.33%
Poultry	403.7	22,577	4,192	0.54%
Sheep and Goats	163.5	9,963	386	2.58%
Total	**2032.6**	**126,931**	**29528**	**0.43%**
1984				
Beef	614.1	129,822	29,484	0.44%
Dairy	461.5	92,974	18,244	0.51%
Swine	286.1	64,069	9,509	0.67%
Poultry	336.9	56,789	11,145	0.51%
Sheep and Goats	127.0	23,805	464	5.13%
Total	**2310.9**	**453,281**	**70,774**	**0.64%**
1996				
Beef	467.7	178,383	33,846	0.53%
Dairy	381.8	143,802	20,888	0.69%
Swine	269.9	98,850	10,930	0.90%
Poultry	306.1	91,915	19,947	0.46%
Sheep and Goats	121.7	42,634	608	7.01%
Total	**2108.0**	**720,919**	**89,359**	**0.81%**

Source: Fuglie et al. 2000



Source Table 4-4

Figure (4-3) U.S. Livestock Research Intensity 1970-1996

4.3 U.S. Private Animal Research

Available information on private agricultural research expenditures in the United States is limited and incomplete, but what is known about the components of livestock private investment is presented. In this section, a review of estimated funds from private sources is summarized.

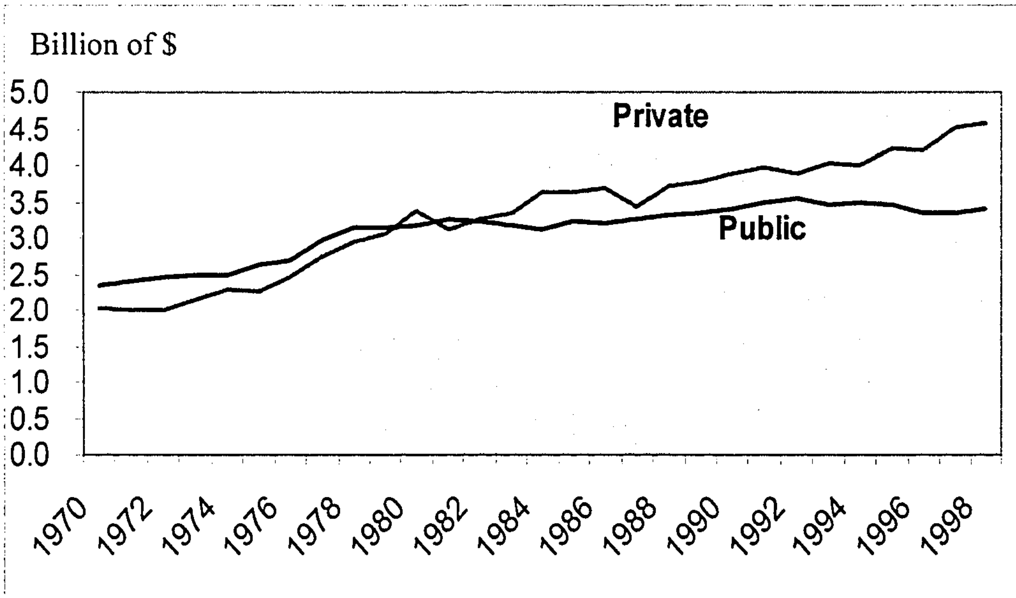


Figure (4-4) U.S. Public and Private Research Expenditure

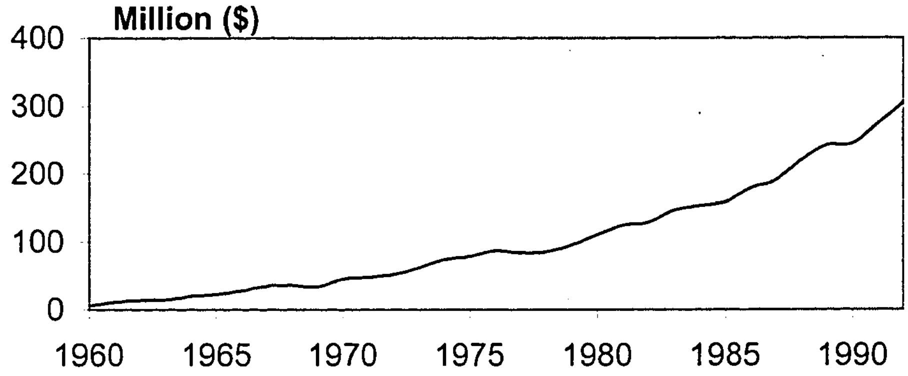
Figure (4-4) shows that private research expenditure has been more than public research spending since the early 1980s. In 1998, private research funds were more than double the value in 1970. Alston et al. (1999) reported that there was nearly a 17-fold increase in the amount of privately conducted research in the past three decades, which is a substantially faster rate of growth than occurred in the public sector. They also noticed that for every dollar of publicly conducted research in 1992, the private sector spent $1.31, compared with just $0.94 in the early 1960s.

The demand for animal research and new technology in areas of animal health and breeding has increased because of the growth in global demand for animal production, especially for poultry and swine. Fuglie et al. (2000) summarized estimates of private investment in animal research based on a phone survey in 1997 and 1998 to major corporations with programs in animal breeding, health, nutrition, and machinery. Klotz et al. (1995) found that private sector investment in animal research increased from 6 million dollars in 1960 to about $300 million in 1992. They included R&D on livestock, as well as on domestic horses and pets. The author's estimates relied on only members of the Pharmaceutical Manufacturers Association (PMA). There are other privately owned companies not included in their data. One may suspect that there is an over or under estimation in these figures. They also cited estimates of animal research expenditure performed by the private sector in animal breeding of about $100 million in 1992.

Fuglie et al. (1996) estimated that total private expenditure of animal research in 1996 was $453.2 million compared to $666.7 million for the public research the same year. In animal breeding research, Fuglie et al. (2000) showed that many of the companies are multinational and have emerged over the past several years to become major developers of improved animal breeds to producers. It is very clear that private animal research, because of its multinational characteristics, can be considered spill over research to all states without a specific real geographical pattern of distribution.

Total private investment in animal breeding was estimated to be $118.4 million in 1996. While the private-sector animal breeding expenditure was less than the public-sector investment ($284 million), the private sector was a major investor in basic poultry research and was responsible for most applied breeding research for broilers, layers, and swine.

The same study estimated private animal health research to be $252.7 million in 1995, making animal health the top subject area of private R&D, because it represents more than half of private expenditure in total animal R&D investment. Fuglie et al. (2000) showed that companies increased investment in animal health research because of high demand and global growth of animal production. Global sales of animal health products were estimated to be more than $14.3 billion dollars in 1995. About half of these sales are pharmaceutical products. Cattle health products sales to ranchers around the globe represented about one third of total animal health products sales. A quarter of sales went to the swine industry, and the rest (about 45%) was produced for poultry, sheep, pets and other animal health (Fuglie et al. 2000). Figure (4-5) shows private sector investment in animal health during the period 1960-1992. Animal health R&D increased from only $6 million dollars in 1960 to over $496 million in 1997.



Source: Klotz et al. 1995

Figure (4-5) U.S. Private Sector R&D in Animal Health, 1960-1990

Other areas of applied private research include both private research in animal nutrition and animal machinery such as technology related to dairy plants and milking machines. Fuglie et al. (2000) estimated total investment of $47.9 million in animal nutrition research and estimated another $33.5 million in animal machinery in 1996. These estimates were obtained using assumptions related to a correlation between animal feeds and animal machinery sales during year 1996. A time series data for these types of animal research is not available.

Another subject related to the livestock industry is R&D investment for food and kindred products. Klotz et al. (1995) showed that the total private investment on food processing increased from only $92 million in 1960 to over 1.2 billion dollars in 1997. Food processing research and development by the private sector has almost doubled every ten years since 1960.

In conclusion, the U.S. agricultural private sector invested over $350 million in animal research in 1997. Two thirds (about $250 million) were used for research related to animal health and protection. The other third funds research in animal breeding (about $100 million). The private sector invests very little in areas such as animal machinery, feed and nutrition, and livestock management and economics. The private sector is probably uncertain of research and development outcomes in the livestock sector because of the biological characteristics of the animal and the longer lag for research benefits compared to crops and food processing.

4.4 Northern Plains Public (SAES) Animal Research

In order to build the R&D sector for the purpose of this study, there is a need to use sector-wise research and development expenditures for the required economies in the selected the Northern Plains States. There are slight differences between the data obtained from the National Science Foundation and data from the U.S. Department of Agriculture on Research and Development spending. In total, data obtained from IMPLAN databases matched the National Science Foundation statistics. However USDA data is more precise when it comes to differences between different livestock commodities. Table (4-5) shows the total (all agricultural and non agricultural research) R&D expenditure in the selected Northern Plains States (Colorado, Kansas, Nebraska, and South Dakota) classified by the source of fund (Appendix A shows the Social Accounting Matrix of Colorado). Total expenditure of the R&D sector in the SAM models matches the data obtained in Table 4-5. The state of Colorado spent over $3.2 billion in research and development in all agricultural and non-agricultural sectors in 1997. Kansas spent about $1.4 billion the same year. Nebraska spent $275 million in R&D, while South Dakota spent $71 millions in the same year. The NSF data is used only for the purpose of checking consistency and accuracy of the IMPLAN data when all the economy's sectors are included. For simulating the supply shocks to the livestock sector in later chapters of this study, data from the USDA is used due to the greater detail needed. The following section explores data from the Current Agricultural Research Inventory System (CRIS) of the USDA to provide details about spending by commodity in the Northern Plains Region.

Table (4-5) Total Agricultural and Non-Agricultural Public and Private R&D in the Northern Plains States in 1997 (Thousand Dollars)

State	Public				Private	Total
	Federal	State	Universities	Non Profits		
Colorado	1,340,231	26,833	50,422	36,910	1,750,815	3,205,211
Percent	42%	1%	2%	1%	55%	100%
Kansas	255,490	45,002	56,752	8,809	984,483	1,350,536
Percent	19%	3%	4%	1%	73%	100%
Nebraska	82,981	47,089	49,290	5,139	90,860	275,359
Percent	30%	17%	18%	2%	33%	100%
South Dakota	41,955	8,341	3,043	1,484	16,542	71,365
Percent	59%	12%	4%	2%	23%	100%
Regional Total	**1,720,657**	**127,265**	**159,507**	**52,342**	**2,842,700**	**4,902,471**
Percent	**35%**	**3%**	**3%**	**1%**	**58%**	**100%**

Source: Summarized from National Science Foundation (NSF), State Profiles, 2000

Many sponsors supported agricultural research, however the USDA (SAES) is the biggest supporter of public agricultural research. Annually, the ERS publishes reports of the Inventory of Agricultural Research- Current Research Information System (CRIS, 1990-1997) that contain valuable information about agricultural research expenditure at the state level, classified by source of USDA funding and destination subject and commodity. Table (4.6) reports agricultural research expenditures among different commodities for the period 1990-1997 for the selected Northern plains states.

4.4.1 Livestock Research Cost in The Northern Plains

In Colorado, the Agricultural Experiment Station's total investment in animal and biotechnology related to animal research summed to over $5.3 million in 1997 (Table 4-6). More than half of the USDA funding for animal research (about $3.1 million) was used for beef research. Forage crops research ranked second, with an investment of $737,009, and dairy cattle came in third, at $583,120. USDA funding for all agricultural research in Colorado increased from $25 million in 1990 to about $29 million in 1997, while funding for animal research decreased from $6.3 million to about $5.3 million over the same period.

The commodity facing the greatest decline in federal funding to animal research in Colorado was beef research, as it decreased from $4.2 million in 1990 to $3.1 million in 1997. Animal research funds for dairy, poultry, pasture, and forage crops research grew faster than beef research between 1990 and 1997. In other words, most animal research saw increased funding throughout the last decade except for beef research in Colorado.

Table (4-6) Total USDA (SAES) Research Investment (Thousand $) Allocated to Selected States of the Northern Plains 1990-1997

Colorado	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Pasture	25	6	40	67	90	51	48	46
Forage Crops	692	306	796	892	623	645	549	737
Poultry	70	95	8	0	26	100	92	119
Beef Cattle	4,239	4,341	3,544	3,894	3,891	3,910	3,181	3,142
Dairy Cattle	260	53	196	323	371	510	408	584
Swine	2	5	17	87	0	0.3	0	0
Sheep and Wool	631	712	420	459	425	430	412	359
Food	369	462	431	685	113	157	189	289
Bio Cell System	58	60	48	60	51	50	35	30
Total	6,346	6,041	5,498	6,465	5,588	5,854	4,914	5,307
All Other Agricultural Research	18,946	18,963	21,567	21,904	24,438	22,558	23,229	23,620
Total	**25,291**	**25,004**	**27,066**	**28,369**	**30,026**	**28,412**	**28,144**	**28,926**

Kansas	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Pasture	0	0	0	0	0	0	35	46
Forage Crops	1,074	1,084	1,338	1,241	1,076	1,083	1,519	1,320
Poultry	1,232	1,266	890	628	414	365	484	444
Beef Cattle	6,786	6,742	6,281	5,922	6,615	7,107	6,269	7,376
Dairy Cattle	1,110	1,543	1,382	1,645	1,572	1,478	2,143	2,155
Swine	1,700	1,994	1,759	2,236	2,277	2,126	1,918	2,449
Sheep and Wool	733	856	1,115	964	1,072	990	847	480
Food	579	542	968	1,100	1,087	935	799	467
Bio Cell System	134	127	3	13	36	18	39	20
Total	13,349	14,154	13,736	13,748	14,150	14,103	14,054	14,758
All Other Agricultural Research	24,838	25,222	26,817	27,764	29,440	30,559	30,689	31,039
Total	**38,187**	**39,376**	**40,553**	**41,512**	**43,590**	**44,662**	**44,744**	**45,796**

Table (4-6) Continued Total USDA (SAES) Research Investment (Thousand $) Allocated to Selected States of the Northern Plains 1990-1997

Nebraska	1990	1991	1992	1993	1994	1995	1996	1997
Pasture	276	332	361	331	257	332	380	329
Forage Crops	872	1,086	540	415	472	557	447	567
Poultry	887	884	924	764	659	576	578	744
Beef Cattle	9,297	10,536	11,693	11,461	12,075	11,324	10,296	10,248
Dairy Cattle	1,285	1,288	1,656	1,650	1,675	1,978	2,213	2,166
Swine	5,329	4,051	3,473	3,592	3,331	3,320	5,488	5,776
Sheep and Wool	1,926	2,310	1,856	1,875	1,833	1,769	1,422	1,373
Food	455	500	937	1,142	1,170	1,185	1,577	1,407
Bio Cell System	0	0	52	57	105	117	114	196
Total	20,327	20,987	21,493	21,288	21,578	21,158	22,516	22,806
All Other Agricultural Research	19,780	25,725	29,043	31,201	32,832	35,552	58,390	36,398
Total	**40,107**	**46,712**	**50,536**	**52,489**	**54,410**	**56,711**	**80,905**	**59,204**

South Dakota	1990	1991	1992	1993	1994	1995	1996	1997
Pasture	7	10	16	14	0	0	16	26
Forage Crops	433	455	340	316	465	336	355	510
Poultry	119	128	112	133	112	146	177	158
Beef Cattle	2,340	2,414	2,715	2,341	2,400	2,256	2,273	1,846
Dairy Cattle	532	679	973	783	992	823	1,083	1,044
Swine	915	1,096	885	965	1,058	1,054	1,116	1,105
Sheep and Wool	298	259	288	254	431	154	249	410
Food	56	58	70	0	0	0	0	0
Bio Cell System	0	0	0	0	0	0	0	0
Total	4,700	5,099	5,399	4,806	5,458	4,768	5,268	5,098
All Other Agricultural Research	7,004	8,212	8,562	10,180	8,940	9,049	8,961	8,814
Total	**11,704**	**13,311**	**13,961**	**14,986**	**14,398**	**13,817**	**14,229**	**13,912**

Kansas's public agricultural research is estimated to be $46 million dollars in 1997, compared to $38 million in 1990. About $14.7 million of the total public agricultural research was devoted to animal research. In Kansas, as in Colorado, beef research funding of $7.3 million represented about half of the total agricultural experiment station animal research budget ($14.8 million). However, Kansas beef research funding grew during the period 1990 to 1997 from around $6.7 million to over $7.3 million. Poultry, sheep and wool research funds in Kansas declined during the same time period. Funding research in dairy cattle and swine roughly doubled from $1 million in 1990 (Table 4-6).

Nebraska recorded the highest spending in public agricultural research among the other four selected Northern Plains states during the period 1990 to 1997. A little less than a third of agricultural research funds were used for animal research ($22.8 million out of total agricultural research fund of $59 million). Half of the public animal research money was used to support beef research. Beef research funds in Nebraska have been stable at about $10 million annually since 1990. Dairy cattle research funds almost doubled between 1990 and 1997.

In South Dakota, total public agricultural research was estimated to be between $11.7 and $13.9 million during the period 1990 to 1997. In South Dakota about 37% of agricultural research funds obtained from USDA every year are allocated to animal research. Animal research funds in South Dakota are also stagnant at this level at about $4.6 to $5.4 million annually. Public animal research's larger components in South Dakota are beef, dairy cattle, and swine with research funds varying between $1.8, $1, and $1.1 million respectively.

4.5 Animal Research Scientist / Years in the Northern Plains Region

The inventory of agricultural research published by the CRIS system of the USDA shows the yearly number of scientists working in different subjects related to animal research, who were supported by the state agricultural experiment stations in great detail. Table (4-7) shows that the number of full-time equivalent animal research scientists in Colorado went down from 11.3 to 7.3 scientists between 1990 and 1997. In Kansas the number of scientists also decreased from 44.4 full time equivalents to 32.7 during the same time period (1990 – 1997). The USDA public funding in Nebraska supported another 38 scientists reported to be working in animal-related research. Adding the 20 full-time equivalent scientists in South Dakota, the total is equal to about 106 scientists working on animal research in the four States (Table 4-7).

Table (4-7) Animal Research Scientists in Selected Northern Plains States (Scientist/Years)

Colorado	1990	1991	1992	1993	1994	1995	1996	1997
Pasture	0.1	0.0	0.1	0.1	0.2	0.1	0.1	0.1
Forage Crops	2.3	0.9	1.4	1.6	1.5	2.1	1.3	1.9
Poultry	0.5	0.2	0.0	0.0	0.1	0.1	0.1	0.1
Beef Cattle	8.2	7.0	6.8	8.0	6.1	6.0	6.0	6.1
Dairy Cattle	0.5	0.2	0.1	0.4	0.4	0.4	0.3	0.6
Swine	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Sheep and Wool	2.1	1.4	0.8	1.2	1.1	1.0	0.9	0.5
Food	1.1	2.2	0.0	1.8	0.6	0.7	0.7	1.0
Bio Cell System	0.4	0.3	0.9	0.3	0.3	0.3	0.3	0.3
Total	15.2	12.2	10.1	13.5	10.3	10.7	9.7	10.6
All Other Agricultural Research	54.2	49.8	53.8	51.6	56.7	54.1	51.8	46.4
Total	69.4	62.0	63.9	65.1	67.0	64.8	61.5	57.0
Animal Research	11.3	8.8	7.7	9.7	7.7	7.5	7.3	7.3
Animal Research %	16.3%	14.2%	12.1%	14.9%	11.5%	11.6%	11.9%	12.8%

Kansas	1990	1991	1992	1993	1994	1995	1996	1997
Pasture	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2
Forage Crops	5.4	4.5	5.4	6.2	5.3	5.3	7.2	5.6
Poultry	4.1	4.1	3.0	2.1	2.2	1.7	2.4	2.1
Beef Cattle	25.7	22.3	19.3	16.0	16.2	16.8	18.8	22.4
Dairy Cattle	4.9	5.0	4.4	5.6	4.9	5.0	4.7	4.9
Swine	6.8	7.3	5.9	8.4	6.0	6.6	6.8	8.6
Sheep and Wool	2.9	2.6	3.1	2.4	3.4	3.8	3.0	1.9
Food	2.0	3.0	4.2	4.7	4.0	3.2	2.5	1.3
Bio Cell System	1.3	1.1	0.0	0.1	0.2	0.1	0.1	0.1
Total	53.1	49.9	45.3	45.5	42.2	42.5	45.7	47.1
All Other Agricultural Research	144.6	126.4	132.1	134.0	136.8	139.9	136.9	137.8
Total	197.7	176.3	177.4	179.5	179.0	182.4	182.6	184.9
Animal Research	44.4	41.3	35.7	34.5	32.7	33.9	35.7	39.9
Animal Research%	22.5%	23.4%	20.1%	19.2%	18.3%	18.6%	19.6%	21.6%

Table (4-7 Continued) Animal Research Scientists in the Northern Plain Selected States (Scientist/Years)

Nebraska	1990	1991	1992	1993	1994	1995	1996	1997
Pasture	0.6	0.7	0.9	0.6	0.6	0.5	0.4	0.5
Forage Crops	3.4	3.2	1.8	1.3	1.6	1.6	0.9	0.9
Poultry	3.9	3.8	4.0	3.9	3.2	2.4	2.4	1.9
Beef Cattle	16.0	17.1	18.9	17.0	18.8	18.5	16.3	18.6
Dairy Cattle	4.4	4.3	4.8	4.9	4.9	5.6	5.1	5.3
Swine	13.1	12.6	10.3	9.8	9.9	10.5	11.1	11.2
Sheep and Wool	2.3	3.3	2.5	2.4	2.1	1.9	1.2	1.2
Food	2.3	2.0	1.3	2.7	3.5	2.2	3.0	4.5
Bio Cell System	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4
Total	46.0	47.0	44.9	43.0	45.0	43.6	40.8	44.5
All Other Agricultural Research	103.1	107.1	111.7	106.5	118.1	121.5	114.0	110.3
Total	149.1	154.1	156.6	149.5	163.1	165.1	154.8	154.8
Animal Research	39.7	41.1	40.5	38.0	38.9	38.9	36.1	38.2
Animal Research%	26.6%	26.7%	25.9%	25.4%	23.9%	23.6%	23.3%	24.7%

South Dakota	1990	1991	1992	1993	1994	1995	1996	1997
Pasture	0.1	0.1	0.1	0.3	0.0	0.0	0.0	0.3
Forage Crops	3.4	3.3	3.0	2.1	3.4	2.3	2.3	20.0
Poultry	1.2	1.1	1.1	1.0	0.8	1.2	1.0	0.9
Beef Cattle	6.8	5.9	8.6	7.4	9.0	8.5	5.2	7.6
Dairy Cattle	4.0	4.6	4.7	4.1	5.3	4.5	4.6	4.0
Swine	5.4	6.1	5.6	5.7	6.7	7.2	5.3	7.3
Sheep and Wool	1.4	0.8	1.1	1.0	1.4	0.7	0.8	1.0
Food	0.6	0.6	0.6	0.0	0.0	0.0	0.0	0.0
Bio Cell System	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	22.9	22.5	24.8	21.6	26.6	24.4	19.2	41.1
All Other Agricultural Research	50.2	50.3	54.3	55.3	52.5	51.9	57.5	31.2
Total	73.1	72.8	79.1	76.9	79.1	76.3	76.7	72.3
Animal Research	18.8	18.5	21.1	19.2	23.2	22.1	16.9	20.8
Animal Research%	25.7%	25.4%	26.7%	25.0%	29.3%	29.0%	22.0%	28.8%

4.6 Value of Livestock Production in the Northern Plains States

Table (4-8) shows that the gross value of animal production in the selected Northern Plains states totaled over $15 billion in 1997. The final value of animal output produced value in Colorado reached $2.9 billion in 1997, slightly less than the value reported in 1990 ($3.1 billion). In Kansas, total animal production value is estimated to be around $5 billion annually. The value of animal products at the farm level varied between $5.3 and $6.2 billion in Nebraska during the same time period. Relatively, South Dakota produced the lowest quantity of meat and other animal products. Animal production value in South Dakota is estimated to be $1.7 billion in 1997, down from $2.1 billion in 1990. Table (4-8) shows the animal production value between meat animals, dairy products, poultry and eggs, and other livestock products in the four selected states.

Table (4-8) Value of Livestock Production in The Selected Northern Plain States in Million of Dollars (1990-1997)

Colorado	1990	1991	1992	1993	1994	1995	1996	1997
Final animal output	3,079	2,678	2,798	2,987	2,734	2,743	2,821	2,960
Meat animals	2,752	2,239	2,453	2,621	2,413	2,292	2,365	2,494
Dairy products	188	166	189	189	214	206	246	223
Poultry and eggs	131	141	96	107	107	112	132	119
Miscellaneous livestock	25	24	27	28	30	34	37	38
Home consumption	7	7	5	6	7	6	6	8
Value of inventory adjustment	-24	100	28	36	-38	93	36	77
Kansas	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Final animal output	5,016	4,756	4,966	4,930	4,947	4,641	4,612	4,927
Meat animals	4,753	4,562	4,591	4,666	4,561	4,329	4,308	4,713
Dairy products	163	141	151	135	142	143	168	163
Poultry and eggs	24	21	19	24	27	32	37	37
Miscellaneous livestock	29	32	38	38	32	29	24	23
Home consumption	12	9	14	12	14	13	12	12
Value of inventory adjustment	36	-10	152	55	171	94	63	-21
Nebraska	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Final animal output	6,228	5,898	5,758	6,008	5,318	5,331	5,397	5,629
Meat animals	5,789	5,670	5,408	5,574	5,140	4,882	5,007	5,221
Dairy products	172	144	151	136	138	133	148	134
Poultry and eggs	73	78	75	100	90	104	140	135
Miscellaneous livestock	44	42	43	42	31	28	24	17
Home consumption	11	11	10	10	9	9	9	10
Value of inventory adjustment	140	-47	73	144	-90	176	69	112
South Dakota	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Final animal output	2,047	2,015	1,904	1,969	1,767	1,675	1,607	1,744
Meat animals	1,697	1,597	1,481	1,684	1,383	1,434	1,329	1,495
Dairy products	221	201	211	207	202	196	212	181
Poultry and eggs	52	57	51	50	45	53	71	72
Miscellaneous livestock	24	24	24	25	29	32	40	33
Home consumption	13	14	12	12	11	10	10	11
Value of inventory adjustment	40	122	125	-9	98	-49	-54	-48
Region Total Value of Animal Production	16,371	15,347	15,426	15,894	14,766	14,390	14,436	15,259

Source: National and State Net Value Added, Net Cash Income, Cash Receipts, Government Payments, and Production. ERS. USDA. 1990-1997

Table (4-8) figures were used to estimate the animal public research intensity index in the four selected Northern plains states during the period 1990 to 1997. Intensity of animal public research is estimated by simply dividing the dollar cost of public research expenditure for meat animals, dairy cattle, and poultry and eggs by the value of production in the four states during the period 1990 to 1997 (Table 4-9). The measure indicates the relationship between growth of production value (Table 4-8 above) and growth of funding of animal research (Figure 4.4 below).

Overall regional research intensity did not vary much during the last decade, but detail of research intensity showed a large variation within the breakdown of intensity. Dairy cattle and poultry research intensity had a greater variation compared to beef research. For example, poultry research intensity diminished noticeably in Colorado, Kansas, and Nebraska between 1990 and 1997, while dairy cattle research intensity increased significantly during the same period. Changes in research intensity can be related to both changes in research funding and growth of value of production. Gross value of production seems stable in the region, leaving changes in funding to be the factor determining the intensity of research. Dairy, swine, and poultry research funding witnessed a large variation causing the intensity of research to also vary during the last decade (Figures 4-6 A to D). By varying research intensity the public sector sent signals to the private sector to intensify research in dairy, swine and poultry as shown above. This proof that allocation of research among different applications related to different animal commodities is very sensitive and can shift focus of the private research to reallocate R&D funding among areas of applied research.

Table (4-9) Animal Public SAES Research Intensity in The Selected Northern Plain States (1990-1997)*

Colorado	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Total Animal Research	0.17%	0.19%	0.15%	0.16%	0.17%	0.18%	0.15%	0.14%
Meat animals	0.18%	0.23%	0.16%	0.17%	0.18%	0.19%	0.15%	0.14%
Dairy Cattle	0.14%	0.03%	0.10%	0.17%	0.17%	0.25%	0.17%	0.26%
Poultry and eggs	0.05%	0.07%	0.01%	0.00%	0.02%	0.09%	0.07%	0.10%
Kansas	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Total Animal Research	0.23%	0.26%	0.23%	0.23%	0.24%	0.26%	0.25%	0.26%
Meat animals	0.19%	0.21%	0.20%	0.20%	0.22%	0.24%	0.21%	0.22%
Dairy Cattle	0.68%	1.09%	0.91%	1.22%	1.11%	1.03%	1.27%	1.32%
Poultry and eggs	5.10%	5.95%	4.57%	2.65%	1.56%	1.13%	1.30%	1.19%
Nebraska	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Total Animal Research	0.30%	0.32%	0.34%	0.32%	0.37%	0.36%	0.37%	0.36%
Meat animals	0.29%	0.30%	0.31%	0.30%	0.34%	0.34%	0.34%	0.33%
Dairy Cattle	0.75%	0.89%	1.10%	1.21%	1.21%	1.49%	1.50%	1.62%
Poultry and eggs	1.21%	1.13%	1.24%	0.76%	0.74%	0.56%	0.41%	0.55%
South Dakota	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Total Animal Research	0.21%	0.23%	0.26%	0.23%	0.28%	0.26%	0.30%	0.26%
Meat animals	0.21%	0.24%	0.26%	0.21%	0.28%	0.24%	0.27%	0.22%
Dairy Cattle	0.24%	0.34%	0.46%	0.38%	0.49%	0.42%	0.51%	0.58%
Poultry and eggs	0.23%	0.23%	0.22%	0.27%	0.25%	0.27%	0.25%	0.22%
Region Intensity of Animal Research	0.24%	0.27%	0.26%	0.25%	0.28%	0.28%	0.28%	0.28%

* Research Intensity = (($ of Research/ $ value of Production) X 100

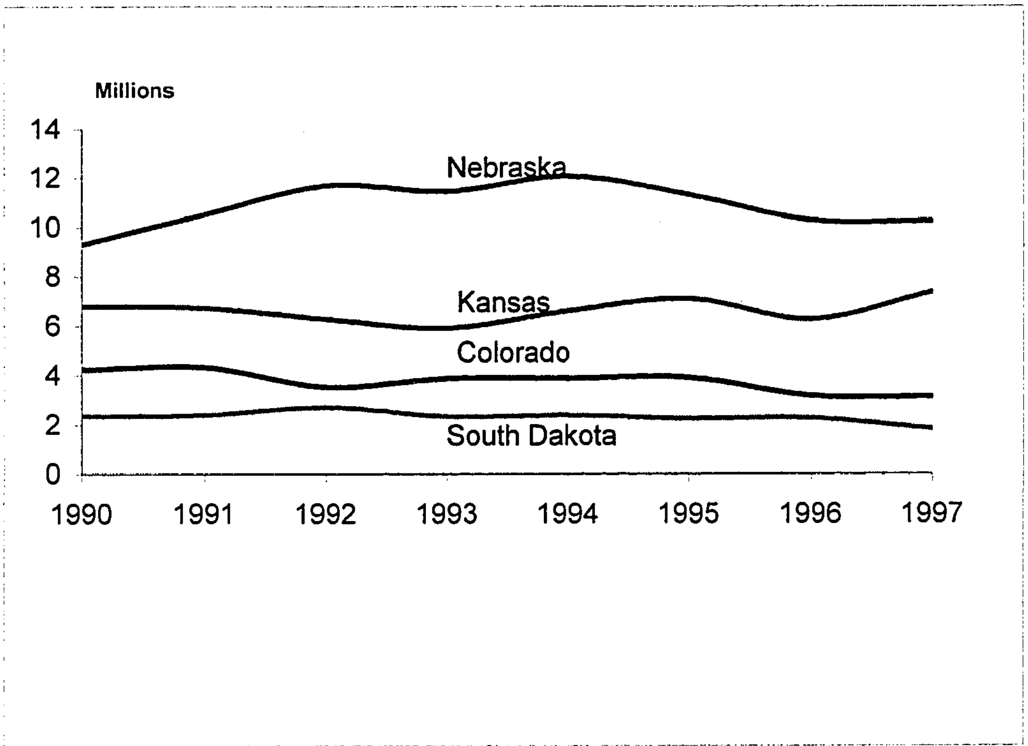


Figure (4-6 A) Beef Public USDA (SAES) Research Expenditure of Selected Northern Plains States 1990-1997

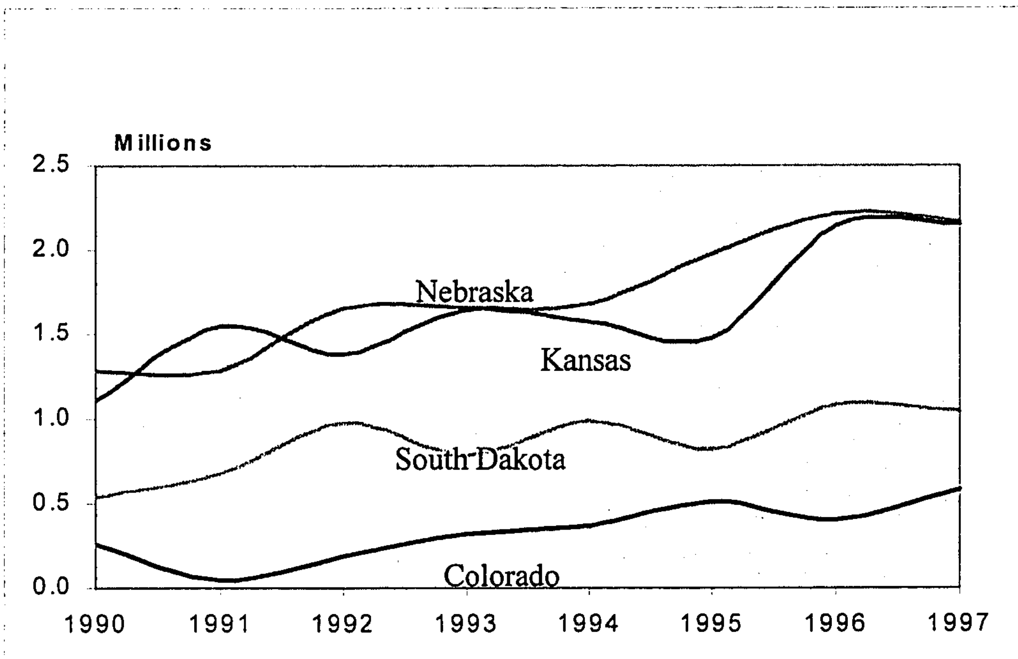


Figure (4-6 B) Dairy Cattle Public USDA (SAES) Research Expenditure of Selected Northern Plains States

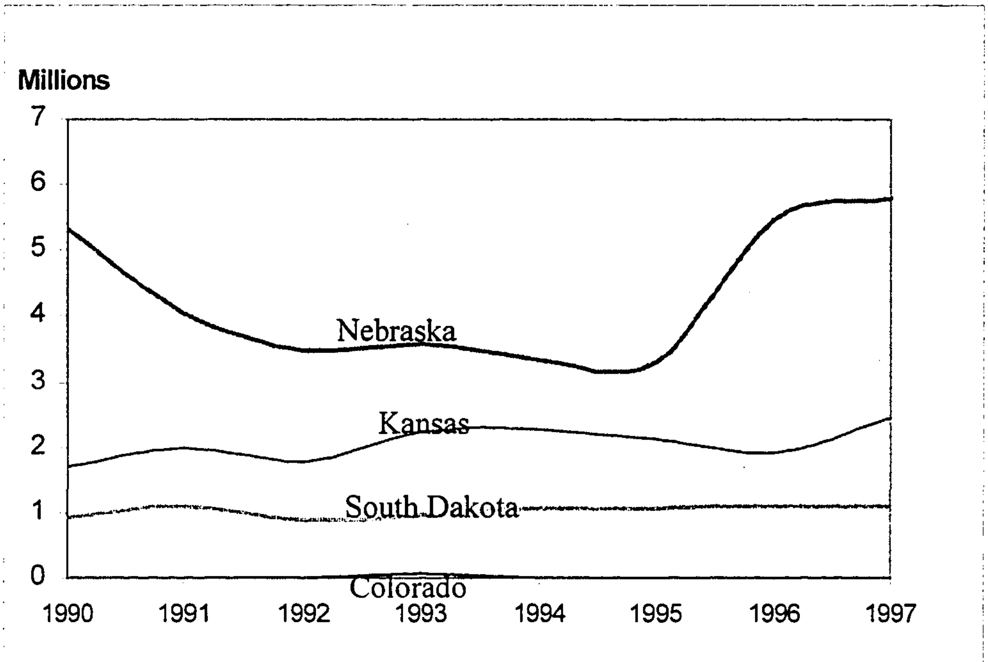


Figure (4-6 C) Swine Public USDA (SAES) Research Expenditure of Selected Northern Plains States 1990-1997

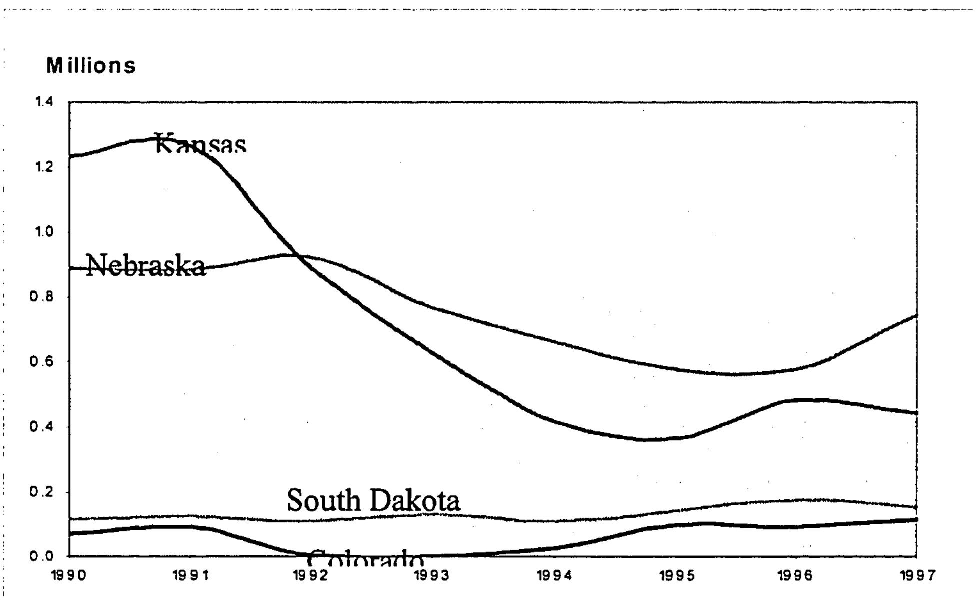


Figure (4-6 D) Poultry Public USDA (SAES) Research Expenditure of Selected Northern Plains States 1990-1997

4.7 Building the R&D Sector SAM

Input-output data derived from IMPLAN for this research included a sector for research and development. The R&D column in the SAM model of investment in R&D was compared to total investment in agricultural research from the National Science Foundation (NSF) at the state levels. For the purpose of this study the R&D considered as a separate sector within the SAM structure and framework. Data from CRIS (Current Research Information System), National Science Foundation (NSF) publications and IMPLAN were combined to build the expenditure and income estimates of this research SAM's R&D sector (Appendix B). Previous studies, which evaluated rates of return to investment in agricultural research, used only direct cost of research. Direct costs include only material, labor, and capital expenditure of the agricultural R&D. In this study the scope goes beyond that to incorporate other costs paid by the economy, such as the opportunity cost of using resources in R&D rather than any other investment.

There is a direct cost that the R&D sector pays, however there are returns to factor of production that the R&D gains as a result of the investment. Working within the CGE model allows for these returns (returns to labor, capital, and land) to the R&D sector to be counted. The argument this study is raising is that direct expenditure cost of R&D does not represent the real cost of investment. R&D Investment requires a combination of resources from all sources and providers of the factors of production, which include all economic agents.

Chapter Five: Results; Productivity and Benefits of Livestock Research

5.1 Introduction

Productivity captures the relationship between outputs and inputs in the livestock production sector. It is most commonly expressed as Total Factor Productivity (TFP), which is the ratio of total output, usually measured in an index form, to total inputs, also measured as an index. If the ratio of total outputs to total inputs is increasing, more outputs can be obtained for a given level of inputs.

Ahearn et al. (1998) estimated that the average annual growth in farm output was 1.88 percent over 1948-1994, one of the highest rates of productivity growth of all industries.

Ball et al. (2001) concluded that a properly constructed measure of productivity growth for the aggregate farm sector at the national level is certainly important. It provides a useful summary statistic indicating how production is being advanced through productivity gains in agriculture. However national level productivity may mask important state-specific or regional trends. Ball et al. (2001) showed high productivity volatility across states which makes the national productivity a function of productivity differences among the individual states. One remarkable similarity that exists across all states is that productivity is increasing everywhere. For the period 1960-1996, every state exhibited a positive and generally substantial average annual rate of productivity growth. There is considerable variance following a climatic regional pattern. The median rate of productivity between 1960 and 1996 was 1.94 percent per year. Nearly half of the states (19 of 48) had productivity growth rates averaging more than 2 percent per year. Only two states (Oklahoma and Wyoming) had an average rate of growth less than 1 percent per year. When coefficients of variation of productivity were compared for all 48 states, Ball et al. (2001) showed a narrowing of the range of level of productivity between 1960 and 1987. This result indicated that, while some states grew more rapidly than others, the cross-section dispersion decreased, which implies that the states that grew most rapidly were those with lower initial levels of productivity. This finding's consistent with Gerschenkron's (1952) notion of the advantages of relative backwardness. The states that were particularly far behind had the most to gain from the diffusion of technical information and proceeded to grow most rapidly.

Figure (5-1) shows an accelerating livestock productivity in most of selected Northern Plains Sates. The trend of livestock productivity in the major livestock production states in the Northern Plains has been increasing significantly since 1960s. Also, the graph shows that average productivity in the region has grown faster than the national average in recent years (except for South Dakota, which is close to the national average). This makes the region an ideal case study for investigating the share of technology and research on productivity growth over the last four decades, because the extent of technology diffusion and spill over. If a state shows high recent rates of productivity growth, it may indicate that the state is a recipient of research and development spill out from other states.

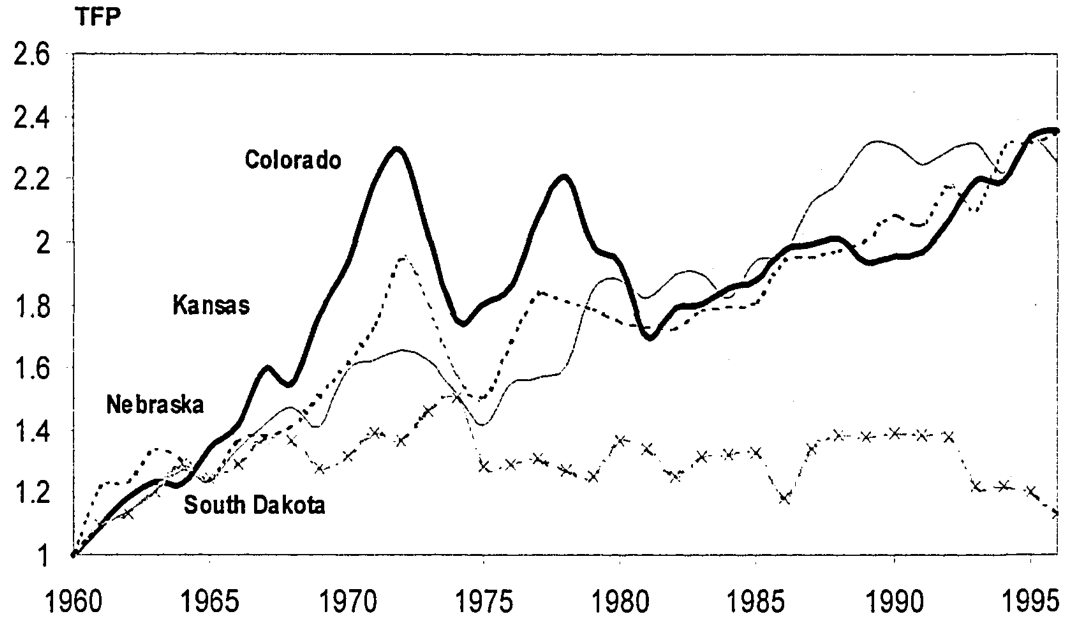


Figure (5-1) Livestock Productivity in the Selected Northern Plains States 1960-1996

Source: Ball and Nehring, USDA, 1998.

5.2 Selected Northern Plains Productivity

The rise in livestock's relative productivity during the 1970's is very obvious in the graphs of selected Northern Plains States (5-2 to 5-4). However the productivity graphs show that adoption of these new technologies varies slightly from one state to another. Nebraska, Colorado, and Kansas showed earlier adoption of technology compared to South Dakota. Since the early 1980s, both Colorado and Kansas showed a steady pattern of increasing livestock productivity. Productivity increases and growth of the livestock production sector since 1980s is due to number of factors including improvements in the dairy sector, improved breeds, higher nutrition efficiency, and better disease control methods.

5.3 Benefits of Livestock Research and Development – Colorado Productivity

Figure (5-2) shows the Colorado livestock sector experienced strong productivity growth. The livestock sector witnessed an increase of more than double of productivity over the last 36 years. The biological processes and characteristics of crops and livestock productivity are extremely different, so crop and livestock production might be expected to respond differently to regional geo-climatic conditions, research and development and to extension services.

Table (5-1) shows that Colorado livestock productivity outperformed crop productivity in most of the series, especially for the period 1987 to 1996. The average livestock productivity annual rate of growth between 1960-1996 was 2.05%, compared to 1.69% for crops. One could relate increasing livestock productivity in Colorado to a specifically high rate of poultry productivity that contributed to the overall livestock productivity. Demand for high quality beef also played a major role as an incentive for ranchers to produce more and increase their efficiency to gain from increasing demand. Increasing demand for exports of livestock is considered as another factor that encouraged ranchers either to increase output using the same amount of inputs or producing the same amount of output by applying less amount of inputs.

Table (5-1) Colorado—Farm Output, Input Use, and Productivity, 1960-96 (1960 = 1.0000)

Year	Total Farm Output	Livestock	Crops	Total Farm Input	Capital	Land	Labor	Materials	TFP
1960	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1961	1.0370	1.0869	0.9732	1.0029	0.9942	0.9833	0.9537	1.0322	1.0339
1962	1.0430	1.1817	0.8647	1.0507	0.9913	0.9558	0.9514	1.1272	0.9926
1963	1.0200	1.2357	0.7487	1.0279	0.9858	0.9521	0.8714	1.1278	0.9923
1964	1.0195	1.2298	0.7541	1.0021	0.9770	0.9561	0.8076	1.1154	1.0174
1965	1.0581	1.3407	0.7154	1.0419	0.9754	0.958	0.7883	1.2046	1.0155
1966	1.1747	1.4171	0.8757	1.0936	0.9972	0.9705	0.8227	1.2798	1.0741
1967	1.2400	1.5943	0.8073	1.1571	1.0249	1.0022	0.8538	1.3757	1.0717
1968	1.2711	1.5532	0.9258	1.1393	1.0477	1.0039	0.9001	1.3088	1.1157
1969	1.4351	1.768	1.0251	1.2405	1.0619	0.9769	0.8934	1.5279	1.1569
1970	1.5608	1.9342	1.0975	1.3002	1.0739	0.9688	0.8983	1.6524	1.2004
1971	1.7074	2.1918	1.0814	1.4047	1.1065	0.9873	0.8523	1.8828	1.2155
1972	1.7371	2.2888	1.0049	1.4444	1.116	0.9593	0.8097	1.9932	1.2026
1973	1.6211	2.0267	1.0962	1.3052	1.1287	0.9811	0.8912	1.6691	1.2420
1974	1.4824	1.7522	1.1159	1.2611	1.1619	0.9960	1.0872	1.4929	1.1756
1975	1.5144	1.8058	1.1245	1.2185	1.1778	0.9629	1.0032	1.4517	1.2428
1976	1.5709	1.8601	1.1805	1.2585	1.2042	0.9774	0.8878	1.5748	1.2483
1977	1.7060	2.0728	1.2168	1.3176	1.2254	0.9791	0.8443	1.7109	1.2948
1978	1.7968	2.2085	1.2457	1.4608	1.2583	0.9743	0.8136	2.0157	1.2300
1979	1.7384	1.989	1.4681	1.4005	1.2803	0.9664	0.7478	1.9194	1.2413
1980	1.7464	1.9297	1.5955	1.4273	1.3280	0.9688	0.8686	1.9127	1.2236
1981	1.6278	1.703	1.6315	1.3331	1.3291	0.9590	0.9530	1.6716	1.2211
1982	1.6492	1.7904	1.5576	1.3500	1.3066	0.9462	0.7545	1.8167	1.2216
1983	1.6743	1.8003	1.6072	1.3446	1.2765	0.8962	0.7739	1.8485	1.2452
1984	1.7506	1.8558	1.7187	1.3285	1.2648	0.9043	0.7745	1.8037	1.3177
1985	1.8379	1.8806	1.9068	1.3372	1.2322	0.894	0.9646	1.757	1.3744
1986	1.8126	1.977	1.6949	1.3177	1.1699	0.8691	0.8315	1.8117	1.3756
1987	1.8454	1.9917	1.7609	1.3153	1.1086	0.8343	0.9991	1.7844	1.4030
1988	1.8352	2.0119	1.6943	1.3064	1.0967	0.8223	0.8400	1.8303	1.4047
1989	1.7672	1.9374	1.6313	1.2527	1.0926	0.8242	0.8738	1.7027	1.4107
1990	1.8300	1.9553	1.7757	1.2331	1.0783	0.8131	0.7823	1.7034	1.4840
1991	1.8306	1.9684	1.7521	1.1511	1.0656	0.8013	0.6206	1.6061	1.5903
1992	1.8928	2.0665	1.7509	1.1646	1.0600	0.8169	0.5768	1.6573	1.6253
1993	2.0060	2.1982	1.8404	1.1880	1.0455	0.8181	0.5648	1.7197	1.6885
1994	2.0042	2.1929	1.845	1.2248	1.0368	0.8173	0.5492	1.8167	1.6364
1995	2.0641	2.3323	1.7964	1.2734	1.0153	0.8182	0.5516	1.9398	1.6210
1996	2.0924	2.3502	1.8397	1.2615	1.0079	0.8238	0.6251	1.8485	1.6586
Average Annual Rates of Growth									
1960-96	0.0205	0.0237	0.0169	0.0065	0.0002	-0.0054	-0.0131	0.0171	0.0141

Source: USDA. ERS. Productivity in the United States 1960-1996

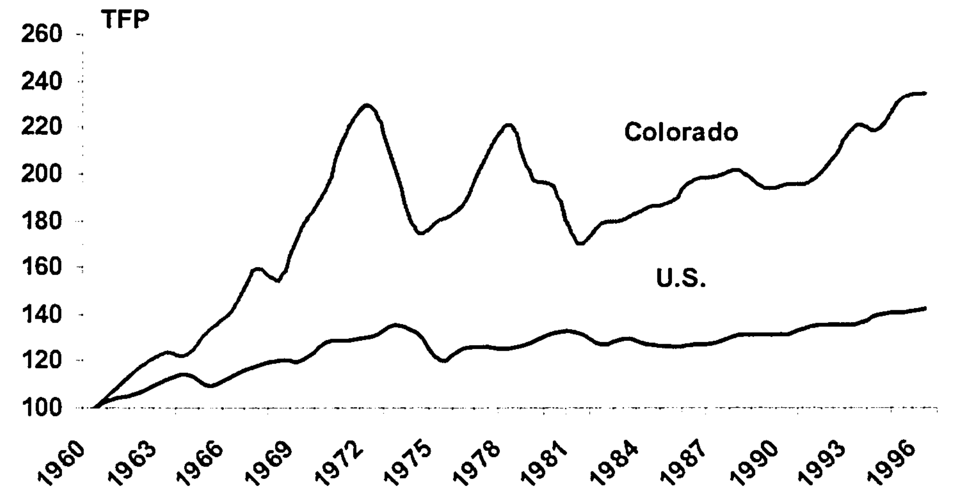


Figure (5-2) Total Factor Productivity for Livestock Output in the United States and Colorado, 1960-1996

Table (5-1) shows that Colorado Total Factor Productivity (TFP) steadily increased from 1 in 1960 to 1.6586 in 1996, while productivity of livestock more than doubled for the same period. The pattern of Colorado livestock productivity seems more fluctuating compared to the crop productivity especially during the period of late 1960s to early 1980s. Since 1980, the pattern of livestock productivity increased over 22% due to number of factors including technology adoption. Ahearn (1998) identified several factors have been the most important sources of productivity change in agriculture. These factors include research and development, extension, infrastructure and government programs. Even though productivity change is a good sign for technological progress, alone it cannot be used to measure rate of return to investment in livestock research. A high rate of growth in Total Factor Productivity for livestock in Colorado could mean a high return to investment in livestock research, although other factors might have caused the increasing productivity.

Ball et al. (2001) studied agricultural total factor productivity and made a comparison of estimates of growth for the 48 contiguous States for the period 1960-1996, relying on the same data provided above. Colorado ranked 11th in this study on growth in livestock output. Ball et al. estimated a positive correlation between productivity growth and growth of the capital-labor ratio, implying embodiment of technology in capital. The states that show very high growth rates of productivity compared to others are those states which spill in technology is transferred from states that adopted technology in earlier years.

5.4 Benefits of Livestock Research and Development – Kansas Productivity

Kansas's livestock productivity shows a smoother, increasing pattern of productivity compared to the other states. As in Colorado, livestock total factor productivity in Kansas is higher than crop productivity. Kansas is another major regional producer and exporter of livestock products, along with Colorado and Nebraska. Total farm output productivity in Kansas is relatively high (Figure 5-3). This indicates that large portions of gains in livestock productivity are due to adoption of technologies that produce more output with same amount of input or reduce costs of production and increase livestock productivity. The average Kansas livestock annual rate of growth for livestock productivity between 1960-1996 was 2.37% compared to 1.55% for the crops (Table 5-2).

In Ball et al. (2001), Kansas livestock ranked 10th in terms of growth in livestock output during the period 1960-96 among the 48 contiguous States.

Table (5-2) Kansas--Farm Output, Input Use, and Productivity, 1960-96 (1960 = 1.0000)

Year	Total Farm Output	Livestock	Crops	Total Farm Input	Capital	Land	Labor	Materials	TFP
1960	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1961	1.0325	1.2141	0.8973	1.0436	1.0084	0.9505	0.9374	1.1328	0.9894
1962	0.9795	1.2342	0.7918	1.0113	1.0086	0.9277	0.9166	1.0824	0.9686
1963	0.9819	1.3433	0.723	1.0428	1.0122	0.9396	0.8841	1.1631	0.9416
1964	0.9713	1.3113	0.726	0.9889	1.0155	0.9266	0.8645	1.0626	0.9823
1965	1.0301	1.2391	0.8625	0.9938	1.0244	0.9214	0.8532	1.0792	1.0365
1966	1.0227	1.3662	0.7668	1.0352	1.0626	0.915	0.8284	1.1785	0.9879
1967	1.081	1.3838	0.8501	1.0276	1.0827	0.9662	0.7732	1.1737	1.052
1968	1.1514	1.4087	0.9518	1.0277	1.1196	0.9478	0.7262	1.2041	1.1204
1969	1.2638	1.504	1.0796	1.0604	1.1502	0.9057	0.6724	1.3446	1.1918
1970	1.2593	1.6155	0.9729	1.0692	1.176	0.8905	0.6583	1.3792	1.1778
1971	1.4338	1.743	1.2003	1.0973	1.1872	0.9058	0.6676	1.4349	1.3067
1972	1.5432	1.9459	1.2159	1.18	1.1985	0.8648	0.6641	1.6709	1.3078
1973	1.5497	1.7888	1.3801	1.1732	1.2047	0.9535	0.6966	1.5917	1.3209
1974	1.2798	1.5689	1.0841	1.0792	1.2719	0.9744	0.6506	1.3768	1.1859
1975	1.3316	1.5078	1.1912	1.0649	1.2935	0.968	0.6242	1.3571	1.2504
1976	1.4113	1.6806	1.2135	1.1649	1.3341	0.9657	0.6809	1.54	1.2116
1977	1.5617	1.8345	1.36	1.186	1.3728	0.9614	0.6756	1.5852	1.3167
1978	1.4615	1.813	1.1931	1.3161	1.3927	0.9123	0.6445	1.9524	1.1105
1979	1.6177	1.7888	1.5474	1.3451	1.4104	0.9147	0.7552	1.9431	1.2026
1980	1.4714	1.7547	1.2766	1.3595	1.4616	0.9595	0.8122	1.9111	1.0824
1981	1.5036	1.733	1.3573	1.2864	1.4268	0.9598	0.8485	1.7168	1.1688
1982	1.6191	1.7257	1.5831	1.3002	1.3669	0.9396	0.7716	1.8483	1.2453
1983	1.4872	1.7844	1.2838	1.2829	1.3487	0.8463	0.7773	1.8844	1.1592
1984	1.5957	1.7998	1.475	1.2265	1.315	0.8895	0.5856	1.8317	1.301
1985	1.718	1.811	1.7008	1.2246	1.2907	0.8872	0.645	1.7961	1.4029
1986	1.7266	1.943	1.6004	1.2274	1.2275	0.8537	0.5742	1.9135	1.4068
1987	1.7201	1.9557	1.5754	1.1855	1.1715	0.821	0.5505	1.8609	1.451
1988	1.6104	1.9755	1.328	1.1541	1.1121	0.8121	0.4916	1.8581	1.3954
1989	1.54	2.0073	1.1529	1.1517	1.0822	0.842	0.5212	1.8277	1.3372
1990	1.8056	2.087	1.6393	1.2054	1.054	0.8478	0.5588	1.9466	1.4979
1991	1.696	2.0546	1.4289	1.1236	1.0471	0.8326	0.4769	1.8111	1.5094
1992	1.876	2.1747	1.6909	1.1644	1.0116	0.859	0.4591	1.941	1.6112
1993	1.7749	2.1027	1.5495	1.1553	1.0032	0.8628	0.4657	1.9142	1.5363
1994	2.0069	2.3049	1.8293	1.1714	0.9787	0.8721	0.4467	1.9839	1.7133
1995	1.7797	2.3164	1.3807	1.2358	0.9748	0.8724	0.5395	2.0481	1.4401
1996	1.9965	2.3456	1.7484	1.2292	0.9471	0.8939	0.4928	2.0851	1.6243
Average Annual Rates of Growth									
1960-96	0.0192	0.0237	0.0155	0.0057	-0.0015	-0.0031	-0.0197	0.0204	0.0135

Source: USDA. ERS. Productivity in the United States 1960-1996

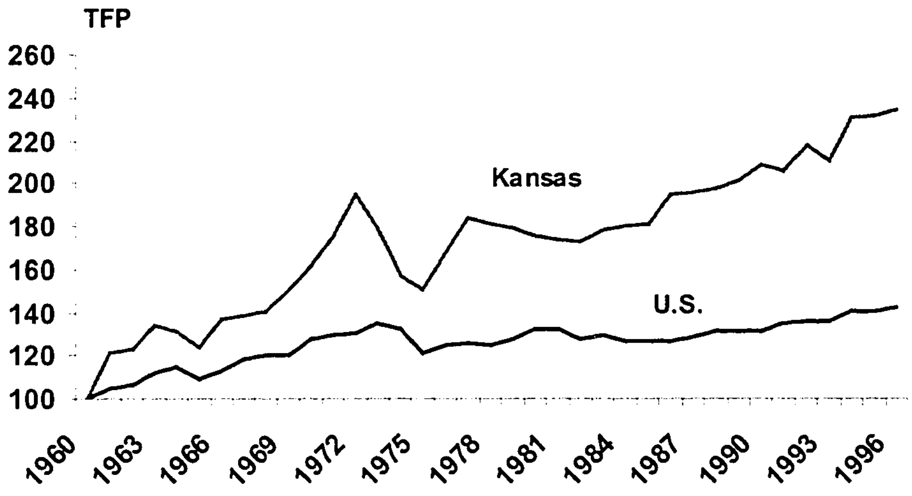


Figure (5-3) Total Factor Productivity for Livestock in the United States and Kansas, 1960-1996

5.5 Benefits of Livestock Research and Development – Nebraska Productivity

In Nebraska, Total Factor Livestock Productivity has more than doubled since 1960, showing higher rates compared to the national average (Figure 5-4). Average livestock productivity growth in Nebraska is estimated to be 2.26% annually over the period 1960- 1996. However, crop productivity in Nebraska is higher than livestock productivity. The Crop TFP in Nebraska is estimated to be 2.74% annually for the same time period. Livestock productivity in Nebraska also showed a smooth pattern of increasing productivity in livestock.

Table (5-3) shows that livestock productivity in Nebraska increased from 1 in 1960 to 2.25 in 1996. In other words, In Nebraska, as in Colorado, livestock productivity more than doubled since 1960. Ball et al. (2001) ranked Nebraska 13th among the states in livestock productivity growth.

Table (5-3) Nebraska --Farm Output, Input Use, and Productivity, 1960-96 (1960 = 1.0000)

Year	Total Farm Output	Livestock	Crops	Total Farm Input	Capital	Land	Labor	Materials	TFP
1960	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1961	0.9729	1.0795	0.8582	1.0094	1.0021	0.9295	0.9429	1.0617	0.9638
1962	1.028	1.1378	0.9099	1.0193	0.9961	0.9192	0.9187	1.1007	1.0086
1963	1.0511	1.2001	0.8951	1.0398	1.0114	0.9356	0.8452	1.1906	1.0108
1964	1.0333	1.27	0.8031	0.9992	1.0182	0.9041	0.8002	1.141	1.0341
1965	1.0534	1.2365	0.8682	0.9974	1.0238	0.9024	0.7906	1.1441	1.0562
1966	1.229	1.3395	1.1077	1.0504	1.0561	0.8815	0.7456	1.3008	1.17
1967	1.235	1.4167	1.049	1.0512	1.1106	0.9562	0.7047	1.3093	1.1749
1968	1.2421	1.4742	1.0118	1.0618	1.15	0.9167	0.6773	1.364	1.1698
1969	1.3226	1.4104	1.2394	1.0461	1.1715	0.906	0.6614	1.3369	1.2643
1970	1.3311	1.5936	1.0543	1.0986	1.2062	0.9039	0.6461	1.4953	1.2116
1971	1.4506	1.6278	1.2719	1.11	1.1996	0.9358	0.6579	1.5023	1.3068
1972	1.5213	1.659	1.3973	1.1664	1.2194	0.8919	0.6947	1.6235	1.3043
1973	1.5495	1.6256	1.505	1.217	1.2399	0.9778	0.7113	1.7015	1.2732
1974	1.3094	1.521	1.1426	1.1668	1.296	1.0121	0.803	1.4946	1.1223
1975	1.4147	1.4182	1.4021	1.1009	1.2932	1.0065	0.8108	1.3475	1.285
1976	1.4631	1.5478	1.3829	1.174	1.3402	1.0052	0.844	1.4778	1.2463
1977	1.6615	1.5698	1.7447	1.1682	1.3838	1.0019	0.7351	1.5309	1.4223
1978	1.7244	1.6045	1.8396	1.2896	1.4374	0.9549	0.8091	1.7804	1.3371
1979	1.9386	1.8515	2.0008	1.3908	1.4293	0.9676	0.794	2.0278	1.3939
1980	1.8207	1.8808	1.6931	1.4274	1.5272	0.9963	0.8393	2.0484	1.2755
1981	1.9909	1.819	2.1167	1.3501	1.5021	0.9952	0.7907	1.8817	1.4746
1982	1.9808	1.9004	2.0037	1.3866	1.4651	0.9691	0.7838	2.0271	1.4285
1983	1.7071	1.8968	1.433	1.3217	1.4582	0.8361	0.6952	2.0115	1.2916
1984	1.9569	1.8233	2.0174	1.2959	1.4236	0.9508	0.7581	1.8288	1.5101
1985	2.1844	1.9421	2.3557	1.305	1.4061	0.9461	0.7892	1.8471	1.6738
1986	2.1424	1.9614	2.2437	1.2807	1.2952	0.9132	0.7063	1.9063	1.6729
1987	2.1504	2.1268	2.043	1.2481	1.2064	0.8672	0.6644	1.9117	1.7229
1988	2.1506	2.1906	1.9532	1.242	1.1628	0.8685	0.657	1.9201	1.7315
1989	2.2364	2.3067	1.9938	1.2639	1.1876	0.9047	0.6657	1.9485	1.7694
1990	2.3492	2.3121	2.2453	1.2872	1.1371	0.9001	0.6881	2.008	1.825
1991	2.3152	2.246	2.2622	1.214	1.1592	0.9069	0.6342	1.8584	1.9071
1992	2.4303	2.2886	2.4771	1.206	1.1216	0.9186	0.5461	1.9145	2.0152
1993	2.2349	2.3134	1.949	1.1884	1.1049	0.9026	0.4561	1.9548	1.8806
1994	2.4628	2.2226	2.6441	1.1831	1.0639	0.9348	0.5399	1.8698	2.0816
1995	2.2579	2.3333	2.0658	1.2043	1.0597	0.9201	0.5402	1.9343	1.8749
1996	2.5202	2.2533	2.6856	1.2311	1.0275	0.9427	0.5679	1.9827	2.0472
Average Annual Rates of Growth									
1960-96	0.0257	0.0226	0.0274	0.0058	0.0008	-0.0016	-0.0157	0.019	0.0199

Source: USDA. ERS. Productivity in the United States 1960-1996

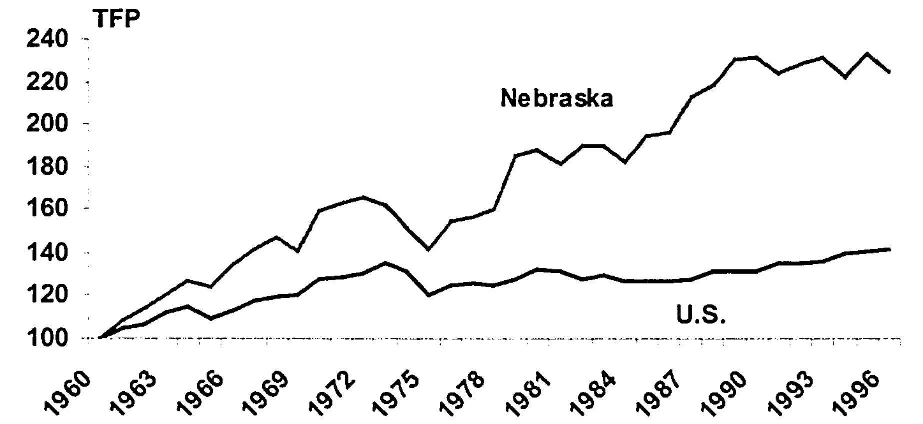


Figure (5-4) Total Factor Productivity for Livestock Output in the United States and Nebraska, 1960-1996

5.6 Benefits of Livestock Research and Development – South Dakota Productivity

Figure (5-5) shows that South Dakota Total Factor Livestock Productivity doubled since 1960, showing a fluctuating pattern above the national average before 1982, close to the national average during the 1980s and early 1990s, but below the national average from 1994 to 1996. Average livestock productivity growth in South Dakota is estimated to be 2.26% annually over the period 1960- 1996. However crop productivity in South Dakota is higher than livestock productivity. The Crop TFP in South Dakota is estimated to be 2.57% annually for the same time period. South Dakota livestock productivity differs from the other Northern Plains States as it shows a larger variation during the last four decades (Table 5-4).

Table (5-4) South Dakota --Farm Output, Input Use, and Productivity, 1960-96 (1960 = 1.0000)

Year	Total Farm Output	Livestock	Crops	Total Farm Input	Capital	Land	Labor	Materials	TFP
1960	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1961	0.9572	1.0959	0.7869	0.9991	1.0058	0.9656	0.939	1.0316	0.958
1962	1.0518	1.1355	0.9494	1.0124	0.9896	0.9547	0.9311	1.0698	1.039
1963	1.1014	1.2015	0.9791	1.0564	1.0013	0.9588	0.9006	1.1693	1.0425
1964	1.0454	1.291	0.7663	1.0343	1.0153	0.9527	0.8491	1.1469	1.0107
1965	1.1027	1.2447	0.9313	1.0206	1.0062	0.9389	0.8254	1.1368	1.0805
1966	1.1195	1.2917	0.914	1.0383	1.024	0.9267	0.8189	1.174	1.0783
1967	1.2312	1.3719	1.0612	1.0676	1.0423	0.9662	0.7867	1.2386	1.1533
1968	1.2457	1.3642	1.1022	1.0503	1.0742	0.9375	0.7606	1.2113	1.186
1969	1.1916	1.2797	1.0871	1.0671	1.0969	0.9187	0.7578	1.2532	1.1167
1970	1.1636	1.3152	0.9744	1.0533	1.0959	0.9139	0.7078	1.2553	1.1048
1971	1.3038	1.3937	1.2068	1.0684	1.0964	0.9428	0.696	1.2889	1.2203
1972	1.3203	1.3677	1.2952	1.0423	1.099	0.9048	0.665	1.2601	1.2666
1973	1.368	1.4622	1.2716	1.1386	1.1071	0.9578	0.7395	1.4191	1.2015
1974	1.2365	1.5077	0.9565	1.0935	1.1444	0.9886	0.8173	1.2588	1.1308
1975	1.1904	1.2841	1.0617	1.0527	1.1374	0.9859	0.7861	1.1941	1.1308
1976	0.9183	1.2902	0.5497	0.9938	1.1544	0.9811	0.7418	1.0913	0.924
1977	1.3091	1.3092	1.3503	1.0388	1.1192	0.9785	0.8219	1.1674	1.2602
1978	1.3591	1.2717	1.5249	1.1212	1.1837	0.948	0.7433	1.4071	1.2122
1979	1.3822	1.2548	1.6186	1.1485	1.1764	0.9542	0.8027	1.4396	1.2034
1980	1.3151	1.3666	1.2549	1.1487	1.2444	0.9735	0.8186	1.3905	1.1448
1981	1.4385	1.3421	1.5687	1.1338	1.2193	0.9656	0.8987	1.3093	1.2687
1982	1.534	1.2539	1.909	1.1253	1.1869	0.9478	0.7207	1.4512	1.3632
1983	1.4105	1.3178	1.518	1.1498	1.1766	0.8543	0.9099	1.4719	1.2267
1984	1.6286	1.3201	2.0305	1.0895	1.1427	0.9273	0.7194	1.3885	1.4949
1985	1.6364	1.3317	2.0327	1.1011	1.1312	0.9196	0.7615	1.4021	1.4861
1986	1.5925	1.1864	2.1383	1.0042	1.0387	0.8986	0.6101	1.322	1.5859
1987	1.6461	1.3384	2.0286	1.0287	0.9911	0.8665	0.6837	1.3681	1.6002
1988	1.3187	1.3876	1.1362	0.9981	0.9673	0.8607	0.6562	1.3215	1.3213
1989	1.5177	1.3817	1.6086	0.9452	0.9328	0.888	0.6776	1.156	1.6056
1990	1.7231	1.3925	2.1118	0.9719	0.9239	0.8791	0.6097	1.3121	1.773
1991	1.7224	1.3831	2.1275	0.9574	0.9353	0.8744	0.6451	1.2321	1.799
1992	1.7829	1.3815	2.2924	0.9059	0.9276	0.8931	0.5149	1.2286	1.9681
1993	1.5079	1.223	1.8453	0.8952	0.9259	0.8641	0.4936	1.2353	1.6843
1994	1.8344	1.2227	2.6791	0.9155	0.9142	0.8956	0.5428	1.2256	2.0036
1995	1.5938	1.2017	2.1251	0.9719	0.9176	0.8922	0.5886	1.3356	1.6399
1996	1.8771	1.1341	2.8702	0.9467	0.8931	0.9099	0.5666	1.293	1.9829
Average Annual Rates of Growth									
1960-96	0.0175	0.0035	0.0293	-0.0015	-0.0031	-0.0026	-0.0158	0.0071	0.019

Source: USDA. ERS. Productivity in the United States 1960-1996

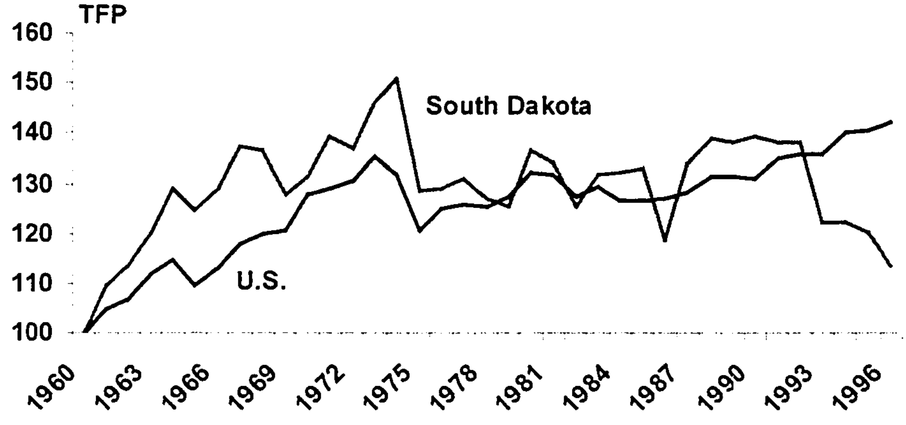


Figure (5 -5) Total Factor Productivity for Livestock Output in the United States and South Dakota, 1960-1996

Table (5-4) shows that livestock productivity in South Dakota increased from 1 in 1960 a to 1.13 in 1996. But South Dakota livestock productivity shows a larger variation compared to the other three states. Ball et al. (2001) ranked South Dakota 38th nation wide.

5.7 Regional Growth of Livestock Productivity and Implications on Direct Spill Over Implications

Some states' productivity grew faster than others, which implies that states that were farthest behind the productivity leaders had the most gain from the diffusion of technical knowledge and proceeded to grow the most rapidly.

Figure (5-6) shows some selected states' percentage change in livestock productivity. For example, the state of North Carolina ranked first among all 48 contiguous states in terms of livestock productivity. Arizona ranked second, while Illinois ranked last. In the Northern Plains, Colorado, Nebraska, and Kansas come in the middle category. South Dakota ranked in a lower category. This implies that states such as North Carolina and Arizona benefited the most from livestock technology diffusion and most likely spill in benefits of livestock research. The Northern Plains states played a role by being both spill out and spill in leaders. States like South Dakota benefited the least from diffusion of livestock technology.

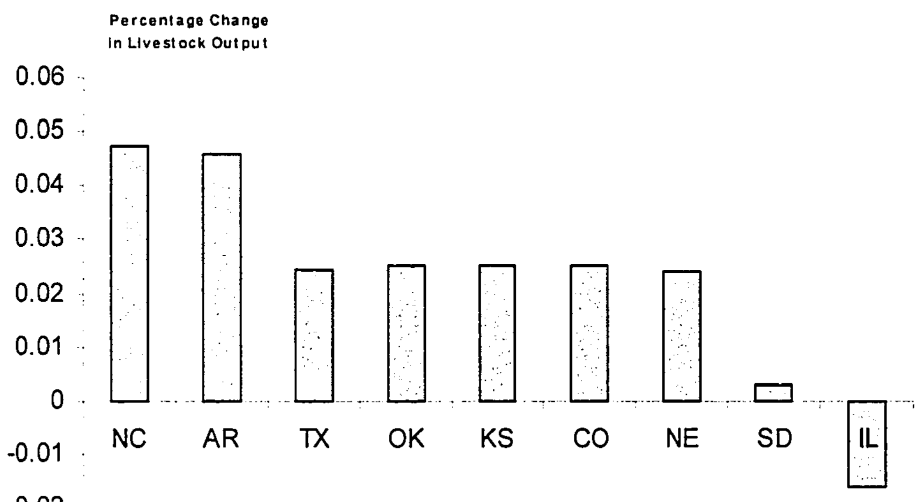


Figure (5-6) Growth in Livestock Output in Selected States 1960-1996

Source: Ball et. al, ERS, 2001

5.8 Cash Receipts of the Livestock Sectors in the Northern Plains Selected States

Table (5-5) shows that the study area contribution varied between 23% and 32% of the nation's cash receipts for livestock during the period 1988 –1999 (NASS, April, 2000). Value of cash receipts did not fluctuate similarly to the productivity during the last two decades, which implies that there are other factors that determine the benefits to the farmers. These other factors include the demand for the final products, final prices and prices of traded products.

Investment in livestock basic knowledge, applied research and technology transfer in the region has a multiplicative impact because of the big share of the region nationally and because of the large number and volume of other businesses that support backward and forward services of the livestock sector. Investment in R&D affects farmer income as new technologies enable farmers to produce more output using the same amount of input or producing the same output using less inputs or at lower cost of inputs. The circulation of cash generated from livestock activities in the economy creates new jobs, encourages entrepreneurship, and increases investment in capital stock in the region. It also impacts neighboring states through inter-state trading when it spills out. For these reasons, estimates of rate of return to investment in R&D should include investigation of all productivity, demand side effects and business impacts. The business impact includes an impact from the direct cash investment, a second round of cash flow when businesses buy from each other, and the impact of the investment on the society by creating more jobs and increasing income levels of households.

Table (5-5) Cash Receipts of Livestock and Livestock Products in the Northern Plains Region (In Million $)

Year	Colorado	Kansas	Nebraska	South Dakota	Other States in Northern Plains Region [a]	Region Total	U.S. Total	Study Area/ U.S.
1988	2,666	4,311	5,390	2,110	2,799	17,275	46,589	31.07%
1989	2,649	4,416	5,646	2,031	2,829	17,571	46,426	31.75%
1990	3,073	4,996	6,076	2,294	2,854	19,293	51,165	32.13%
1991	2,663	4,800	5,933	2,125	2,696	18,219	50,172	30.94%
1992	2,955	4,558	5,674	1,966	2,839	17,992	47,796	31.70%
1993	2,441	4,372	4,707	1,292	2,204	15,016	50,970	25.14%
1994	2,224	4,295	4,380	1,036	2,249	14,183	46,662	25.58%
1995	2,081	4,081	4,126	1,079	1,840	13,208	44,865	25.34%
1996	2,072	3,966	4,135	971	1,643	12,787	44,154	25.24%
1997	2,148	4,285	4,403	1,155	2,228	14,220	49,689	24.13%
1998	2,135	4,026	4,268	982	2,015	13,425	43,344	26.33%
1999	2,320	4,521	4,583	1,281	2,251	14,956	53,002	23.97%

[a] Other states in the Northern Plains Include Montana, North Dakota, Utah, and Wyoming
Source NASS, USDA, Meat Animals, Production, Disposition, and Income, 1988-2000

5.9 Rate of Return to Investment in Livestock Research

Many studies have estimated the specific returns to different commodities. Most commodities show high rates of return, but estimates of individual commodities vary widely among studies. There is a great variation across these studies' time periods and approaches, which makes them difficult to compare. However, there is a noticeable difference between the rate of return to livestock research and crop research. Livestock returns are lower, and even negative, in recent studies. It is thought that research on livestock has a larger lag than research on plants due to the more sophisticated characteristics and physiology of the animals compared to plants.

These studies offer a wide range of estimates that varies between “negative” to 86 percent depending on animal commodity and/ or period of study (Fuglie et al. 1996). Most of these studies used the production function or a productivity measure to estimate return to investment in animal research. Limitations of these studies are that they may ignore or underestimate the importance of technology spillover across regions and they study the supply side of the commodity without considering consumer demand impact and trade of these commodities. Interstate research spillovers can be significant because improved animal technology is often directly transferable across geographical boundaries (Fuglie et al. 1996). The other drawback of these studies is that they ignore the multiplier impact of investment, which includes the direct, indirect and induced impacts of the investment. Inclusion of the multiplier part of benefits could cause a significant increase in real rate of returns to investment in R&D. The previous studies were underestimating the returns to research and extension when these impacts are not included.

Chapter Six: Results; Social Accounting Matrix – Livestock Research and Development Multipliers

6.1 Introduction: The SAM Structure

The objective of this chapter is to explain the initial Social Accounting Matrices (SAM) for the four selected states (Colorado, Kansas, Nebraska, and South Dakota). This chapter also contains the main data presentation, and initial multipliers for R&D in the four states analyzed in this research. By implications, this gives perspectives on the structure of agriculture in each of the states. This chapter also explore the opportunity cost that the economy's sectors pays in term of loss investment because livestock research investment might have been used somewhere else rather than the livestock sector. Livestock research investment is using resources otherwise invested in the other sectors' R&D. The multipliers effect approach is used to assess what cost each of the economy's sector pays to cope with livestock productivity shock. The increase in cost for each of these sectors in term of lost multiplier effects indicates how much is the opportunity cost paid.

Perretto (1996) explored the idea of using market structure as a component of the endogenous technological progress departing from the traditional theory of growth. He claimed the class of GE models developed in recent years to explain forces that determine innovation and growth improves our understanding of the phenomenon. In Perretto model, the number of firms is determined by the zero profits, net of R&D costs, beyond those necessary to cover the sunk fixed costs of production.

Like input-output accounts, Social Accounting Matrices (SAM) provides a comprehensive accounting structure of regional, market-based productive activities and utilizes similar double-entry book-keeping standards. Unlike input-output, however, social accounts focus on the household as a relevant unit of analysis and provide a comprehensive and additional set of accounts that track how household income is generated and distributed. Where input-output tables are focused on industries and their respective relationships with regional output, SAMs extend this into a more complete range of market mechanisms associated with generating household income. The relevant focus thus shifts from how regional output is produced to also address how regional income is generated and distributed. This comprehensive element is particularly important in regional CGE models which focus on both production processes and the economics of household factor supply, commodity demand, and government interaction (Vargas et. al 1998).

The SAM has become used increasingly in the last three decades as a general equilibrium data system linking, among other accounts, production activities, factors of production and institutions (firms, households and the government). As such, SAM captures the circular interdependence in any economic system among production, the factorial income distribution (distribution of value added generated by each production activity to the various factors), and income distribution among the institutional agents, including different household groups (Defourny and Thorbecke, 1984).

The Social Accounts Matrix (SAM) for a region tracks the monetary flows between production and service sectors and institutions. The Input/Output (I/O) accounts are a subset of the entire social accounts of a region. The SAM includes market flows between producers of goods and services and consumers as well as transfers between the households and the government. Figure (6-1) shows an illustrative SAM. Each row cell represents an industrial or institutional payment or a transfer. In a SAM framework, value added refers to the total payments or returns to factors of production capital, land and labor. In brief SAM tracks the dollar flows through a replicated economy as sets of income and payments flows across all economic sectors.

	Industry	**Commodity**	**Factors**	**Institutions**	**Government**	**Trade**	**TOTAL**
Industry (detail)		Make					Total Industry Output
Commodity (detail)	Use			Consumption		Exports Output	Total Commodity
Factors -land -labor -capital	Returns to Primary Factors (value added)					Exported Primary Factors (e.g. labor flow)	Total Factor Income
Institutions -households -other	Sales	Sales	Distribution of factor Income		Transfer Payments	Exports	Total Institutional Income
Government	Indirect Business Taxes	Sales Tax	Factor Taxes		Intergovernmental Transfers		Total Government Income
Trade	Imported Purchased Inputs	Imports	Imports			Trans-shipments	Total imports
TOTAL	Total Industry Outlay	Total Commodity Outlay	Total Factor Outlay	Total Institutional Outlay	Total Gov't Outlay	Total Exports	

Figure (6-1) An Illustrative Social Accounting Matrix

Source: Vargas et. al 2000.

Each row and column balance exactly so all flows are counted. Based on IMPLAN 528 categories are aggregated in this study to twenty I/O sectors, and three household categories.

The low-income category includes households earning $20,000 or less, the medium categories includes all households earning more than $20,000 and less than $40,000, while the high households includes households who earn more than $40,000 annually. SAM also includes investment and federal and state government revenues and expenditures (See appendix –A). The SAM models are commonly used in studies of impact analysis. The most useful element of the SAM for impact studies are the multiplier coefficients.

6.2 Direct, Indirect, and Induced Multipliers

There are three types of multipliers investigated in this study for the economies of Colorado, Nebraska, Kansas and South Dakota. These multipliers are the direct, indirect and induced multipliers. Direct multipliers are equal to one because these relate to a change in an economy due to direct first round expenditures before any indirect impact is accounted for. Indirect multipliers happen when firms buy from each other as a result of the expenditure, while induced multipliers are a result from changes in household's expenditure because of income/population increases or decrease due to change in production. Total direct, indirect and induced multipliers together will be referred as the business impact multipliers in this text. The business impact of an investment is all the direct expenditure, the firm's expenditure when they buy from each other more as a result of the original investment plus household and government expenditure when they benefit from the better economy's conditions created by this investment.

6.3 Colorado Value of Output, Employment, Value added and Multipliers

6.3.1 Value of Output, Employment, and Value added

In Colorado, the total value added of the agricultural sector is estimated to be \$3,447 million, with returns to labor at \$579 million, returns to capital of \$484 million, and high returns to land, estimated at \$1,949 million in 1997(table 6-1). Colorado's agricultural sector total value of output is estimated to be \$5.39 billion in 1997. Colorado agriculture's exported products to other states are valued at around \$2.706 billion, representing 50 percent of the sector's value of outlay. This sector exported agricultural products valued at \$462 million to other countries, representing 9 percent of the sector's total value of production. On the other hand, the state of Colorado imported agricultural products locally from other states worth about \$576 million, representing around 10 percent of the total value of the sector outlay, in addition to \$52 million from outside the United States, equivalent to 1 percent of the agricultural sector value outlay in 1997.

Table (6-1) shows that the livestock sector contributed around \$2.9 billion, or 54 percent of the value of output of the agricultural sector in 1997. The livestock sector employs 17,195 employees and generates \$1.2 billion in value added from returns to labor, capital, land and tax revenue available for the government spending, derived from Table (6-1). The value added doubled when all other related agricultural and manufacturing sectors included (such as feed grains, hay and pasture, prepared feeds, meatpacking and poultry processing), as the value added is estimated to be \$2.6 billion for the whole production and manufacturing of livestock products.

Table (6-1) Colorado Value of Output, Employment, and Value Added in Million ($) 1997

Sector	Industry Output	Employment (Number of Jobs)	Return to Labor	Return to Capital	Return to Land	Indirect Business Tax	Value Added
Dairy Farm Products	223	808	23	35	52	2	113
Poultry and Eggs	119	295	9	6	29	1	45
Beef	2,194	9,501	130	199	401	172	902
Sheep Lambs and Goats	144	4,643	9	16	18	8	52
Hogs Pigs and Swine	202	949	8	8	43	18	78
Mis. Livestock	41	1,596	15	4	15	2	36
Total Livestock (Production)	**2,923**	**17,792**	**194**	**268**	**558**	**203**	**1,226**
Food Grains and other Agriculture	1,401	32,119	349	125	622	78	1,174
Feed Grains	408	2,212	9	31	302	60	402
Hay and Pasture	660	13,783	27	60	467	91	645
Total Agriculture	**5,392**	**65,906**	**579**	**484**	**1,949**	**432**	**3,447**
Construction	25,766	225,809	6,613	2,202	2,827	559	12,201
Meatpacking	2,142	6,326	191	2	25	16	234
Other Food Manufacturing	6,237	18,355	800	8	744	421	1,974
Poultry Processing	150	1,141	33	0	6	2	41
Prepared Feeds	225	512	17	0	5	2	24
Manufacturing	34,525	190,936	8,520	424	2,854	310	12,107
Whole Trade and other Trade	21,660	369,360	8,871	675	2,989	3,382	15,918
Food Retail	7,852	212,538	3,131	118	755	749	4,754
Services	101,942	1,113,742	30,369	5,819	23,177	5,510	64,874
Higher Education	1,023	26,175	423	29	38	16	506
R&D	3,171	51,382	1,492	127	190	16	1,825
State and Local government	11,241	254,793	8,926	0	1,211	0	10,137
Federal Government	7,128	115,330	5,333	0	1,442	0	6,775
Other	228	16,496	157	0	71	0	228
Totals	**228,682**	**2,668,801**	**75,456**	**9,888**	**38,286**	**11,415**	**135,044**

6.3.2 Colorado Direct, Indirect, and Induced Multipliers

Table (6-2) shows that primary production sectors have relatively lower multipliers compared to the manufacturing and services sectors. The Colorado total multiplier (direct, indirect and induced) for the livestock sector varied between 2.35 for beef to 1.95 for poultry. By investing one dollar in research and technology the total business impact is about $1.35 for beef to about $0.95 for poultry and eggs sub-sectors.

However these multipliers are higher for the products when they are processed, marketed and distributed to the consumers. As an example, the total multiplier effect of the meatpacking sector was the highest among all the economy's sector multipliers (2.83). This indicates that investment in R&D targeting primary agricultural production benefits producers, but benefits will multiply to the manufacturing and services sectors at higher rates. More evidence of this result is obtained by making a comparison between the poultry and eggs sector multiplier compared with the poultry processing multiplier. The poultry processing total multiplier is estimated to be 2.14, which is about 0.19 higher than the primary poultry and eggs sector. A dollar investment multiples $0.19 higher in the poultry processing compared to poultry and eggs production.

Columns 3 and 4 in table (6-2) show the sources of the multiplier impact in each of the 20 sectors of the Colorado economy. As expected, the indirect impact is higher within the processing and manufacturing sectors compared to the primary crops and livestock and trade sectors. Because indirect multiplier captures the effect when businesses buy from each other, the food processing and other manufacturing sectors spend a higher portion of their expenditure to obtain material and services from the services sector compared to the primary production sectors. Induced impact multipliers however are higher at the food retail, education, research and development, services and government sectors as these sectors affect the households' income directly and significantly.

Table (6-2) Colorado Direct, Indirect and Induced Output Multiplier Effects Based on SAM 1997

Sector	Direct	Indirect	Induced	Total
Dairy Farm Products	1.0000	0.22376	0.93736	2.16112
Poultry and Eggs	1.0000	0.24951	0.70397	1.95348
Beef	1.0000	0.42046	0.93188	2.35234
Sheep Lambs and Goats	1.0000	0.42625	0.88457	2.31081
Hogs Pigs and Swine	1.0000	0.32999	0.80582	2.13581
Mis. Livestock	1.0000	0.06365	1.31673	2.38038
Food Grains and other Agriculture	1.0000	0.12893	1.2636	2.39253
Feed Grains	1.0000	0.01198	1.2301	2.24207
Hay and Pasture	1.0000	0.0188	1.24232	2.26112
Construction	1.0000	0.49875	1.14784	2.64659
Meatpacking	1.0000	0.9867	0.84689	2.83359
Other Food Manufacturing	1.0000	0.5608	0.93685	2.49764
Poultry Processing	1.0000	0.42722	0.71179	2.13901
Prepared Feeds	1.0000	0.55317	0.62126	2.17443
Manufacturing	1.0000	0.59356	1.02273	2.61629
Whole Trade and other Trade	1.0000	0.25401	1.40028	2.65429
Food Retail	1.0000	0.3497	1.27193	2.62163
Services	1.0000	0.34794	1.27098	2.61893
Higher Education	1.0000	0.49434	1.27193	2.76627
Livestock R&D	1.0000	0.40694	1.33004	2.73699
State and Local government	1.0000	0.0983	1.52808	2.62638
Federal Government	1.0000	0.04336	1.51356	2.55692
Other	1.0000	0	1.49245	2.49245

Source: Derived from IMPLAN 1997

The multiplier the Colorado R&D SAM multiplier is 2.74 (Table 6-2).

The link between the impact of R&D and multiplier effects relate to the economy's absorption capacity and the multiplicative effects of investment. An economy with higher multipliers is more responsive to technology and development changes.

Distribution of the multipliers between direct, indirect and induced impacts is a leading factor to determine which sectors will benefit more from technology shocks and how much technology will make the society better-off. For example, data above showed that the indirect meat packing plant sector multiplier is double the beef production indirect multiplier. As a $1 invested in livestock technology, the meat packing plant sector will capture double the magnitude of benefits that the beef production will capture.

6.4 Kansas Value of Output, Employment, Value added and Multipliers

6.4.1 Value of Output, Employment, and Value added

The total value added of the agricultural sector in Kansas is $3,164 million, with $400 million due to returns to labor, $1,100 million in returns to capital, and $1,364 million representing returns to land (Table 6-3). The Kansas agricultural sector generated a value of output was estimated to be $9.257 billion in 1997. Kansas exported agricultural inputs and final products to other states valued at $3.825 billion, equivalent to 41 percent of the total value of production, and exported crops and livestock products to outside of the United States valued at $1.588 billion, representing 17 percent of the total value of agricultural output. However, Kansas imported food and other farm products worth $1.945 billion from other states, which is 21 percent of the total value of the sector outlay. Kansas also imported agricultural products from outside the country estimated at $230 million in 1997, which is 2 percent of the total consumption value.

Table 6-3 showed that the livestock sector contributed around 58 percent of the value of output of the agricultural sector in 1997(about $5 billion). The livestock sector employed 22,079 employees and generated $1 billion in value added. At $2.6 billion, the value added more than doubled when all other related agricultural and manufacturing sectors included (such as feed grains, hay and pasture, prepared feeds, meatpacking and poultry processing). The livestock sector generated higher total value of production compared to Colorado and hired larger number of laborers. However SAM results did not show a relatively higher value added for the state of Kansas compared to Colorado value added of the livestock sector. At the livestock production plus food manufacturing level both Colorado and Kansas generated about a $2.6 billion value added for the livestock industry, indicating high returns to factors of production (labor, capital and land) in Colorado and the Kansas livestock sectors.

Table (6-3) Kansas Value of Output, Employment, and Value Added in Million ($) 1997.

Sector	Industry Output	Employment (Number of Jobs)	Return to Labor	Return to Capital	Return to Land	Indirect Business Tax	Value Added
Dairy Farm Products	163	762	13	32	10	0	55
Poultry and Eggs	37	137	2	2	2	0	7
Beef	4,319	16,944	114	476	216	92	898
Sheep Lambs and Goats	12	626	1	2	0	0	3
Hogs Pigs and Swine	415	2,977	17	19	24	10	71
Mis. Livestock	23	633	2	3	2	0	8
Total Livestock	**4,969**	**22,079**	**149**	**534**	**254**	**102**	**1,042**
Food Grains and other Agriculture	2,323	40,434	207	298	576	91	1,171
Feed Grains	1,340	11,016	28	164	354	70	616
Hay and Pasture	625	18,300	16	104	180	35	335
Total Agriculture	**9,257**	**91,829**	**400**	**1,100**	**1,364**	**298**	**3,164**
Construction	11,234	122,280	2,858	974	946	160	4,937
Meatpacking	5,298	15,671	465	4	63	39	571
Other Food Manufacturing	4,872	16,326	635	6	381	34	1,056
Poultry Processing	0	0	0	0	0	0	0
Prepared Feeds	373	840	30	0	10	3	43
Manufacturing	33,134	181,879	7,810	228	2,080	294	10,412
Whole Trade and other Trade	14,093	245,206	5,509	635	1,947	2,196	10,288
Food Retail	4,079	126,845	1,460	181	381	377	2,399
Services	45,625	568,064	13,207	2,577	10,145	2,208	28,137
Higher Education	577	15,411	241	13	20	8	282
R&D	1,366	25,049	585	39	77	6	707
State and Local government	7,448	206,453	5,848	0	874	0	6,722
Federal Government	3,799	63,618	2,738	0	846	0	3,585
Other	226	9,515	75	0	152	0	226
Totals	**141,381**	**1,688,986**	**41,860**	**5,757**	**19,287**	**5,625**	**72,529**

6.4.2 Kansas Direct, Indirect, and Induced Multipliers

The Kansas R&D SAM multiplier is 2.28. Therefore, an investment in research and development generates $2.28 worth of direct, indirect and induced effect. In general Kansas showed slightly lower multipliers impact compared to Colorado. Livestock multipliers varied between 2.15 for the beef production to 1.64 for poultry and eggs production. As in Colorado the meatpacking' sector in Kansas was ranked first among all economy's sector in output multiplier as the multiplier was estimated to be about 2.6. The multipliers were similar to those reported for Colorado. However results proved again that the manufacturing and processing sectors showed a larger difference between the indirect and induced impact for the meat packing plant. A 1.07 indirect multiplier for the meat packing sector indicated that the processing sector would capture $1.07 of indirect impact for each dollar investment in research and development (table 6-4,) higher than the indirect multipliers for all other sectors.

Table (6-4) Kansas Direct, Indirect and Induced Output Multiplier Effects Based on SAM 1997

Sector	Direct	Indirect	Induced	Total
Dairy Farm Products	1.0000	0.3149	0.5932	1.9081
Poultry and Eggs	1.0000	0.2918	0.3565	1.6484
Beef	1.0000	0.6088	0.5435	2.1523
Sheep Lambs and Goats	1.0000	0.3342	0.4982	1.8324
Hogs Pigs and Swine	1.0000	0.4301	0.4326	1.8627
Mis. Livestock	1.0000	0.3119	0.5505	1.8623
Food Grains and other Agriculture	1.0000	0.3031	0.7071	2.0102
Feed Grains	1.0000	0.3243	0.6653	1.9896
Hay and Pasture	1.0000	0.2767	0.7152	1.9918
Construction	1.0000	0.3417	0.7332	2.0749
Meatpacking	1.0000	1.0718	0.5232	2.5950
Other Food Manufacturing	1.0000	0.5456	0.5561	2.1018
Poultry Processing	0.0000	0.0000	0.0000	0.0000
Prepared Feeds	1.0000	0.4986	0.4112	1.9098
Manufacturing	1.0000	0.3649	0.6021	1.9670
Whole Trade and other Trade	1.0000	0.2162	1.0307	2.2469
Food Retail	1.0000	0.3371	0.9157	2.2528
Services	1.0000	0.3126	0.8907	2.2033
Higher Education	1.0000	0.4258	0.8951	2.3209
Livestock R&D	1.0000	0.3829	0.9006	2.2835
State and Local government	1.0000	0.0840	1.1020	2.1859
Federal Government	1.0000	0.0394	1.0759	2.1153
Other	1.0000	0.0000	0.8897	1.8897

Source: Derived from IMPLAN 1997

6.5 Nebraska Value of Output, Employment, Value added and Multipliers

6.5.1 Value of Output, Employment, and Value added

The total value added of the agricultural sector in Nebraska is estimated to be $3,346 million in 1997. The share of returns to labor is $370 million, $1,414 million due to returns to capital, and $1,273 million are returns to land. The state of Nebraska's total value of agricultural production was $10.598 billion in 1997. The state exported domestically to other states about $5.329 billion of food and other agricultural products. That is 50 percent of its total value of production. Nebraska also exported to the outside world around $1.557 billion of agricultural production, or 15 percent of its value of production. The total value of imported agricultural goods and services to the state is estimated to be about $1.595 billion, $1.505 billion from other states, and $94 million from the rest of the world. Total value of imports represented 15 percent of the total value of the state consumption of agricultural products (Table 6-5).

Nebraska is a leading state in livestock production and food manufacturing in the Northern Plains. Table (6-5) also shows that the livestock sector in Nebraska contributed 53 percent of the value of output of the agricultural sector in 1997 ($5.6 billions). The livestock sector employed 21,158 employees and generated $1.1 billion in agricultural value added, (table 6-5). At $3.3 billion the value added tripled when all other related agricultural and manufacturing sectors are included (such as feed grains, hay and pasture, prepared feeds, meatpacking and poultry processing).

Table (6-5) Nebraska Value of Output, Employment, and Value Added in Million ($) 1997

Sector	Industry Output	Employment (Number of Jobs	Return to Labor	Return to Capital	Return to Land	Indirect Business Tax	Value Added
Dairy Farm Products	134	424	7	29	7	0	43
Poultry and Eggs	136	330	6	9	7	0	22
Beef	4,510	14,861	132	560	179	77	948
Sheep Lambs and Goats	12	449	0	2	0	0	3
Hogs Pigs and Swine	806	4,798	28	42	38	16	123
Mis. Livestock	17	296	1	2	1	0	5
Total Livestock	**5,615**	**21,158**	**174**	**644**	**232**	**93**	**1,144**
Food Grains and other Agriculture	1,779	26,383	138	296	347	59	840
Feed Grains	2,506	18,203	45	343	533	105	1,026
Hay and Pasture	698	14,038	13	131	161	32	336
Total Agriculture	**10,598**	**79,782**	**370**	**1,414**	**1,273**	**289**	**3,346**
Construction	6,167	74,097	1,815	539	173	49	2,577
Meatpacking	6,156	18,095	570	7	74	46	697
Other Food Manufacturing	4,815	16,120	671	9	449	37	1,166
Poultry Processing	199	1,588	41	1	5	1	47
Prepared Feeds	493	1,112	40	1	13	4	57
Manufacturing	13,140	83,001	3,041	132	1,247	99	4,518
Whole Trade and other Trade	8,491	169,044	3,359	378	1,172	1,325	6,235
Food Retail	2,447	84,273	867	81	221	221	1,390
Services	33,016	425,380	10,284	1,749	6,292	1,366	19,691
Higher Education	597	17,582	288	10	3	1	303
R&D	707	13,119	309	22	43	3	377
State and Local government	6,369	123,756	3,954	0	1,082	0	5,036
Federal Government	2,235	36,768	1,597	0	494	0	2,091
Other	272	6,966	52	0	220	0	272
Totals	**95,700**	**1,150,683**	**27,258**	**4,342**	**12,761**	**3,442**	**47,803**

6.5.2 Nebraska Output Direct, Indirect, and Induced Multipliers.

The Nebraska total livestock output multipliers were similar to or relatively higher than Colorado and Kansas, except for the higher Colorado sheep, lambs and goats multiplier. The output multiplier for dairy farm products is the second highest compared to the other selected states' multipliers (South Dakota 2.27, Nebraska 2.24, Colorado 2.16, and Kansas 1.91). In poultry, and eggs the four states is ranked as follows: both

Nebraska and South Dakota reported a multiplier of 2.0, Colorado 1.96, and Kansas 1.65. In beef, the highest multiplier is estimated in both South Dakota and Nebraska was 2.5, Colorado showed a 2.4 multiplier, and Kansas is the lowest with a 2.2. Even though the range is not very large between the maximum and the minimum beef output multipliers, these results indicate that South Dakota and Nebraska are showing a higher growth prospective in adopting more beef research and technology. For the sheep, lambs and goat product the states of Colorado and South Dakota showed a relatively higher multiplier 2.4. Nebraska ranked third (2.1 output sheep, lambs, and goats multiplier), and Kansas sheep, lambs and goat multiplier was estimated to be 1.8. Hogs, pigs and swine production has a higher production multiplier in South Dakota with an estimate of 2.4 and relatively lower ones in Colorado and Nebraska (2.1 for both), and the lowest in Kansas as it is estimated to be 1.8.

Table (6-6) Nebraska Direct, Indirect and Induced Output Multiplier Effects Based on SAM 1997

Sector	Direct	Indirect	Induced	Total
Dairy Farm Products	1.0000	0.4135	0.8288	2.2423
Poultry and Eggs	1.0000	0.4514	0.5538	2.0052
Beef	1.0000	0.6993	0.7826	2.4819
Sheep Lambs and Goats	1.0000	0.4039	0.6897	2.0937
Hogs Pigs and Swine	1.0000	0.6069	0.6349	2.2418
Mis. Livestock	1.0000	0.4538	0.7500	2.2037
Food Grains and other Agriculture	1.0000	0.4978	1.0454	2.5432
Feed Grains	1.0000	0.5321	0.9678	2.4999
Hay and Pasture	1.0000	0.4651	1.0212	2.4863
Construction	1.0000	0.5174	1.0739	2.5912
Meatpacking	1.0000	1.2169	0.7736	2.9905
Other Food Manufacturing	1.0000	0.7130	0.8597	2.5727
Poultry Processing	1.0000	0.9086	0.7772	2.6858
Prepared Feeds	1.0000	0.6881	0.6466	2.3347
Manufacturing	1.0000	0.5547	0.9275	2.4821
Whole Trade and other Trade	1.0000	0.2534	1.3702	2.6237
Food Retail	1.0000	0.4462	1.2304	2.6767
Services	1.0000	0.3896	1.2067	2.5963
Higher Education	1.0000	0.4836	1.2452	2.7288
R&D	1.0000	0.4351	1.2262	2.6614
State and Local government	1.0000	0.2140	1.3296	2.5436
Federal Government	1.0000	0.0564	1.4141	2.4705
Other	1.0000	0.0000	1.0906	2.0906

Source: Derived from IMPLAN 1997

6.6 South Dakota Value of Output, Employment, Value added and Multipliers

6.6.1 Value of Output, Employment, and Value added

Total value added of the agricultural sector in South Dakota is $1,856 million, with returns due to labor of $135 million, about $892 million in returns to capital, and $689 million due to returns to land (Table 8). The state of South Dakota's total output value of the agricultural sector was $5.197 billion in 1997. About $2.673 billion is in the value of production exported domestically to other states, while $1.036 billion is exported to foreign countries. Export percentages of total value of production were 51 percent and 20 percent for local and foreign respectively. South Dakota imported food and other agricultural products valued at $829 million from other states of the U.S., and imported total of $104 million of agricultural products from foreign countries. Total imports by this state represent 18 percent of the total value of consumption

Table 6-7 shows that the livestock in South Dakota sector contributed around about $1.8 billion (35%) of the value of output of the agricultural sector, which total about $5.2 billion in 1997. The livestock sector employs 8,477 employees and generated $409 million in value added. The value added more than tripled to $1.5 billion when all other related agricultural and manufacturing sectors included (such as feed grains, hay and pasture, prepared feeds, meatpacking and poultry processing).

Table (6-7) South Dakota Value of Output, Employment, and Value Added in Million ($) 1997

Sector	Industry Output	Employment (Number of Jobs	Return to Labor	Return to Capital	Return to Land	Indirect Business Tax	Value Added
Dairy Farm Products	181	454	7	46	8	0	61
Poultry and Eggs	72	130	2	6	3	0	11
Beef	1,174	4,917	31	185	42	18	276
Sheep Lambs and Goats	43	1,082	1	8	1	0	10
Hogs Pigs and Swine	297	1,467	8	18	12	5	42
Mis. Livestock	35	428	2	5	2	0	10
Total Livestock (Production)	**1802**	**8478**	**51**	**268**	**68**	**23**	**410**
Food Grains and other Agriculture	1,470	14,276	59	254	261	45	619
Feed Grains	897	5,115	12	144	160	32	348
Hay and Pasture	1,028	14,525	14	226	200	39	479
Total Agriculture	**5,197**	**42,394**	**136**	**892**	**689**	**139**	**1,856**
Construction	2,985	32,891	721	309	107	31	1,168
Meatpacking	1,494	4,359	144	2	20	12	178
Other Food Manufacturing	965	3,359	113	2	82	6	202
Poultry Processing	54	454	9	0	1	0	11
Prepared Feeds	192	425	17	0	6	2	25
Manufacturing	6,732	43,004	1,347	40	413	42	1,842
Whole Trade and other Trade	3,427	73,523	1,277	256	471	537	2,541
Food Retail	1,078	37,488	349	60	95	94	599
Services	11,362	182,451	3,296	909	2,125	450	6,780
Higher Education	132	4,089	61	2	1	0	64
R&D	223	5,054	89	9	7	1	106
State and Local government	1,642	48,459	1,270	0	191	0	1,462
Federal Government	1,076	23,078	822	0	198	0	1,021
Other	354	2,821	19	0	335	0	354
Totals	**36,913**	**503,849**	**9,670**	**2,481**	**4,741**	**1,315**	**18,207**

6.5.2 South Dakota Output Direct, Indirect, and Induced Multipliers

South Dakota output multipliers showed relatively very high expected impact as the state growth in livestock sector is increasing. Table (6-8) summarizes output multipliers for the economy's sectors.

Table (6-8) South Dakota Direct, Indirect and Induced Output Multiplier Effects Based on SAM 1997

Sector	Direct	Indirect	Induced	Total
Dairy Farm Products	1.0000	0.4137	0.8562	2.2698
Poultry and Eggs	1.0000	0.4692	0.5386	2.0078
Beef	1.0000	0.6813	0.8221	2.5034
Sheep Lambs and Goats	1.0000	0.6077	0.8096	2.4173
Hogs Pigs and Swine	1.0000	0.7307	0.6703	2.4010
Mis. Livestock	1.0000	0.5189	0.7702	2.2891
Food Grains and other Agriculture	1.0000	0.5585	1.0072	2.5657
Feed Grains	1.0000	0.5758	0.9703	2.5462
Hay and Pasture	1.0000	0.5013	1.0321	2.5334
Construction	1.0000	0.5834	1.0635	2.6470
Meatpacking	1.0000	1.3057	0.8426	3.1483
Other Food Manufacturing	1.0000	0.8193	0.8607	2.6800
Poultry Processing	1.0000	0.8705	0.6953	2.5658
Prepared Feeds	1.0000	0.7991	0.7065	2.5055
Manufacturing	1.0000	0.6748	0.9023	2.5771
Whole Trade and other Trade	1.0000	0.2459	1.3940	2.6398
Food Retail	1.0000	0.4880	1.2424	2.7304
Services	1.0000	0.3937	1.2152	2.6089
Higher Education	1.0000	0.5152	1.2367	2.7519
R&D	1.0000	0.4800	1.1948	2.6748
State and Local government	1.0000	0.1240	1.4754	2.5994
Federal Government	1.0000	0.0480	1.4739	2.5219
Other	1.0000	0.0000	1.0006	2.0006

Source: Derived from IMPLAN 1997

6.7 Type SAM Multiplier Impacts In the Northern Plains Region

Type SAM multiplier is a percentage of total value added direct. It is computed by dividing indirect, and induced impacts by the direct multiplier. Type SAM multiplier measures the factorial distribution impact of investment to institutions including households and governments. This measure is socially oriented multiplier as it focuses on the welfare impact rather than the direct impact. Type SAM multipliers are the direct, indirect and induced effects where the induced effect is based on information in the social account matrix. This relationship account for the social security and income tax as well as any institutional saving for employees and consider commuting parameters to account for labor moving in or out the state. It is more accurate than the total multipliers when it comes to measuring the welfare impact of an investment.

Table (6-9) Type SAM Multiplier by Sector for the Selected Northern Plains States

Sector	Colorado	Kansas	Nebraska	South Dakota
Dairy Farm Products	3.1194	2.6133	3.1499	3.0661
Poultry and Eggs	2.5115	3.0446	4.2732	4.4555
Beef	2.9699	3.9242	4.5821	4.2417
Sheep Lambs and Goats	3.1434	2.9976	3.5556	3.9634
Hogs Pigs and Swine	2.7976	3.8492	5.1785	5.7809
Mis. Livestock	1.9515	2.5071	3.2733	3.4489
Food Grains and other Agriculture	2.0077	2.2202	2.8174	3.0060
Feed Grains	1.7631	2.3150	3.0401	3.1553
Hay and Pasture	1.7812	2.1343	2.7225	2.7876
Construction	3.0478	2.4804	3.1158	3.2591
Meatpacking	9.9885	7.2294	8.3882	8.5440
Other Food Manufacturing	3.8081	3.8868	4.4587	5.1020
Poultry Processing	3.2925	0.0000	4.0123	4.1970
Prepared Feeds	7.3739	5.2907	6.9673	6.7312
Manufacturing	3.6611	2.8427	3.3565	4.0181
Whole Trade and other Trade	2.3955	2.0738	2.2795	2.2735
Food Retail	2.6341	2.2882	2.6471	2.7048
Services	2.5502	2.2031	2.5292	2.5180
Higher Education	3.1714	2.6515	2.9393	3.0207
Research and Development	2.8423	2.5247	2.7887	2.9875
State and Local government	2.0972	1.8073	2.0978	2.0055
Federal Government	1.9990	1.7308	1.8971	1.9070
Other	1.9083	1.5465	1.6128	1.5487

Multiplier results indicate that the manufacturing, processing, and trade sector captures more of the returns value of the dollar investment in the R&D compared to the primary production sectors such as the crops and livestock sectors. When business buy and sell to each other, larger numbers of employees will be hired, returns to capital are higher because of the faster turn over of capital, and the government generates higher revenues that will be distributed to a larger portion of population. Value added is the summation of this value. Value added from investment in livestock research, if it distributed throughout the economy following the multipliers effects shown above, is expected to be captured by the processing, manufacturing, and trade sectors more than the primary livestock production sectors. This is referred to be the vertical spill over of livestock across the production, processing and trade sectors.

6.8 Opportunity Cost of R&D

Alston et al. (1995) discussed the social opportunity of government revenue and claimed that government revenue has significant implications for the calculation of net research benefits. They reviewed previous empirical studies where the social cost of government spending found to be in the range 1.2 to 1.5 times the amount spent. To account for the real opportunity cost of investment in this study net prices after taxes are used for the base model and simulations.

Opportunity cost is concerning the trade-off between different types of research and development programs. The dollar invested in certain area of research could have been used in another research and generate higher or lower benefits. From society perspective, efficiency of R&D dollar allocation between different research programs depends on using the investment in the least cost and/ or highest benefits combination of these programs. Changes in technology produced by new research in one sector affect other industries producing substitutes, complements products and services and also affect consumers and government. Because of resource scarcity, there is opportunity cost for each economic sector's R&D that is unique in its economic and social characteristics. Each industry generates different types of benefits and use technology in different style than the other industries.

Table (6-9) above showed that the type SAM multiplier is different among economic sector for each of the selected states. Type SAM multiplier is used to approximate the opportunity cost because it is built including the income distributional effects when household income being affected by the commercial activities.

Meatpacking sector showed the highest Type SAM multiplier between the other economic sectors for all the selected states (Colorado, Kansas, Nebraska and South Dakota). If the beef production sectors Type SAM multipliers subtracted from the meatpacking sectors multipliers (because the beef sectors is providing the raw material to the meatpacking sectors) the results are 7.0, 3.3, 3.8, and 4.3 for Colorado, Kansas, Nebraska, and South Dakota respectively. This indicated a higher opportunity cost through the vertical linkage between production and food producing as research targeted primary production compared to food processing because of the higher distributional impact of the food processing sectors. Food processing possibly pays more wages and circulate cash throughout the economy larger the beef primary production. However, one will not forget that these two sectors are vertically linked and spillover largely to each other.

Good example from table (6-9) will be making the comparison between two unrelated sectors. Beef production sectors Type SAM multipliers are 3.0, 3.9, 4.5, and 4.2 compared to 3, 2.4, 3.1, and 3.3 for the construction sectors in Colorado, Kansas, Nebraska, and South Dakota respectively. Beef production Type SAM multipliers are higher than construction multipliers (except for Colorado were they are equal). Research and development investment in the construction sectors have higher opportunity costs compared to beef research and development.

Other example is the comparison between dairy and services sectors between the Northern Plains states. Type SAM multipliers of dairy sectors are 2.6, 2.6, 3.1, and 3.1

compared to service sector multipliers 2.6, 2.2, 2.6, and 2.5 in Colorado, Kansas, Nebraska, and South Dakota respectively. Dairy Type SAM multipliers are higher than services sectors multipliers. Opportunity cost of performing research and development in dairies has lower opportunity costs compared to the services sectors.

Table 6-9 also showed relatively high Type SAM multipliers to the prepared feed sectors within the selected states (7.4, 5.2, 6.9, and 6.7 for Colorado, Kansas, Nebraska and South Dakota respectively). If the feed grains multipliers subtracted from prepared feed multipliers results are 5.6, 3.0, 4.0, and 4.5 for Colorado, Kansas, Nebraska and South Dakota respectively, which are still very high. A conclusion could be noticed that both the backward linkages (e.g. prepared feed) and the forward linkages of the beef production generate high Type SAM multipliers, which shows a lower opportunity cost. Research and development in these areas is promising because it provides higher dividends to the society compared to the other economic sectors.

In general the livestock sub-sectors (dairy, poultry, beef, sheep and hogs) showed a relatively high Type SAM multipliers. Nebraska shoed slightly higher comparative advantages in the livestock sub-sectors compared to the other states in the region. Colorado showed higher Type SAM multipliers in the meatpacking and prepared sectors compared to the other meatpacking and prepared feed sectors in the region.

Differences between the states Type SAM multipliers in the region between states and sub-sectors indicated differences in opportunity costs of conducting livestock research among the sub-sectors as well as among the states. Regional coordination between these livestock sector (inputs, production, processing, and marketing) and between the states reduces the loss due to investing in a higher opportunity cost sector rather than a lower one.

6.9 Livestock R&D Direct Trade Spill over

If the spillover follows the same pattern as the intermediate and final product trade flows (Walmsley, 1998), spillover through intermediate and final products calculation considering these percentages, by using the multiplier effect approach, can be estimated for Colorado as follow:

Spillover = (Spill in) – (Spill out) = (11%) – (59%) = -49%.

This indicates that around half of the returns to agricultural research and development in Colorado might spill-out to other states and rest of the world. By investing $ 1 the state will capture 9 cents and the others captured another 9 cents.

Applying the same formula explained above for spill over effect, the state of Kansas net spillover percentage is – 35%. This means by investing $ 1 in R&D Kansas State capture 4 cents and 2 cents flow to the outside.

Nebraska spillover net percentage is equal to –50%. As a result it is expected that R&D investment benefits will equally divided between staying to be captured by the investing state and the other 50 percent to spillover to the other states and outside the country. Nebraska State will benefit 8 cents of each $1 invested in R&D and another 8 cents will benefit other states and other world countries.

Calculation of spillover over for the state of South Dakota showed (-71+18%) = -53%. This indicates that the State South Dakota capture less than half of returns to investment in agricultural research and more than half of the befits spill out from the R&D sector to the outside.

Table (6-10) Relationship Between Spillover and Share of the Livestock Sector

State	Export to the Other States	Export to Foreign Countries	Import from the Other States	Import from Foreign Countries	(1) Net Trade	(2) Total Output	Net Spill over (Spill-in-Spillout) (1)/(2)	Livestock Share of the Ag. Output
		Million Dollars						
Colorado	2,706	462	576	52	2,540	5,390	0.47	0.74
Kansas	3,825	1,588	1,945	250	3,218	9,257	0.35	0.43
Nebraska	5,329	1,557	1,505	94	5,287	10,595	0.50	0.84
South Dakota	2,673	1,036	829	104	2,776	5,197	0.53	0.71

Output multiplier also indicates the absorption capacity of the state to receive more spills in of livestock research and technology. The higher the state in output and value added multipliers the larger possibility that the state is in increasing stage of growth and is lacked behind in adopting new innovation and still acting as a receiver of livestock R&D. Having said that, The state of Kansas is further advanced compared to the other states in livestock research and technology adoption as it showed lower rates of output multiplier effects and acts as a sender of spill out agent compared to the other selected Northern Plains States.

From the table above (6-2 to 6-8) States of Nebraska, Colorado, and South Dakota shares of total value of the livestock production sector to the state total value of the agricultural business is the largest compared to the share in the State of Kansas, they are 84%, 74%, 71%, and 43% in Nebraska, Colorado, South Dakota, and Kansas respectively. Net Spillover of the Northern Plains States are –53%, -50%, -49%, and –35% for the States of South Dakota, Nebraska, Colorado, and Kansas respectively.

Productivity gains and so return to investment to agricultural research and R&D spillover are found to be highly influenced by the type of agricultural production.

Colorado, Kansas and Nebraska showed a high levels of productivity compared to the national level. Colorado is the most state experienced fluctuations of livestock productivity responding to demand and prices changes over the last four decades compared to the other states. Colorado productivity changes responding to price changes make it an ideal case study for the region to study the direct, indirect, and induced impacts of livestock research.

Type SAM multipliers result in table 6-9 confirmed results obtained in chapter five about the fact that as much the state had high productivity growth in the past as much it is a leader and spill out benefits to the other followers states. The states of Colorado, Kansas, and Nebraska ranked in the middle range of productivity growth, they experienced a moderate multipliers to the non-agricultural sectors and they all spill in and spill out high benefits relative to the others. One will notice that state like South Dakota ranked below the national average livestock productivity, experienced high multipliers because the agricultural and non-agricultural sectors are currently at early stages of growth and the state spill in higher than the other Northern Plains states.

Discussion of both the agricultural total factor productivity and the socio-economic characteristics of each of the selected Northern Plains States (SAM indicators) showed that each state had its own special features. The absorption capacity of each state to apply new technology and adopt results of livestock research relies heavily on the economic structure of that state (all its economy's agents interacting), state past and current livestock productivity pattern, and its expected multipliers (direct, indirect, and induce) effects to other agricultural and non-agricultural sectors.

Using net trade to proxy for spillover is criticized and considered a general assumption to distinguish between what are the local benefits of research against what spill out to the rest of the world. A more precise method is to trace price impact when research and development affect productivity within a general equilibrium model for each state in the region. Price spillovers (pecuniary impact) occur when a research and development in one country or region has an effect in other countries or regions through effects on prices of good traded between the countries or regions. In the following chapters of this study only price spillovers considered when it comes to the effects to outside Colorado. Inside Colorado both output price effects and spillovers of livestock research results to the other sectors in the economy are considered.

Yee and Huffman (2001) concluded that spillin research stocks impact agricultural productivity positively. They estimated larger rates of return to state investment in agricultural research compared to other studies due to incorporation of the spillin variable in their model. Yee and Huffman estimated TFP elasticities to changes in regional agricultural R&D, Spillin R&D, extension and infrastructure for six different regions in the U.S. (Table 6-11). For the Mountain region (including Colorado)Yee and Huffman estimated 0.13, 0.24, 0.004, and 0.01 elasticities for agricultural R&D, Spillin R&D, extension and infrastructure respectively. Using the best-selected model, only the Pacific and the Northeast regions found to be having higher elasticities (0.16 and 01.9) of own agricultural R&D compared Mountain region (0.13). The Mountain region reported the lowest spill in elasticity compared to the other regions (0.24) table (6-11). The

Mountain region also reported to have the lowest elastiticies with respect to extension and infrastructure investment compared to the other region. A conclusion of Yee and Huffman results is that the contribution of the own R&D effects in agricultural productivity inside the Mountain region is the highest relative to all other regions in the country. Spill in, extension and highway lower elasticies implies a higher contribution of the own R&D in Mounatian's agricultural productivity. When investment in own agricultural R&D in the Mountain region increases by 1% the agricultural TFP increases by 0.13%.

Table (6-11) TFP or Output Elasticites with Respect to Public Policy Variables*

Region	Own R&D	Spillin R&D	Extension	Highway
Northeast	0.19	0.33	0.05	0.26
Southeast	0.08	0.38	0.07	0.03
Central	0.1	0.4	0.03	0.14
Northern Plains	-0.01	0.35	-0.19	0.52
Southern Plains	0.09	0.24	0.16	0.15
Mountain	0.13	0.24	0.004	0.01
Pacific	0.16	0.49	-0.07	0.13

* Only preferred model results included
Source: Yee and Huffman (2001)
Northeast- ct, de. Ma, md, me, nh, nj, ny, pa, ri, vt
Southeast- al,fl, ga, ky, nc, sc, tn, va, wv
Central- in, il, ia, mi, mo, mn, oh, wi
Northern Plains- ks, ne, nd, sd
Southern Plains- ar, la, ms, ok, tx
Mountain- az, co, id, mt, nv, nm, ut, wy
Pacific- ca, or, wa

In the Mountain region, Yee and Huffman results indicated that investment in R&D is paying high dividends compared to both extension services and infrastructure. The spillin elasticity indicated that investment in R&D in other regions is beneficial to the Mountain region producer and consumers because it is paying higher dividends than it is own R&D. A dollar investment in agricultural R&D in the Mountain generates relatively very high returns. In the following chapters of this study there is no difference between spill in and own R&D because the own R&D is significant and highly paying back to investment in the region.

Chapter Seven: CGE Simulations on Returns and Spillover of Investment in Livestock Research in Colorado

7.1 Introduction

Investment in livestock research has a *direct* cash impact to the targeted commodity or sector (i.e dairy farm products), *direct* impact to the other agricultural and non-agricultural sectors not targeted by research, *indirect* effect when these sectors buy from each other, and *induced* impact when household income and returns to factor of production change. The indirect and induced technological changes from livestock research can have significant economy-wide implications for employment and returns to factors of production, as well as for production, consumption and trade of non-livestock commodities and services. Thorough livestock productivity adjustments, technical changes in the livestock sector affect the relative prices of agricultural and non-agricultural products not targeted directly by the new research or technology. These indirect and induced changes in the product market can lead to further changes in factor markets. Most of the previous studies on rate of return (ROR) to investment in agricultural R&D did not consider the direct effects to other (non-targeted) agricultural sub-sectors, direct effects to non-agricultural sectors and the indirect and induced effects to all of these sectors.

Alston et al (1995) discussed the indirect and induced impact of agricultural productivity changes and concluded that productivity changes in agriculture can affect foreign exchange rates, food prices, domestic capital generation, labor use in onagricultural production, rural markets of nonagricultural goods, and relative factor prices. In their work entitled, "Science Under Scarcity", the authors conclude that the factor market responses vary depending on the nature of the technical change;

> " *The impact on nonagricultural production of these research-induced factor market responses are difficult to predict in general and vary depending upon the nature of the technical change, among other things. Usually, however, one would expect impacts on nonagricultural production to yield additional benefits to augment the direct impacts measured from partial-equilibrium model of agricultural-sector benefits* "

This study provides observed results of targeted and untargeted direct indirect, and induced impacts of research, as well as spillover of livestock research in Colorado as a case study for the Northern Plains region using the Computable General Equilibrium Model and the SAM multipliers.

The lags of livestock research are assumed to total thirty-five years and to follow the adoption path shown in figure (7-1). The first two years after conducting research are assumed to be pre-research adoption years. Over the following seven years, there is a development lag as benefits of research increase linearly. The adoption process lag is assumed to take another six years, when the benefits of research stagnate at their maximum level. Benefits decline linearly over the next 20 years as the value of research decays. The full process, on value of research, lasts for 35 years.

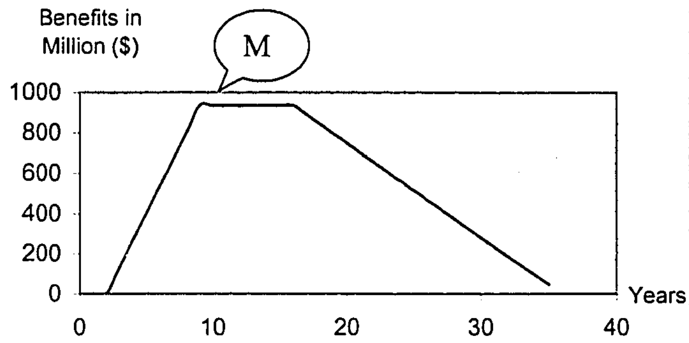


Figure (7-1) Trapoziod Benefits of Livestock Research

To find impacts of livestock research, the CGE is used to repeat the findings of previous studies estimated returns to livestock research, which counts only targeted direct impacts. When the CGE can repeat the findings of these studies, previously uncounted impacts, untargeted direct, indirect, and induced effects can be estimated. In this study three different simulations are discussed to represent three different types of livestock research. Twenty percent-targeted direct initial ROR is the first simulation, which represents a commodity specific (beef) research impacts. This simulation did not require more assumptions than the base CGE regular framework discussed earlier in chapter three. The second simulation, which represents both beef and dairy sectors, started with an initial ROR of forty percent. This simulation estimated the most common ROR found in previous studies. The third simulation started with initial ROR of sixty percent to livestock research (beef, dairy, hogs, sheep and lamb, and feed grains). This third simulation represents the major livestock groups plus feed grains because they are a major livestock input.

To repeat these studies, I used the following Yee and Huffman (2001) equations for production and productivity functions, which assume a single output aggregate production function with embodied technical change, supply of livestock changes simulated :

$$Q = AF(K,L,M)(OWNRD)^{\delta_1}(EXT)^{\delta_2}(SPILLIN)^{\delta_3}(HIWAY)^{\delta_4}$$

$$P \equiv \frac{Q}{F(K,L,M)} = A(OWNRD)^{\delta_1}(EXT)^{\delta_2}(SPILLIN)^{\delta 3}(HIWAY)^{\delta 4}$$

Where Q is the aggregated output into one index of output, and is a constant. F(•) is a well behaved function, K is physical capital input, L is labor input, M is material input , OWNRD is the state's own public research stock, SPILLIN is the public research stock from other states, EXT is extension stock, and HIWAY is highway stock.

This format of the production function fits the framework of the CGE model because both the output value and factors of production are present in both the production function and the CGE. Total Factor Productivity (TFP) changes are attributed to research and development, extension services, spill in to the states from outside, and infrastructure. The direct, indirect and induced effects of investment in livestock research are estimated at various levels of returns, 20, 40 and 60 percent, to the investment by changing parameters of the productivity function (changing the parameter of OWNRD) to simulate supply changes. The impacts of these changes affect the economic and social indicators (i.e. Gross State Product, households income, total value of livestock production, value of exports, and imports), aggregate, domestic, and value added prices, direct, indirect and induced impact, and returns to factors of production, and tax revenue.

Changes in supply responding to simulate OWNRD is used to count for after research benefits.

Based on figure (7-1), livestock research benefits reach the maximum (M) (in year 9). This value used as a reference point to calibrate the CGE for providing the targeted ROR that fits the path shown in figure (7-1). Stream of benefits including direct, indirect, and induced impact is calculated over thirty-five years to estimate new discounted total impact RORs (total impact RORs include direct effect to targeted-commodity or sector, other direct to non-targeted sector, indirect, and induced impacts). The total impact ROR then disaggregated to its components (all direct, indirect and induced effect on ROR) using the SAM multipliers to proxy different effects on the economy.

7.2 The Base Model

Table 7-1 highlights the main social and economic indicators of the base model. The base model results shows that Colorado Gross State Product (GSP) is estimated at $110.3 billion. The state hires about 1.4 million working households who generated about $78.7 billion in wages. The agricultural sector plays a major role in the economy because it provides food and other products and services valued at $4.025 billion. Half of the value of the agricultural supply is due to the livestock sector's production. The livestock sector relied on feed grain and hay inputs (backward linkages), the major component of cash expenses, which are estimated to cost about $1.9 billion. Value of production of the meat packing sector, which depends completely on livestock sector products (forward linkages) as inputs, are valued around $ 2 billion.

The State of Colorado exports to the other states and the outside countries production valued at $60.7 billion and imports from outside the state products and services valued at $28.7 billion. Value of livestock exports in the base model estimated at $1.5 billion while the State of Colorado imports other livestock products valued at $806 million in the base model. Beef exports represent 41% of Colorado's agricultural exports (Table 7-1).

7.3 Twenty Percent Rate of Return to Beef R&D

This simulation started with the lower level estimated in previous studies of rate of returns to livestock research (20%). Results of this simulation showed the lower levels of expected impacts. The difference between this simulation and previous studies is the inclusion of impacts on all other agricultural and non-agricultural sector not counted using the production function and economic surplus approaches. The livestock research impacts include the direct effects on the livestock sector (the research-targeted sector), effects to non-targeted sectors, indirect effects when businesses buy from each other, and induced effects when households gains a higher levels of income and the economy expands its exports, reduce imports. These impacts are a result of the *pecuniary* effects of productivity rather than direct resource use. They are not a direct impact of resource reallocation but rather they provide economic stimulus when prices of inputs or output are changing.

7.3.1 Pecuniary Effect for Twenty Percent ROR in Beef Research

An advantage of the CGE model is the possibility, provided within the modeling framework, to study the impact of productivity from research and development on prices. Table 7-1 shows the changes in aggregate (including export), domestic, and value added (returns to factor of production) prices. Beef aggregate prices drop about 10%, beef domestic prices drop 18%, and its value added price drops 32%. Feed grains, hay and pasture, and prepared prices increase, because productivity benefits of research requires usage of more inputs. Because raw material (beef) becomes more abundant to the meatpacking, the sector's aggregate and domestic prices also drop. However, hog prices increase because of the expected negative direction between pork and beef prices. As opposite to the beef, meat packing sector, and input sectors, this simulation does not show noticeable changes in the other economy's sector.

Table (7-1) Changes in Aggregate, Domestic and Value Added Prices For Twenty Percent ROR

Sector	Aggregate Price	Domestic Price	Producer Value Added Price
Dairy Farm Products	0.18%	0.24%	0.16%
Poultry and Eggs	0.20%	0.31%	0.32%
Beef	-10.35%	-18.52%	-31.80%
Sheep Lambs and Goats	0.02%	0.12%	0.04%
Hogs	1.09%	2.21%	3.65%
Miscellaneous Livestock	0.20%	0.22%	0.22%
Feed Grains	2.14%	2.15%	2.17%
Hay and Pasture	2.21%	2.23%	2.27%
Food Grains and other Agriculture	0.21%	0.24%	0.26%
Meat Packing	-3.23%	-4.97%	0.30%
Poultry Processing	0.07%	0.12%	0.13%
Other Food Manufacturing	0.03%	0.08%	0.08%
Prepared Feed	1.74%	1.97%	0.11%
Food Retail	0.03%	0.04%	0.10%
Wholesale and Other Trade	0.19%	0.21%	0.12%
Manufacturing	0.08%	0.11%	0.12%
Construction and Mining	0.07%	0.10%	0.12%
Services	0.06%	0.07%	0.08%
Education	0.09%	0.10%	0.11%
Research and Development	0.09%	0.11%	0.12%

7.3.2 Social and Economic Indictors for Twenty Percent ROR to Beef Research

The first simulation investigates beef specific-commodity research impacts. The initial ROR for this simulation is twenty percent. Column five in table 7-2 shows the percentage changes in the listed social and economic indicators when a 20% rate of return to investment in beef research experiment is applied to the Colorado livestock CGE model. Colorado Gross State Product (GSP) rises about 0.5% (from \$110.3 to \$110.9

billion) because of the twenty percent rate of return to investment in beef research. Total labor force (measured by the number of working households) increases about 0.14% to 1.37 million. As a result of hiring more laborers and because of the higher household income, gross household income improves 0.25% (from \$78.7 to \$78.9 billion). The production value of the agricultural sector increases from \$4.025 to \$4.33 billion (about 7.6%) because of the increased beef productivity from the twenty percent rate of return to investment in beef research.

Investment in beef research has both backward and forward effects within the beef production and manufacturing industries. On the backward side the value of feed grains, prepared feed and hay sector, which are inputs for beef production and feeding, for the beef production gain about 3.01% (from \$1.89 to \$1.95 billion). Because of the higher prices of feed grains and hay, producers of these inputs generate higher values for their production. While on the forward side the meatpacking sector increases its value of production from \$1.90 to \$1.95 billion (2.82%) because of the pecuniary effect of raw material (beef) lower prices. Relatively, the meatpacking sector benefits less from a dollar invested in beef research compared to the feed grains and hay sectors. This result shows that returns to beef research spill out vertically in terms pecuniary effects across agricultural inputs and food processing sectors. Spill out towards backward linkages is slightly higher in value relative to the effects on the forward links in this simulation (Table 7-2).

Table (7-2) Economic Indicators for Twenty Percent Rate of Return to Investment in Colorado Beef R&D

Economic Indicator	Unit	Base	20% Beef R&D ROR	Change %
Gross State Product (GSP)	Billion ($)	110.286	110.864	0.52%
Total Labor Force (Number of Working Households)	No. of Household	1,369,530	1,371,484	0.14%
Gross Households Income	Billion ($)	78.734	78.928	0.25%
Agricultural Sector Value of Production	Billion ($)	4.025	4.330	7.58%
Livestock Sector Value of Production	Billion ($)	1.882	2.143	13.87%
Value of Feed Grains, Prepared Feed and Hay	Billion ($)	1.89	1.947	3.01%
Food Manufacturing Value of Production	Billion ($)	6.687	6.739	0.78%
Meat Packing Plans Value of Production	Billion ($)	1.898	1.951	2.82%
Total Value of Exports	Billion ($)	60.729	61.394	1.09%
Total Value of Imports	Billion ($)	28.711	28.781	0.25%
Total Value of Livestock Exports*	Billion ($)	1.552	1.681	8.30%
Total Value of Livestock Imports*	Billion ($)	0.806	0.806	-0.05%

* Production subsectors only (Beef, Dairy, Poultry, Swine, and other Livestock)

7.3.3 Direct, Indirect and Induced Effects for a Twenty Percent ROR to Investment in Beef Research

Total impact of twenty percent ROR to investment beef research found to be $837 million, which is shown in table 7-3. The direct effect of the twenty percent rate of return to investment in beef research is estimated to be $334.3 million, indirect effect is estimated to be $128.5 million, and induced impact estimated to be another $374 million. About one third ($253.4 million) of the total impact accrues within the beef production sector and the other two thirds ($584 million) accrues to the other agricultural and non-agricultural sectors.

The last column in table 7-3 shows the percentage impact for each of the twenty sectors. Beef productivity change because of research and development is causing about 18% higher value of production for this sector because of expansion of productivity. The meat packing sector impact estimated to be 2.8% because this sector has lower priced inputs (beef). The hog sector generates a higher value of production also because this sector benefited from the higher output prices as a substitute for beef when the beef prices when down. Feed grains, hay and pasture, and prepared feed sectors generate more income because prices of these inputs went up.

In conclusion, one third of the benefits stays within the targeted research sector, but about two thirds of the direct, indirect and induced benefits to investment in beef research spills out to the other sectors of the economy.

Table (7-3) Direct, Indirect and Induced Effects of Investment in Livestock Research for Twenty Percent ROR in Million ($)

Sector	Base	20% ROR Change	Direct	Indirect	Induced	Total Impact	Impact %
Dairy Farm Products	149.328	149.791	0.214	0.048	0.201	0.463	0.31%
Poultry and Eggs	65.809	66.219	0.210	0.052	0.148	0.410	0.62%
Beef	1,402.036	1,655.419	107.715	45.290	100.378	253.383	18.07%
Sheep Lambs and Goats	116.178	116.282	0.045	0.019	0.040	0.104	0.09%
Hogs	112.386	119.164	3.173	1.047	2.557	6.778	6.03%
Miscellaneous Livestock	35.922	36.102	0.076	0.005	0.100	0.180	0.50%
Feed Grains	346.156	359.973	5.775	0.745	7.297	13.817	3.99%
Hay and Pasture	555.807	578.954	10.324	0.124	12.700	23.147	4.16%
Food Grains and other Agriculture	1,241.504	1,248.364	3.034	0.057	3.769	6.860	0.55%
Meat Packing	1,897.537	1,950.993	20.198	10.074	23.184	53.456	2.82%
Poultry Processing	89.206	89.651	0.157	0.155	0.133	0.445	0.50%
Other Food Manufacturing	4,700.031	4,698.779	-0.501	-0.281	-0.470	-1.252	-0.03%
Prepared Feed	988.247	1,007.868	9.173	3.919	6.529	19.621	1.99%
Food Retail	6,002.768	6,013.681	5.019	2.776	3.118	10.913	0.18%
Wholesale and Other Trade	17,381.840	17,462.910	30.986	18.392	31.691	81.070	0.47%
Manufacturing	26,539.430	26,668.976	48.806	12.397	68.342	129.546	0.49%
Construction and Mining	30,307.280	30,364.575	21.855	7.643	27.798	57.295	0.19%
Services	62,906.070	63,039.517	50.955	17.729	64.763	133.447	0.21%
Education	23,981.460	24,024.738	15.645	7.734	19.899	43.278	0.18%
Research and Development	2,636.288	2,640.319	1.473	0.599	1.959	4.031	0.15%
Total	**181,455.283**	**182,292.275**	**334.332**	**128.524**	**374.135**	**836.992**	

7.3.4 Adjusted ROR to Investment in Beef Research

Estimates of direct, indirect and induced impacts are used to determine the stream of benefits to beef research over thirty five years lag. When the CGE model is simulated to evaluate rate of return to a directly targeted commodity (beef only) starting from initial rate of return of 20%, the estimated ROR was found to be 16% because of the opportunity cost of the resources used for beef research. This indicated that previous studies overestimated the ROR to beef research because of exclusion of opportunity cost. When all direct benefits to the beef as well as all agricultural and non-agricultural sectors included the ROR rises to 25%. When indirect benefits are included, the ROR is estimated to be 28%. When induced effects also added to the benefits of research ROR rise to 35%. The inclusion of direct-non-targeted benefits, indirect, and induced benefits to the calculation process of ROR caused a 15% increase in this ratio.

7.4 Forty Percent Rate of Return to Livestock R&D

The forty percent ROR simulation is a representation of another type of livestock research, which targets both beef and dairy commodities. The productivity gains at the level of forty percent ROR to research and development lead to expanding inter-state and international trade. This expansion in trade usually requires more services (meat packing, transportation, storage and other services). In other words, a forty percent rate of return to investment in livestock requires infrastructure modification (i.e better services, financing, packaging and highways usage to transport products). When economy's other sectors respond to higher beef and dairy productivity, more resources within these sectors need to be employed to match the productivity increases in the livestock sector.

7.4.1 Pecuniary Effect for Forty Percent ROR in Livestock Research

Table 7-4 shows the changes in aggregate, domestic, and value added prices. Research and development affected prices significantly. Beef aggregate prices drop about

13%, beef domestic prices drop 23%, and its value added price drops 64%. Dairy products aggregate prices drop 28%, domestic producer prices drop 33%, while dairy products value added price drop 81%. This result indicates that dairy products prices are more responsive to changes in quantity produced relative to the beef prices in all levels of price across the production and marketing channels.

Feed grains, hay and pasture, and prepared prices increase, because productivity benefits of research in both beef and dairy products require usage of more inputs. Because raw materials (beef) become more abundant to the meatpacking sector, aggregate and domestic prices also drop. However, hog prices increase because of the expected negative direction between pork and beef prices. Aside from beef, meatpacking sector, and the agricultural inputs sectors, this simulation shows a relatively higher response in the other agricultural and non-agricultural sectors, which demonstrates that resources are needed in the other sectors to match the productivity changes in beef and dairy sectors.

Table (7-4) Changes in Aggregate, Domestic and Value Added Prices For Forty Percent ROR to Livestock Research

Sector	Aggregate Price	Domestic Price	Value Added Price
Dairy Farm Products	-28.13%	-32.87%	-80.91%
Poultry and Eggs	0.40%	0.61%	0.71%
Beef	-13.86%	-22.97%	-64.02%
Sheep Lambs and Goats	0.02%	0.12%	0.01%
Hogs	1.52%	3.13%	4.96%
Miscellaneous Livestock	0.37%	0.41%	0.41%
Feed Grains	3.81%	3.83%	3.73%
Hay and Pasture	3.93%	3.98%	3.88%
Food Grains and other Agriculture	0.39%	0.45%	0.50%
Meat Packing	-4.41%	-6.72%	0.15%
Poultry Processing	0.05%	0.09%	-0.06%
Other Food Manufacturing	-0.27%	-0.72%	0.04%
Prepared Feed	3.07%	3.48%	-0.08%
Food Retail	-0.15%	-0.19%	-0.15%
Wholesale and Other Trade	0.14%	0.16%	-0.01%
Manufacturing	0.00%	0.00%	-0.02%
Construction and Mining	0.02%	0.03%	0.05%
Services	-0.08%	-0.10%	-0.13%
Education	0.03%	0.03%	0.06%
Research and Development	0.03%	0.03%	-0.03%

7.4.2 Social and Economic Indictors for Forty Percent ROR to Livestock Research

Column five in table 7-5 shows the percentage changes in the listed social and economic indicators when a 40% rate of return to investment in beef and dairy research is applied to the Colorado livestock CGE model. Colorado Gross State Product (GSP) rises about 1.71% (from \$110.3 to \$112.171 billion) because of the investment in beef and dairy research. Total labor force (measured by the number of working households) increases about 1.33% to total 1.39 million. As a result of hiring more laborers and because of the higher household income, gross household income improves 1.21% (from $78.7 to $79.69 billion). The production value of the agricultural sector increases from $4.025 to $4.46 billion (about 10.8%) because of the increased beef and dairy productivity resulting from the forty percent rate of return to investment in livestock research.

With regard to backward linkages, the value of feed grains, prepared feed and hay sectors used for beef and dairy production gain about 5.76% (from $1.89 to $2.23 billion). Because of the higher prices of feed grains and hay, producers of these inputs generate a higher value of their production. While on the forward linkages side, the meat packing sector increase its value of production from $1.89 to $1.98 billion (4.35%) because of the pecuniary effect related to the lower raw material (beef) prices. Relatively, the meat packing sector benefit less from a dollar invested in beef research compared to the feed grains and the hay sectors. This result shows that the pecuniary effects of returns to beef research spill out vertically across the agricultural inputs and food processing sectors. Spill out towards backward linkages is slightly higher in value relative to the effects on forward linkages in this simulation too (Table 7-6). Because these effects shows the same pattern with both 20% and 40% simulation, one can conclude that pecuniary effects travel across the backward and the forward links with the same proportional impact. In other words this result may confirm Freebairn et al.'s (1982) that a distribution of benefits (cost reduction) in a multistage analysis of inputs suppliers, farmers, marketers, and consumer system is the same among these beneficiaries. This research shows that this is true not only on the cost reduction side but also on the distribution of gains from more value added and profits.

Table (7-5) Economic Indicators for Forty Percent Rate of Return to Investment in Colorado Livestock R&D

Economic Indicator	Unit	Base	40% Livestock R&D ROR	Change %
Gross State Product (GSP)	Billion ($)	110.286	112.171	1.71%
Total Labor Force (Number of Working Households)	No. of Households	1,369,530	1,387,774	1.33%
Gross Household Income	Billion ($)	78.734	79.687	1.21%
Agricultural Sector Value of Production	Billion ($)	4.025	4.459	10.79%
Livestock Sector Value of Production	Billion ($)	1.882	2.232	18.58%
Value of Feed Grains, Prepared Feed and Hay	Billion ($)	1.890	1.999	5.76%
Food Manufacturing Value of Production	Billion ($)	6.687	6.809	1.83%
Meat Packing Plans Value of Production	Billion ($)	1.898	1.980	4.35%
Total Value of Exports	Billion ($)	60.729	61.480	1.24%
Total Value of Imports	Billion ($)	28.711	29.107	1.38%
Total Value of Livestock Exports*	Billion ($)	1.552	1.738	11.97%
Total Value of Livestock Imports*	Billion ($)	0.806	0.716	-11.13%

* Production sub-sectors only (Beef, Dairy, Poultry, Swine, and other Livestock)

7.4.3 Direct, Indirect and Induced Effects for a Forty Percent ROR to Investment in Livestock Research

Direct, indirect and induced impacts as supply of beef and dairy change and generate about forty percent rate of return to investment in beef research is shown in table 7-6 which summed to $2.6 billion. Direct effects of a forty percent rate of return to investment in beef and dairy research estimated to be $1 billion, where the indirect effect is estimated to be $382.9 million, and the induced impact is estimated to be another $1.2

billion. Only about $339 million of the total impact accrues within the beef and dairy production sectors and the rest (2.2 billion) accrue to the other agricultural and non-agricultural sectors. This figure indicates that for the productivity to improve to such level a significant changes are required in the non-agricultural sectors.

The last column in table 7-6 shows the percentage impact for each of the twenty sectors. Beef productivity change because of research and development is causing about 24% higher value of production for this sector because of expansion of productivity. The meat packing sector impact estimated to be 4.35% because this sector uses lower prices of inputs (meat). The hog sector generates a higher value of production also because this sector benefited from the higher output prices as a substitute for beef when the beef prices decline. The dairy farm products witnessed a lower value of supply responding to lower prices. The negative impact on the dairy farm sector (-0.37%) indicated that this sector is more sensitive to price changes compared to quantity changes in. The hog sector benefit from higher output prices of beef because of its capacity to response to export possibility, while the dairy sector does not. Dairy sector seems less capable of producing products which are transferable across states boundaries compared to beef and hog sectors. Prices of dairy products went down as a result of research and development, but the decline of prices was large enough to prevent the value of total supply from increasing because most of the dairy production in Colorado is raw milk for local consumption. Feed grains, hay and pasture, and prepared feed sectors generate more income because prices of these inputs went up.

In conclusion to this simulation, productivity gains can has both positive and negative impacts within the economy's sectors. Also rate of return to investment in livestock research beyond some level requires structural changes in the infrastructure sectors.

Table (7-6) Forty Percent ROR Direct, Indirect and Induced Effects of Investment in Livestock Research in Million ($)

Sector	Base	40% ROR Change	Direct	Indirect	Induced	Total Impact	Impact %
Dairy Farm Products	149.33	148.78	-0.255	-0.057	-0.239	-0.550	-0.37%
Poultry and Eggs	65.81	66.82	0.520	0.130	0.366	1.015	1.54%
Beef	1402.04	1741.01	144.100	60.588	134.284	338.972	24.18%
Sheep Lambs and Goats	116.18	116.39	0.090	0.038	0.080	0.208	0.18%
Hogs	112.39	122.23	4.609	1.521	3.714	9.844	8.76%
Miscellaneous Livestock	35.92	36.49	0.238	0.015	0.313	0.566	1.57%
Feed Grains	346.16	371.05	10.406	1.342	13.149	24.897	7.19%
Hay and Pasture	555.81	597.63	18.655	0.223	22.948	41.826	7.53%
Food Grains and other Agriculture	1241.50	1259.25	7.847	0.148	9.749	17.744	1.43%
Meat Packing	1897.54	1980.10	31.195	15.558	35.807	82.560	4.35%
Poultry Processing	89.21	90.79	0.559	0.552	0.474	1.585	1.78%
Other Food Manufacturing	4700.03	4738.81	15.525	8.706	14.544	38.776	0.83%
Prepared Feed	988.25	1030.42	19.718	8.424	14.035	42.176	4.27%
Food Retail	6002.77	6066.19	29.169	16.135	18.121	63.425	1.06%
Wholesale and Other Trade	17381.84	17648.37	101.874	60.469	104.189	266.532	1.53%
Manufacturing	26539.43	27087.98	206.665	52.496	289.389	548.550	2.07%
Construction and Mining	30307.28	30526.14	83.482	29.194	106.183	218.858	0.72%
Services	62906.07	63542.60	243.051	84.568	308.914	636.532	1.01%
Education	23981.46	24203.39	80.228	39.660	102.044	221.931	0.93%
Research and Development	2636.29	2657.61	7.791	3.171	10.363	21.325	0.81%
Total	**181,455.283**	**184,032.055**	**1,005.467**	**382.880**	**1,188.426**	**2,576.772**	

7.4.4 Adjusted ROR to Investment in Beef Research

Estimates of direct, indirect and induced impacts used to derive the stream of benefits to beef research over thirty five years lag. When the CGE model simulated to shift the production function of beef and dairy starting from initial rate of return of a 40% the estimated ROR found to be 35% because of the opportunity cost of the resources used for beef and dairy research. When all direct benefits (targeted and non-targeted) to the beef and dairy as well as all agricultural and non-agricultural sectors included ROR rise to 64%. When Indirect benefits included the ROR is estimated to be 76%. When induced effects also added to the benefits of research ROR rise to 104%. The inclusion of direct-non-targeted benefits, indirect, and induced benefits to the calculation process of ROR caused a 69% increase in this ratio.

7.5 Sixty Percent Rate of Return to Livestock R&D

This simulation is designed to capture the effect of basic livestock research, which targets all sectors (beef, dairy, hogs, poultry and feed grains). As in the previous simulation, resources from other sectors are needed to make the productivity shocks reasonable. Basic research has a long-term impact and its immediate direct impact is expected to be lower than applied research. This simulation approximates the impact of research when costs and benefits are spread across the livestock production sectors including a cost reduction when the feed grains sector increases its productivity as new technology adopted. Example of this type of research would be basic nutrition study, which study the metabolism of animal feeding on specific grains on animal weight. The feed grain sector is included in this simulation to portray livestock nutrition basic research, which target the animal feeding material and the physiology factors on productivity. It is essential to have abundant lower prices feed for the productivity gains to occur in real livestock operations. This study provides empirical case study, similar basic livestock research may occur affecting other related sectors.

7.5.1 Pecuniary Effect for Sixty Percent ROR in Livestock Research

Table 7-7 shows the changes in aggregate, domestic, and value added prices. Research and development affected prices significantly. All livestock commodities aggregate prices drop in the range between 10 to 32% because the basic research benefits are spread over the sector's commodities. Domestic producer prices decrease varies between 9 to 33%, while the value added prices drop between 25 to 79%. Feed grains prices, as a targeted sector by research in this simulation, drop to the livestock producer by 32%. Prepared feed prices decrease, because raw material prices (feed grains) went down. Because raw materials become more abundant to meatpacking, poultry processing, other food manufacturing sectors' aggregate and domestic prices also drop because the supply of raw materials for these industries increases. In general, prices of most commodities in the economy are lower because basic research reaches more sectors directly ant its pecuniary impact spills out vertically to more sectors than the commodity-specific research.

Table (7-7) Changes in Aggregate, Domestic and Value Added Prices

Sector	Aggregate Price	Domestic Price	Value Added Price
Dairy Farm Products	-28.44%	-33.18%	-79.58%
Poultry and Eggs	-19.71%	-25.61%	-62.93%
Beef	-10.40%	-18.58%	-44.78%
Sheep Lambs and Goats	-2.66%	-9.02%	-25.16%
Hogs	-14.83%	-22.83%	-62.09%
Miscellaneous Livestock	-29.72%	-31.58%	-49.53%
Feed Grains	-31.93%	-32.07%	-47.93%
Hay and Pasture	6.74%	6.81%	6.48%
Food Grains and other Agriculture	0.42%	0.48%	0.58%
Meat Packing	-4.52%	-6.87%	0.13%
Poultry Processing	-4.59%	-7.32%	0.19%
Other Food Manufacturing	-0.32%	-0.88%	0.05%
Prepared Feed	-6.28%	-7.03%	0.04%
Food Retail	-0.22%	-0.27%	-0.18%
Wholesale and Other Trade	-0.34%	-0.38%	0.00%
Manufacturing	-0.06%	-0.08%	-0.02%
Construction and Mining	-0.01%	-0.02%	0.05%
Services	-0.11%	-0.13%	-0.15%
Education	0.01%	0.02%	0.06%
Research and Development	-0.05%	-0.06%	0.06%

7.5.2 Social and Economic Indictors for Sixty Percent ROR to Livestock Research

Column five in table 7-8 shows the percentage changes in the social and economic indicators listed when a 60% rate of return to investment in basic livestock research is applied to the Colorado livestock CGE model. Colorado's Gross State Product (GSP) rises about 1.95% (from \$110.3 to \$112.433 billion). Total labor force (measured by the number of working households) increases about 1.54% to total 1.39 million. As a result of hiring more laborers and because of the higher household income, gross household income improve 1.24% (from \$78.7 to \$79.71 billion). Production value of the agricultural sector increase from $4.025 to $4.35 billion (about 8.07%) because of the increased livestock productivity resulted from the effect of the sixty percent rate of return to investment in basic livestock research. The total value of agricultural production in this simulation increased relatively less than the 40% scenario because of the impacts of cost reduction when the feed grains sector produces output in lower prices (feed grains productivity lower prices for livestock producers). Even though total value of agricultural production in this scenario is lower than the 40% scenario figures, however other social and economic indicators showed a higher welfare impact. (i.e. higher GSP, total labor, gross household income from wages, and lower food prices). This confirms that basic livestock research has a higher welfare impact compared to livestock commodity-specific research.

The forward linkages, which includes the meat packing, poultry processing, and other food manufacturing sectors increase its value of production from $6.7 to $6.8 billion (2%) because of the pecuniary effect of lower raw material prices (Table 7-8). The meat packing sector's value of production increases 4.5%. Gross value of exports increase about 1.33%, while value of livestock exports specifically increase 7.23%. The economy in total reduces imports by 10%.

Table (7-8) Sixty Percent Rate of Return to Investment in Colorado Beef R&D Economic Indicators

Economic Indicator	Unit	Base	60% Livestock R&D ROR	Change %
Gross State Products (GSP)	Billion ($)	110.286	112.433	1.95%
Total Labor Force (Number of Working Households)	No. of Household	1,369,530	1,390,616	1.54%
Gross Households Income	Billion ($)	78.734	79.710	1.24%
Agricultural Sector Value of Production	Billion ($)	4.025	4.350	8.07%
Livestock Sector Value of Production	Billion ($)	1.882	2.188	16.25%
Value of Feed Grains, Prepared Feed and Hay	Billion ($)	1.890	1.860	-1.56%
Food Manufacturing Value of Production	Billion ($)	6.687	6.821	2.01%
Meat Packing Plans Value of Production	Billion ($)	1.898	1.983	4.49%
Total Value of Exports	Billion ($)	60.729	61.534	1.33%
Total Value of Imports	Billion ($)	28.711	29.144	1.51%
Total Value of Livestock Exports*	Billion ($)	1.552	1.665	7.23%
Total Value of Livestock Imports*	Billion ($)	0.806	0.724	-10.20%

* Production subsectors only (Beef, Dairy, Poultry, Swine, and other Livestock)

7.5.3 Direct, Indirect and Induced Effects for a Sixty Percent ROR to Investment in Livestock Research

Direct, indirect and induced impacts as supply of livestock commodities change and generate about sixty percent rate of return to investment in beef research is shown in table 7-9 which summed to $2.6 billion. Direct effects of sixty percent rate of return to investment in livestock research estimated to be $1 billion, indirect effect is estimated to be $385.5 million, and induced impact estimated to be another $1.2 billion. Only about $306 million of the total impact accrues within the livestock production sector and the rest ($2.4 billion) accrues to the other agricultural and non-agricultural sectors. The figure indicates that for the productivity to improve to such level, significant changes are required in the non-agricultural sectors. These sectors are manufacturing, wholesale and retail trade, services, construction, education, and research and development itself. As stated earlier in this study, the CGE model used to duplicate the economy's sectors interaction and follow the pecuniary impact of productivity as it feeds out to other sectors. These sectors together are the components of the state infrastructure. Infrastructure changes are needed to produce more livestock, such as available feed grains, storage facilities expanding, and meatpacking sector expand to produce larger amount of products, while the transportation system need more resources to ship products and the trade system need to expand facilities to sell the product locally and export to the outside.

The last column in table 7-9 shows the percentage impact for each of the twenty sectors. The productivity of all livestock sectors changes because of research and development. The beef sector's value of production increases about 19%, poultry and eggs, 7.4%, sheep, lambs and goats. 11.5%, hogs, 15.7%, and the cost reduction in the feed grains sector to the livestock producers is about 21%. The prepared feed sector also shows a cost reduction of 2.88%. These results demonstrate that the gains from higher production, lower prices to consumers in the economy from arise from having cheaper inputs. Meatpacking and poultry processing sectors also benefit from the availability of cheaper meat, and so expand 4.5 and 3.4% respectively.

Table (7-9) **Sixty Percent ROR Direct, Indirect and Induced Effects of Investment in Livestock Research in Million ($)**

Sector	Base	60% ROR	Direct	Indirect	Induced	Total Impact	Impact %
Dairy Farm Products	149.328	148.945	-0.177	-0.040	-0.166	-0.383	-0.26%
Poultry and Eggs	65.809	70.651	2.479	0.618	1.745	4.842	7.36%
Beef	1,402.036	1,672.565	115.004	48.354	107.170	270.529	19.30%
Sheep Lambs and Goats	116.178	129.602	5.809	2.476	5.138	13.424	11.55%
Hogs	112.386	130.020	8.256	2.725	6.653	17.634	15.69%
Miscellaneous Livestock	35.922	36.007	0.036	0.002	0.047	0.085	0.24%
Feed Grains	346.156	272.418	-30.820	-3.974	-38.944	-73.738	-21.30%
Hay and Pasture	555.807	628.261	32.316	0.387	39.751	72.454	13.04%
Food Grains and other Agriculture	1,241.504	1,261.414	8.805	0.166	10.939	19.910	1.60%
Meat Packing	1,897.537	1,982.725	32.188	16.054	36.946	85.188	4.49%
Poultry Processing	89.206	92.192	1.054	1.040	0.892	2.986	3.35%
Other Food Manufacturing	4,700.031	4,746.342	18.542	10.398	17.371	46.311	0.99%
Prepared Feed	988.247	959.815	-13.292	-5.679	-9.461	-28.432	-2.88%
Food Retail	6,002.768	6,073.374	32.471	17.962	20.173	70.606	1.18%
Wholesale and Other Trade	17,381.840	17,657.183	105.242	62.467	107.634	275.343	1.58%
Manufacturing	26,539.430	27,158.980	233.414	59.290	326.845	619.550	2.33%
Construction and Mining	30,307.280	30,547.208	91.519	32.004	116.406	239.928	0.79%
Services	62,906.070	63,609.763	268.696	93.491	341.507	703.693	1.12%
Education	23,981.460	24,227.732	89.027	44.010	113.236	246.272	1.03%
Research and Development	2,636.288	2,661.544	9.228	3.755	12.273	25.256	0.96%
Total	**181,455.283**	**184,066.741**	**1,009.794**	**385.507**	**1,216.156**	**2,611.458**	

7.5.4 Adjusted ROR to Investment in Beef Research

Estimates of direct, indirect and induced impacts are used to derive the stream of benefits to beef research over thirty five years lag. When the CGE model simulated to evaluate rate of rate of to basic starting from initial rate of return of a 60% the estimated ROR found to be 57% because of the opportunity cost of the resources used for livestock research. When all direct benefits (targeted and non-targeted) to the livestock research benefits are included, all agricultural and non-agricultural sectors ROR rise to 73%. When indirect benefits included the ROR is estimated to be 86%. When induced effects also added to the benefits of research ROR rise to 117%. The inclusion of direct-non-targeted benefits, indirect, and induced benefits to the calculation process of ROR caused a 60% increase in this ratio. These results need to be taken cautiously because of required structural changes in the non-agricultural sectors to cope with the higher productivity in the livestock sectors.

7.6 Returns to Factor of Production, Households Income and Tax

Table 7-10 contain a comparison of returns to factors of production, household income, and gross federal, state, and sales taxes between the simulations of 20, 40, and 60% ROR. As expected, investment in livestock research affects returns to factors of production and household income significantly. At the 20% level of ROR to investment in livestock research, the changes are moderate because returns to factors does not increase more than 0.32% to land, 0.29% to labor, and 0.25% for capital, however at 40%

ROR to livestock R&D there is about 1.23% increase in return to labor, 1.21% in return to land, and 0.95% in return to capital.

Similar conclusion noticed with regards to household income. At the 20% level of ROR household income increases are 0.28%, 0.30%, and 0.29% for the three different income levels; less than $20,000, $20,000 to $40,000, and more than $40,000 annual income respectively. However, at 40% ROR to beef and dairy research the lower income household group benefit the most compared to the other two groups, because household income rises 1.28%, 1.24%, and 1.18% for the less than $20,000, $20,000 to $40,000, and more than $40,000 annual income respectively (table 7-10).

The basic livestock research clearly contributes to higher returns to factors of production, and higher income to all household categories. Returns to factor of production increases at 1.44%, 1.09%, and 1.22% for labor, capital, and land respectively. The middle-income group witnesses a slightly higher impact than the low and high-income categories, because this group gained about 1.4% in household income compared to 1.35% for the less than $20,000 income level, and about 1.34% increase for the high annual income household group.

Taxes paid by industries and households to the city, state, and federal government were including in the models to use net prices and income. Taking taxes into consideration, corrected for deadweight loss when rates of returns were estimated. Taxes deadweight loss defined to the value of foregone production resulting from imposition of taxes in an economy (Fuglie et al. 1996). Net prices of taxes are used in this study to avoid the drawback of deadweight loss in previous studies. Total tax imposed in the economy is relatively the least with basic research. Total tax increases 0.44% for the 20%

ROR to beef research, 1.41% for the 40% beef and dairy research, and 1.43% for the livestock research. This results confirms Fuglie et. al (1996) that adjustment for taxes deadweight loss is very large if returns are heavily weighted to near term but much smaller if returns the returns are more heavily weighted to the future. Basic research tend to target longer terms objectives compared to applied and commodity-specific research.

Table (7-10) Changes in Returns to Factors of Production, Households Income, and Tax in Billion ($)

Measure	Base	20% ROR	Change %	40% ROR	Change	60% ROR	Change %
Returns to Factors of Production							
Labor	75.057	75.273	0.29%	75.983	1.23%	76.134	1.44%
Capital	9.888	9.914	0.25%	9.982	0.95%	9.996	1.09%
Land	38.215	38.339	0.32%	38.678	1.21%	38.682	1.22%
Household Income							
Less than $20,000	6.189	6.206	0.28%	6.268	1.28%	6.273	1.35%
$20,000 to $40,000	24.63	24.705	0.30%	24.934	1.24%	24.976	1.40%
More than $40,000	65.523	65.714	0.29%	66.299	1.18%	66.398	1.34%
Total Tax*	16.634	16.707	0.44%	16.869	1.41%	16.872	1.43%

* Tax include federal, state, sales, and unemployment tax

7-7 Adjusted Rates of Return to Investment in Livestock Research

In conclusion, the pecuniary impact of livestock research in Colorado is found to be significant. Previous studies did not adjust for very important factors, which causes over-or under-estimation of ROR to livestock. Mainly, these factors include the backward and forward effects to the sectors of the economy. When measuring rates of return to investment in livestock research, using production function or economic surplus approach alone is not enough to capture these effects. The other direct effect not measured before is the effect to the agricultural and non-agricultural not-targeted directly by research. This study provided a case study of measuring all indirect and induced impact of livestock research. Because the CGE model portrays all interacting sectors of the economy, it is a more valid technique to incorporates opportunity costs and limited resources, and allows tracing of the price effects. Adjusted RORs accounts for these resource limits and the price effects are represented in Table 7-11.

Table 7-11 Adjusted Rates of Return to Investment in Livestock Research

Model	Simulation Direct ROR	All direct*	Direct and Indirect	Direct, Indirect, and Induced
Initial 20 % ROR	16	25	28	35
Initial 40% ROR	35	64	76	104
Initial 60% ROR	58	73	86	117

* All direct include direct to agricultural and non-agricultural targeted and not-directly targeted sectors

Livestock research in Colorado returns high benefits to the producer, marketer, and consumer. Rates of return to investment in livestock research are estimated in the range between 16 to 117% depending on the nature of technological change and the level of indirect and induced impact. Livestock research spills out to the other agricultural and non-agricultural sectors directly through traded commodities and indirectly through the prices. Livestock research in Colorado found to be an ideal case study because the state is a leader in the region in production, marketing and research. Colorado spills out about 47% of the benefits of agricultural research through trade and price effects to other states and rest of the world.

7-8 Livestock Research Spatial Pecuniary Spillover

To highlight the possibilities of spatial spill over from Colorado livestock research another simulation performed. This simulation adjusted the beef and dairy exports prices by 10% less, starting from the 40% ROR prices discussed earlier. The goal of this section is to study the impact of lower export prices, which indicates other states and rest of the world benefit from the pecuniary price impact of livestock research in Colorado. The results of this simulation focus on the differences between the 40% ROR and the lower livestock exports prices to record expected spatial pecuniary impact in term of prices and socio-economic indicators. Further study may perform similar simulations to the other Northern Plains States to follow the spill in and spill effects out between these states.

Because of lower exports prices the local aggregate prices of beef will increase about 0.68% because domestic price increases 0.82% and value added price increases 0.77% compared to the 40% ROR simulation prices (Table 7-12). These results are expected because spillover affects local beef consumers negatively. Lower quantity of local supply of beef (more export pecuniary effect because of lower prices in other states) increase prices for local consumers. However dairy sector witnesses lower prices because of the resource shift from this sector to the beef sector.

The beef sector uses more resources to meet the demand for exports. The hog sector also suffers lower prices for the same reason. Other sectors of the economy share the cost, which the state pays to provide beef production in lower prices in other states. Relatively, increasing in beef prices was lower the decrease of other sectors prices. This result showed that producer in Colorado might suffer from lower export prices because of the pecuniary impact of spill out.

Table (7-12) Spatial Spillover Impact in Aggregate, Domestic and Value Added Prices

Sector	Aggregate Price	Domestic Price	Value Added Price
Dairy Farm Products	-2.66%	-2.63%	-2.54%
Poultry and Eggs	-0.26%	-0.40%	-0.32%
Beef	0.68%	0.82%	0.77%
Sheep Lambs and Goats	-0.03%	-0.14%	-0.05%
Hogs	-1.56%	-3.19%	-2.85%
Miscellaneous Livestock	-0.25%	-0.28%	-0.26%
Feed Grains	-1.34%	-1.35%	-1.35%
Hay and Pasture	-1.39%	-1.41%	-1.40%
Food Grains and other Agriculture	-0.16%	-0.19%	-0.17%
Meat Packing Plants	0.06%	0.09%	-0.06%
Poultry Processing	-0.11%	-0.19%	-0.07%
Other Food Manufacturing	-0.06%	-0.16%	-0.03%
Prepared Feed	-1.09%	-1.24%	0.00%
Food Retail	-0.10%	-0.13%	-0.09%
Wholesale and Other Trade	-0.18%	-0.20%	-0.11%
Manufacturing	-0.10%	-0.13%	-0.07%
Construction and Mining	-0.09%	-0.11%	-0.06%
Services	-0.09%	-0.10%	-0.07%
Education	-0.11%	-0.13%	-0.10%
Research and Development	-0.12%	-0.14%	-0.10%

The social and economic indicators of this simulation show a negative impact at the state level because GSP reduced 0.35% (from $112.171 to $111.775 billion), number of working household decreased 0.13% from 1.388 million to 1.385 million, and gross household income from wages decreased 0.35% (table 7-13).

The agricultural sector suffers from livestock benefits which spills out to other states about 7%, The livestock sector suffer the most (12.9%), and the meatpacking sector, which produces meat products for exports suffered 10.7% in its value of production. These results indicates that the spatial spill over effects have a vertical impact to the forward and backward linkages that are significant. Spatial spillover has a negative welfare impact as well because the state and household income become less.

Table (7-13) Economic Indicators Spatial Spillover

Economic Indicator	Unit	40% Livestock R&D ROR	Spatial Price Spillover	Change %
Gross State Product (GSP)	Billion ($)	112.171	111.775	-0.35%
Total Labor Force (Number of Working Households)	No. of Households	1,387,774	1,385,945	-0.13%
Gross Household Income	Billion ($)	79.687	79.406	-0.35%
Agricultural Sector Value of Production	Billion ($)	4.459	4.144	-7.06%
Livestock Sector Value of Production	Billion ($)	2.232	1.944	-12.89%
Value of Feed Grains, Prepared Feed and Hay	Billion ($)	1.999	1.963	-1.82%
Food Manufacturing Value of Production	Billion ($)	6.809	6.601	-3.05%
Meat Packing Plans Value of Production	Billion ($)	1.980	1.767	-10.74%
Total Value of Exports	Billion ($)	61.480	61.130	-0.57%
Total Value of Imports	Billion ($)	29.107	28.899	-0.71%
Total Value of Livestock Exports*	Billion ($)	1.738	1.473	-15.27%
Total Value of Livestock Imports*	Billion ($)	0.716	0.645	-9.85%

* Production sub-sectors only (Beef, Dairy, Poultry, Swine, and other Livestock)

Chapter Eight: Conclusions and Policy Implications

8.1 Conclusions

Investment in livestock basic knowledge, applied research and technology transfer in the region has a multiplicative impact because of the significant share of livestock production in the region and because of the large number and volume of other businesses that support backward and forward services of the livestock sector. Investment in livestock R&D affects farmers' and marketers' income when new technologies enable them to produce more output using the same amount of input or producing the same amount of output using less amount or cost of inputs. Investment in livestock research affects consumers when livestock products become available with lower prices, with higher quality, and that are safer.

The circulation of cash generated from livestock activities in the economy creates new jobs, encourages entrepreneurship, and increases investment in capital stock in the region. The impact also spills out to neighboring states through inter-state trading, research publications, conferences and similar disseminations. For these reasons, estimates of rates of return to investment in research and development should include investigation of all productivity effects, the time-lagged effect of research, tax collection deadweight loss, and business impacts, including indirect, induced, and pecuniary impacts. The business impact includes an impact from the direct cash investment to the targeted livestock sector, the direct cash investment to non-targeted agricultural and non-agricultural sectors to finance research and new technology, a second round of cash flow when businesses buy from each other, and the impact of the investment to the society by creating more jobs and increasing income levels of households. This research focus is to trace livestock research impacts in the region by assuming not only direct impacts included in previous studies, but also indirect and induced impacts.

Adjusted rates of return to livestock research help federal and state agricultural research policy makers correctly weight the value of different types of livestock research. In other words, corrected rates of return to investment in livestock research are valid policy tools for research priority setting.

Previous studies e.g. Alston et al. (1995) suggest the need for a more representative model of the economy in order to avoid the drawbacks of the studies that investigated rate of return to investment in agricultural research. A large number of the estimates of returns to investment in agricultural research have been addressed by using the production function approach and many have been addressed by using the economic surplus approach. However, other economy sectors interact with the research and development in agriculture. Productivity and production function approaches may lack the ability to represent all economic sectors and to accurately disentangle sources of productivity growth because of the exclusion of the pecuniary impact of changing prices. Productivity measures may also over or underestimate infrastructure expenditures and may under-signify the value of returns to factors of production because of the focus on the output gains rather than following all food chains backward and forward. Economic surpluses studies looked at the welfare impact, but it is a partial equilibrium rather than general equilibrium approach, which portrays all economic agents (producers, manufacturers, households, state and federal governments, and traders).

Few studies provided empirical results on the usefulness of rates of return estimation and how could it be used to assess the impact of investment in a specific type of commodity research. This study provided an empirical work that investigates returns and impacts of investments in livestock research with consideration for both the commodity's demand, when economic sectors interact with each other and the spatial dimension when the state spills in and spills out to neighboring states in the Northern Plains region.

This research developed a regional Social Accounting Matrices (SAM) for Colorado and the Computable General Equilibrium Model (CGE) of Colorado as a case study for regional Northern Plains to study the effects of investment in livestock research. The CGE model accounts for most of the disadvantages of the methods summarized in the literature review in chapter 2. The SAM and the CGE models are used to address issues related to the social cost of using public tax to finance agricultural research. SAM and CGE are more comprehensive and have the advantage of capturing the direct, indirect, and induced effects of investment in livestock research compared to the other methods because they include the livestock production sector as well as all economic sectors, households, governments, and interstate trade.

8.1.1 Lessons Learned From Previous Studies

The majority of studies (1964-1993) showed a core average 40-60 percent return to investment in public agricultural research. Basic research earned the greatest rates, at 60-90 percent, and extension earned less than 30 percent. Basic research has the greatest return, which drives up the average return for public research compared to private research. Only about 15 percent of private research is basic, compared to 41 percent in the public sector, which explains why private research has generated a lower rate of return than the public sector. There has been a general pattern of increasing rates of return from agricultural research over time. A possible explanation is the lag of agricultural research benefits, which can take up to 30 years to be fully realized. In the 1990s, much of the agricultural research benefits were due to research conducted in the 1960s and the 1970s.

8.1.2 Funding Issues and Implications

The public sector focuses on basic research and the private sector focuses on applied research. However private research is found to be under-investing in livestock research because of the uncertainty related to the biological characteristics of the livestock research. Total U.S. public and private funding for livestock research was estimated to be $1.2 billion in 1996. On average in the United States, the federal government provided 27 percent of funding of livestock research, states and local governments cover 23 percent, and other non-governmental public account for sources up to 12 percent, leaving the remaining 38 percent for the private sector. It is not the same picture for total agricultural research, where the private sector outspends the federal and state governments combined (Hoag and Fathelrahman 2000). This indicates that the private sector invests more in crop and other agricultural products and inputs compared to livestock research and technologies.

In Colorado, the Agricultural Experiment Station's (CAES) total investment in livestock and biotechnology related to livestock research summed to over $5.3 million in 1997. More than half of the CAES funding for livestock research (about $3.1 million) was used for beef research. Forage crops research ranked second, with an investment of $737,009, and dairy cattle came in third, at $583,120. CAES funding for all agricultural research in Colorado increased from $25 million in 1990 to about $29 million in 1997, while funding for livestock research decreased from $6.3 million to about $5.3 million over the same period. This means in Colorado public livestock research funds had decreased significantly in real terms since 1990.

Research intensity is an index that measures the relationship between the value of investment in research to the gross value of production in a specific year for a specific sector or commodity (research intensity = ($ of research/ $ of production) X 100). Regional research intensity did not vary substantially during the last decade, but details of research intensity demonstrated great variation within the breakdown of intensity. Dairy cattle and poultry research intensity had a greater variation than beef research. For example, poultry research intensity diminished noticeably in Colorado, Kansas, and

Nebraska between 1990 and 1997, while dairy cattle research intensity increased significantly during the same period. Gross value of production seems stable in the region, leaving changes in funding to be the factor determining the intensity of research. Dairy, swine, and poultry research funding witnessed significant variations causing the intensity of research to also vary during the last decade. By varying research intensity, the public sector sent signals to the private sector to intensify research in dairy, swine and poultry and under-invest in beef.

8.1.3 Benefits of Livestock Research

Benefits of research and development includes productivity gains. There is accelerating livestock productivity in most of selected Northern Plain sates. The trend of livestock productivity in the major livestock production states in the Northern Plains has been increasing significantly since the 1960s. Average productivity in the region has grown faster than the national average in recent years (except for South Dakota, which is close to the national average). This makes the region an ideal case study for investigating the share of technology and research on productivity growth over the last four decades. That implies differences in the extent of technology diffusion and research and technology spill over. If a state shows high recent rates of productivity growth, it may indicate that the state is a recipient of research and development spill out from other states.

Colorado's livestock sector experienced strong productivity growth. The livestock sector witnessed more than a doubling of productivity over the last 36 years. Colorado livestock productivity outperformed its crop productivity counterpart in most of the series, especially for the period 1987 to 1996. The annual rate of growth of average livestock productivity between 1960-1996 was 2.05%, compared to 1.69% for crops. Demand for high quality beef also played a major role as an incentive for ranchers to produce more and increase their efficiency to gain from increasing demand. Increasing demand for exports of livestock is considered as another factor that encouraged ranchers either to increase output using the same amount of inputs or produce the same amount of output by applying less input. This indicates the significant role of demand in productivity increases.

8.1.4 SAM and Multiplier Results

From IMPLAN data, it is seen that the Colorado livestock sector contributed around $2.9 billion or 54 percent of the value of output of the agricultural sector in 1997. The livestock sector employs 17,195 people and generates $1.2 billion in value added as a result of returns to labor, capital, land and tax revenue available for the government spending. The value added doubled (to $2.6 billion) when all other related agricultural and manufacturing sectors were included (such as feed grains, hay and pasture, prepared feeds, meat packing and poultry processing sectors).

The SAM multiplier effect approach showed that the Colorado R&D SAM multiplier is 2.74. This means that $1 invested will generate $2.74 as a result of direct, indirect, and induced effects. The direct effect is the original expenditure resulting from the first round of demand by the economy's industries for raw material, labor and capital. The indirect effect is the value added impact of sectors buying intermediate inputs from each other. The induced effect is based on income as household expenditures rise when they receive more income. The induced effect is derived from the SAM and it also accounts for inter-institutional transfers, such as social security payments. The link between the impact of R&D and multiplier effects relate to the economy's multiplicative effects of investment. An economy with higher multipliers is more responsive to technology and development changes. Distribution of the multipliers between direct, indirect and induced impacts determines which sectors will benefit more from technology shocks and how much magnitude the technology will make the society better off. For example, the meat packing sector multiplier is double the beef production indirect multiplier. For each dollar invested in the livestock technology, the meat packing sector will capture double the magnitude of benefits that the beef production will capture. Multiplier results indicated that the manufacturing, processing, and trade sectors capture more of the returns to a dollar investment in the R&D compared to the primary production sectors such as the crops and livestock sectors.

The Nebraska, Colorado, and South Dakota shares of total value of the livestock production sector relative to the state total value of agricultural business are the largest compared to the share in Kansas, as they are 84%, 74%, 71%, and 43% in Nebraska, Colorado, South Dakota, and Kansas respectively. Net Spillover of the Northern Plains States are –53%, -50%, -49%, and –35% for the States of South Dakota, Nebraska, Colorado, and Kansas respectively. Productivity gains and so return to investment to agricultural research and R&D spillover are found to be highly influenced by the type of agricultural production. Livestock research was found to spill out more than crop research in the region studied.

8.1.5 Lags of Livestock Research

In this study the lags of livestock research are assumed to total thirty-five years. The first two years after implementation of research are assumed to be pre-research adoption years. The following seven years are assumed to be a development lag as benefits of research are increasing linearly. Adoption process lag is assumed to take six years when the benefits of research reach maximum levels. Another twenty years of declining benefits are suggested until research benefits expire. Studies (e.g. Alston and Pardey (1996)) estimated how long research benefits may continue concluded an average of 30 years. Estimated ROR, which does not take these lags into account, may lead to over-investment in research because it values the future dollar the same as today's value.

8.1.6 CGE Rates of Return to Livestock Research

In this study three different simulations are discussed to investigate different types of livestock research. A twenty percent initial ROR is the first simulation, which is designed to represent a commodity specific (beef) research impacts. The second simulation, which investigates both beef and dairy sectors research impact, started with an initial ROR of forty percent. This simulation estimated the most common ROR in previous studies and expands these studies to include the impacts on other sectors affected by livestock research. The third simulation started with initial ROR of sixty percent, which was designed to represent livestock research (beef, dairy, hogs, sheep and lamb, and feed grains). Mostly this type of research benefits broader beneficiaries (producers, marketers, and households).

The first simulation results indicated that one third of the benefits stay within the targeted research sector (in this case the beef sector), but about two thirds of the direct, indirect and induced benefits to investment in beef research spills out to other sectors of the economy. Starting from initial rate of return of 20%, the estimated ROR was found to be 16% because of the opportunity cost of the resources used for beef research. This indicated that previous studies overestimated the ROR to beef research because of exclusion of the opportunity cost. When all direct benefits to the beef as well as all agricultural and non-agricultural sectors included, the ROR rises to 25%. When indirect benefits are included, the ROR is estimated to be 28%. When induced effects are also added to the benefits of research the ROR rises to 35%. The inclusion of direct-non-targeted benefits, indirect, and induced benefits to the calculation process of ROR caused a 15% increase in this ratio.

The second simulation proves that the meat packing sector benefits slightly less from a dollar invested in beef research compared to the feed grains and the hay sectors. This result shows that returns to beef research spills out pecuniary effects vertically across the agricultural inputs and food processing sectors. Spill out towards the backward links is slightly higher in value relative to the effects on forward links. This simulation evaluates the rate of return to directly targeted commodity (beef and dairy only) starting from initial rate of return of a 40% where the estimated ROR was found to be 35%, because of the opportunity cost of the resources used for beef and dairy research. When all direct benefits (targeted and non-targeted) to the beef and dairy as well as all agricultural and non-agricultural sectors included ROR rise to 64%. However, when indirect benefits are included the ROR is estimated to be 76%. When induced effects are also added to the benefits of research, ROR rises to 104%. The inclusion of direct-non-targeted benefits, indirect, and induced benefits in the calculation of ROR caused a 69% increase from the original estimate of 40%, which was designed to simulate a production function studies.

Other conclusions to this study are that productivity gains can have both positive and negative impacts within the economy's sectors. Also rate of return to investment in livestock research beyond some level requires structural changes in the infrastructure sectors.

The CGE model is used to duplicate the economic sectors interaction and follow the pecuniary impact of productivity as it feeds out to other sectors. These sectors together are the components of the state economy along with the institutions (households, state and federal governments). For example, the second simulation (beef and dairy research) showed that infrastructure changes are needed to produce more livestock, add to storage facilities expanding, and meatpacking to produce larger amount of products. The transportation system also needs more resources to ship product and the trading system need to expand facilities to sell the product locally and export to the outside.

When the CGE model simulation was used to evaluate rates of return to basic, research starting from initial rate of return of a 60%, the estimated ROR found to be 57% because of the opportunity cost of the resources used for livestock research resources. When all direct benefits (targeted and non-targeted) to the beef and dairy sector as well as all agricultural and non-agricultural sectors are included, the ROR rises to 73%. When indirect benefits are included the ROR is estimated to be 86%. When induced effects are also added to the benefits, ROR rises to 117%. The inclusion of direct-non-targeted benefits, indirect, and induced benefits to the calculation process of ROR caused a 60% increase in this ratio. These results need to be taken cautiously because of required structural changes in the non-agricultural sectors to cope with the higher productivity in the livestock sectors.

8.1.7 Returns to Factors of Production

Investment in livestock research affects returns to factors of production and households' income significantly. At the 20% level of ROR to investment in livestock research, changes are moderate because returns to factors increases only about 0.32%, however at 40% ROR, there is about 1% increase in returns to factors of production. The basic livestock research clearly contributes to higher returns to factors of production, and higher income to all household categories. The middle-income group witnesses a slightly higher impact than the low and high-income categories.

8.2 Policy Implications

Livestock research involves the investment of scarce resources that otherwise could be used for alternative use. Production of knowledge objectives includes creating both social as well as economic impacts. An example of social benefits is the distribution of these benefits across the economic sectors equitably. If research is targeted to the beef sector, social benefits of research are expected to affect both the backward linkages (e.g. feed grains and prepared feed) proportionally as the forward linkages (e.g. meat packing). Agricultural research policy-makers face a number of questions including how much should be invested, and how much should be allocated to each commodity and non-commodity programs. How much should be allocated to support basic versus applied research is another concern, because there are cross purposes between public and private incentives. Priority setting of livestock research could take one path or another, depending on how much welfare impact's expected from the research. Increasingly, a regional focus of research is becoming a debate in research funding and resource allocation.

Colorado livestock productivity doubled since 1960 due to investment in research and extension, infrastructure, and education. Even though productivity is a good indicator of improvement, it cannot be used alone to measure the rate of return to investment in livestock research because productivity measures do not include the pecuniary impact and have number of other drawbacks (e.g. spill over effect and tax deadweight loss). Using productivity measures alone without consideration for price pecuniary impacts is not a complete tool to evaluate returns to investment in agricultural research.

Beef research in Colorado generates high rates of return. Data has shown that public funding for beef research decreased from \$4.2 million in 1990 to \$3.1 in 1997, while benefits of livestock research in the region are very high. Livestock research for dairy, poultry, pasture, and forage crops research grew faster than beef research. Results of this research suggest encouraging more funds for beef research and general basic livestock research because of their high direct, indirect and induced impacts.

Livestock research spills out vertically to other sectors both backward to inputs and forward to meat and poultry processing. Research in livestock has a high welfare impact because the benefits reach out for producers, marketers and consumers. The welfare impact of livestock research is due to higher returns to factors of production and to higher income for households from cheaper livestock products. Livestock research priority-setting needs to consider the pecuniary impacts on producers, consumers and traders.

Once new technology is available, or research results are found, there is a lag of adoption that varies depending upon type of research or extension. The expected benefit stream of research in the future, not discounted, provides a misleading ROR to livestock research. This study considered a 35 year-lag for livestock research and discounted the stream of direct, indirect, and induced impacts to capture ROR that considered the time dimension of benefits. Previous studies, which do not take research lags, may lead to over investment in agricultural research because they value the dollar today the same as future dollar.

One of the main goals of livestock research is usually enhanced economic efficiency. This economic efficiency should not exclude the impacts to non-agricultural sectors from agricultural research. Accounting for multi-sector impacts increases the estimated livestock ROR. When commodity research is conducted, evaluation of these forward and backwards impacts are elements of the benefits and costs of research investment feasibility.

Relevant further study to this research is investigation of the welfare impacts of rates of return to research of vertically linked agricultural and non-agricultural sectors when research targets each sector separately. An example would be a study that compares the economic and social impact when research targets feed grains, hay, and prepared feeds sectors against other research, which targets the meatpacking and poultry processing sector. The objective of such a study might investigate the impact of research across the livestock industry sub-sectors (inputs, production, processing and trade).

Another relevant research area is the separation between agricultural research and extension service impacts. Investment in cooperative extension is expected to have a different return because of the different characteristics of extension in term of lags, spillover, and deadweight taxes collection loss.

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APPENDICES

APPENDIX A

```
STITLE Colorado ANALYSIS MODEL

*------------------------------------------------------------------------------------------------------
* 1.1 CONTROLS PLACED ON OUTPUT GENERATION
*------------------------------------------------------------------------------------------------------
SOFFSYMLIST OFFSYMXREF
*OPTIONS SYSOUT=OFF, SOLPRINT=OFF, LIMROW=0, LIMCOL=0;
*------------------------------------------------------------------------------------------------------
* 1.2 SET UP FILE FOR SOLUTION VALUES
*------------------------------------------------------------------------------------------------------
FILE RES /c:\colo.RES/; RES.PW=250; RES.ND = 6; RES.LW = 20;
RES.NW=20; RES.LJ = 1; PUT RES;
*------------------------------------------------------------------------------------------------------
* 2. SET DEFINITION
*------------------------------------------------------------------------------------------------------
* 2.1 EXPLICIT SET DECLARATION
*------------------------------------------------------------------------------------------------------
SETS Z ALL ACCOUNTS IN SOCIAL ACCOUNTING MATRIX /
     DFD   Dairy Farm Products
     PAG   Poultry and Eggs
     BEF   Beef
     SLG   Sheep lambs and goats
     HOG   Hogs
     MIL   Miscellaneous Livestocl
     FEG   Feed Grains
     HAP   Hay and Pasture
     FOG   Food Grains
     MPP   Meat Packing Plants
     PLP   Poultry Processing
     OFM   Other Food Manufacturing
     PRF   Prepared Feed
     FDR   Food Retail
     WAT   Wholesale and OtherTrade
     MAN   Manufacturing
     CON   Construction
     SER   Services
     EDU   Education
     RAD   Research and Develcopment
     LAB   LAB
     LAND  LAND
     KAP   KAP
     HH1   MARGINAL CO TAX RATE HOUSEHOLDS LOW
     HH2   MARGINAL CO TAX RATE HOUSEHOLDS MEDIUM
     HH3   MARGINAL CO TAX RATE HOUSEHOLDS HIGH
     INVEST  INVESTMENT
     USSOC  SOCIAL SECURITY
     USPIT  FEDERAL AND STATE INCOME TAX
     STPIT
     UNEMP  Unemployment insurance
     FEDTX  FEDERAL FEES AND TAX
     STATTX STATE FEES AND TAX
     CYSTX  CITY SALES TAX
     CYGFF  CITY GENERAL FUND FEDERAL
     CYGFS  CITY GENERAL FUND STATE
    FEDGOV  FEDERAL GOVERNMENT
     STAGOV STATE GOVERNMENT
     ROW   REST OF WORLD /
F(Z)    FACTORS          / LAB, KAP, LAND/
L(F)     LABOR           /LAB/
LA(F)    LAND            /LAND/
K(F)     CAPITAL          /KAP/
G(Z)    GOVERNMENTS       /USSOC, UNEMP, USPIT, STPIT, FEDTX, STATTX, CYSTX, CYGFF,
                   CYGFS, FEDGOV, STAGOV/
GN(G)   ENDOGENOUS GOVERNMENTS  / FEDGOV, STAGOV /
GX(G)   EXOGENOUS GOVERMENTS   / USSOC, UNEMP, USPIT, STPIT, FEDTX, STATTX, CYSTX/
GS(G)   SALES OR EXCISE TAXES  / FEDTX, STATTX, CYSTX/
GF(G)   FACTOR TAXES        / USSOC, UNEMP, USPIT/
GI(G)   INCOME TAX UNITS      / STPIT, USPIT /
```

```
GH(G)    HOUSEHOLD TAX UNITS      / USPIT, STPIT/
GY(G)    EXOGNOUS TRANSFER PMT   / USSOC, UNEMP, USPIT, FEDTX, STATTX, CYSTX /
GTA(G)   EXOGNOUS TRANSFER PMT   / USSOC, UNEMP, USPIT, FEDTX, STATTX, CYSTX, CYGFF, CYGFS/
GT(G)    ENDOGENOUS TRANSFER PMT  / CYGFS, CYGFF /
H(Z)     HOUSEHOLDS              / HH1, HH2, HH3/
IG(Z)    I+G SECTORS             /DFD, PAG, BEF, SLG, HOG, MIL, FEG, HAP,
                                  FOG, MPP, PLP, OFM, PRF, FDR, WAT, MAN
                                  CON, SER.EDU, RAD, FEDGOV, STAGOV/
I(IG)    INDUSTRY SECTORS        /DFD, PAG, BEF, SLG, HOG, MIL, FEG, HAP,
                                  FOG, MPP, PLP, OFM, PRF, FDR, WAT, MAN
                                  CON, SER,EDU, RAD/
IG2(IG)  ENDOGENOUS GOVERNMENTS   / FEDGOV, STAGOV /
IP(I)    PRODUCTION SECTORS      /DFD, PAG, BEF, SLG, HOG, MIL, FEG, HAP,
                                  FOG, MPP, PLP, OFM, PRF, FDR, WAT, MAN
                                  CON, SER,EDU, RAD/
FG(IG)   PRODUCTION GOV.         /FEDGOV,STAGOV/
T        TAXLOOP                 /BASE, TODAY, simm/
R1H      REPORT 1 FOR SCALARS    / GFREV, SFREV, PIT,
                                  DGF, DSF, DDRE, PDRE, SPI,COMM,
                                  GN, NKI, HH, W, R,RL, L , K, HN,HW, GFSAV, LD,
                                  CMI,HC,SSC, LAND, LAS /
R2H      REPORT 2 FOR STATUS     / M-STAT, S-STAT /
MS       LABELS FOR MODEL STATUS / OPTIMAL, LOCALOP, UNBOUND,
                                  INFSBLE, INFSLOC, INFSINT,
                                  NOOPTML, MIPSOLN, NOINTGR,
                                  INFSMIP, UNUSED, UNKNOWN,
                                  NOSOLUT /
SS       LABELS FOR SOLVER STATUS / OK, ITERATE, RESRCE,
                                  SOLVER, EVALUATE,NOTKNWN,
                                  NOTUSED, PRE-PROC,SETUP,
                                  SLVFAIL, SLVINTER,POST-PROC,
                                  METSYS/
*------------------------------------------------------------------------------------------------
* 2.2 ALIASES
*------------------------------------------------------------------------------------------------
ALIAS (I,J), (I,I1), (Z,Z1), (F,F1), (G,G1), (G,G2), (GI,GI1), (GS,GS1),(GX,GX1), (GN,GN1),
(GH,GH1), (GF,GF1), (H,H1), (IP,JP), (IG,JG),(GY,GY1), (GT,GT1), (GY, GY2);
*------------------------------------------------------------------------------------------------
* 3. PARAMETERS AND EXOGENOUS VARIABLES
*------------------------------------------------------------------------------------------------
* 3.1 SOCIAL ACCOUNTING MATRIX, CAPITAL COEFFICIENT MATRIX AND PARAMETERS
*-----------------------------------------------------------------
TABLE SAM(Z,Z1) SOCIAL ACCOUNTING MATRIX
SONDELIM
SINCLUDE F:\billionsamcolorado.CSV
SOFFDELIM
SINCLUDE F:\fortytestmisc.prn

TABLE BB(I,IG) CAPITAL COMP
SONDELIM
SINCLUDE F:\CAPCOMco.CSV
SOFFDELIM
*------------------------------------------------------------------------------------------------
* 3.2 PARAMETER DECLARATION
*------------------------------------------------------------------------------------------------
SCALARS
* ADA       DOF    CHANGE IN AVERAGE DAILY ATTENDANCE  / 1.00 /
DEPR       DOF    DEPRECIATION RATE
ETAL2       UCB    LAND SUPPLY ELASTICITY       / 3.0 /

PARAMETERS
* PARAMETERS CALCULATED FROM SOCIAL ACCOUNTING MATRIX AND TABLE DATA
A(Z,Z1)      IMPLAN  INPUT OUTPUT COEFFICIENTS
AD(Z,Z1)     IMPLAN  DOMESTIC INPUT OUTPUT COEFFICIENTS
AG(Z,G)      IMPLAN  GOVERNMENT SPENDING SHARES OF NET INCOME
AGFS(Z,G)
ALPHA(F,I)   IMPLAN  FACTOR SHARE EXPONENTS IN PRODUCTION FUNCTION
B(I,IG)
CMIWAGE(L)
* FITC(F,G)   DOF    ALLOCATION OF ITC TO FACTORS
```

```
FCONST(F,I)
GAMMA(I)     CALC    PRODUCTION FUNCTION SCALE
DELTA(I)
SPIN(I)
OWNRD(I)
*KLAOUT(F,IG)         CAPITAL AND LAND EXCLUSION FROM GOV.
PIT(G,H)
PRIVRET(H)
LFOR(LA)              PROPORTION OF LAND INCOME    OUTFLOW
KFOR(K)               PROPORTION OF CAPITAL INCOME  OUTFLOW
GFOR(G)            PROPORTION OF GOVT INCOME OUTFLOW
* CFOR             PROPORTION OF COUNTY OUTFLOW
LBBFOR(L)
LBBFAR(L)
out(G1,G1)
SCALEI(F)          COMMUTING IN SCALE FACTOR
SCALEO(F)          COMMUTING OUT SCALE FACTOR
TAUF(G,F,Z)  DOF    FACTOR TAXES
TAUFH(G,F)   DOF    AGG FACTOR TAXES
TAUFL(G,L)   DOF    EMPLOYEE PORTION OF FACTOR TAXES
TAUFLA(G,LA) DOF    LAND FACTOR TAXES
TAUFK(G,K)   DOF    CAPITAL FACTOR TAXES
TAUFX(G,F,Z)
TAUH(G,H)    DOF    HOUSEHOLD TAXES OTHER THAN PIT
TAUQ(G,IG)   DOF    AVERAGE SALES TAX RATES
TAUC(G,I)   DOF    EXPERIMENTAL CONSUMPTION SALES TAX RATES
*TAUCH(G,HD)        HOUSING CONSUMPTION SALES TAX RATES
TAUV(G,I)   DOF    EXPERIMENTAL CONSUMPTION SALES TAX RATES
TAUN(G,IG)   DOF    EXPERIMENTAL CONSUMPTION SALES TAX RATES
TAUX(G,IG)   DOF    EXPERIMENTAL CONSUMPTION SALES TAX RATES
TAUG(G,I)   DOF    EXPERIMENTAL CONSUMPTION SALES TAX RATES
TAXS(G,GX)   DOF    TAX DESTINATION SHARES
TESTY(H)
TEST10(Z,Z)
TEST20(Z,Z)

* ELASTICITIES AND PIT TAX DATA IMPOSED

BETA(I,H)  UCB    INCOME ELASTICITY OF DEMAND
*BETAH(HD,H)  CAL    INCOME ELASTICITY OF HOUSING DEMAND
ETAD(I)     CALC   DOMESTIC SHARE PRICE ELASTICITIES
ETAE(I)     UCB   EXPORT ELASTICITIES WITH RESPECT TO DOMESTIC PRICE
ETAI(IG)      UCB    EXPERIMENTAL INVESTMENT SUPPLY ELASTICITY
ETAIX(K,IG)
ETAL(LA,IG)           LAND ELASTICITY
ETAL1(IG)
ETALB1(IG)
ETALB(L,IG)
ETAM(I)     UCB    IMPORT ELASTICITIES WITH RESPECT TO DOMESTIC PRICE
ETARA(H)     UCB    L SUPPLY ELASTICITY WITH RESPECT TO AVERAGE WAGE
ETAPIT(H)    UCB    L SUPPLY ELASTICITY WITH RESPECT TO TAXES
ETAYD(H)     UCB    RESPONSIVENESS OF INMIGRATION TO AFTER TAX EARNINGS
ETAU(H)     UCB    RESPONSIVENESS OF INMIGRATION TO UNEMPLOYMENT
ETAPT(H)    UCB    HOUSEHOLD RESPONSE TO TRANSFER PAYMENTS
EXWGE(L)     CALC    EXTERNAL WAGE
ECOMI(L)    CALC    ELASTICITY OF LABOR SUPPLY FOR IN COMMUTTERS
ECOMO(L)     CALC    ELASTICITY OF LABOR SUPPLY FOR OUT COMMUTTERS
JOBCOR(H,L)    CALC    CORRECTION FACTOR BETWEEN HOUSEHOLDS AND JOBS
LAMBDA(I,J) UCB    CROSS PRICE ELASTICITIES
NRPG(H)     UCB    NATURAL RATE OF POPULATION GROWTH
RHO(I)     UCB    EXPONENT IN PRODUCTION FUNCTION

* ARRAYS BUILT TO EXPORT RESULTS TO SEPARATE FILE

R1(R1H,T)   REPORT  SCALAR VARIABLES
R2(R2H,T)   REPORT  SOLVER AND MODEL STATUS VALUES
* INITIAL VALUES OF ENDOGENOUS VARIABLES
CG0(I,G)    DOF    REAL    GOVERNMENT CONSUMPTION
CG0T(I,G)
CH0(I,H)    IMPLAN  REAL    PRIVATE CONSUMPTION
```

```
CHOT(I,H)
CMI0(L)     CALC   REAL   NUMBER COMMUTING IN
CMO0(L)     CALC   REAL   NUMBER COMMUTING OUT
CN0(I)     IMPLAN REAL   INVESTMENT BY SECTOR OF SOURCE
CN0T(I)
CPI0(H)     CALC   PRICE  CONSUMER PRICE INDICES
CX0(I)     IMPLAN REAL   EXPORT CONSUMPTION
D0(I)     CALC   RATIO  DOMESTIC SUPPLY SHARE OF DOMESTIC DEMAND
DD0(Z)     CALC   REAL   DOMESTIC DEMAND
DS0(Z)     CALC   REAL   DOMESTIC SUPPLY QUANTITIES
DQ0(Z)
FD0(F,Z)    IMPLAN REAL   FACTOR DEMAND
IGT0(G,GX)  DOF    NOMINAL INTER GOVERNMENTAL TRANSFERS
KS0(K,IG)   CALC   REAL   CAPITAL STOCK
*LAS0(LA)   CALC   REAL   LAND STOCK
 LAS0(LA,IG)
HH0(H)     DOF    HHDS   NUMBER OF HOUSEHOLDS
HN0(H)     DOF    HHDS   NUMBER OF NONWORKING HOUSEHOLDS
HW0(H)     DOF    HHDS   NUMBER OF WORKING HOUSEHOLDS
* ITC0(I)   DOF    NOMINAL INVESTMENT TAX CREDIT
M0(I)     IMPLAN REAL   IMPORTS
MI0(H)     DOF    REAL   IN MIGRATION
MO0(H)     DOF    REAL   OUT MIGRATION
N0(K,IG)    CALC   REAL   GROSS INVESTMENT BY SECTOR OF DESTINATION
NKI0      CALC   NOMINAL NET CAPITAL INFLOW
KPFOR0(K)    CALC   CAPITAL OUTFLOW
LNFOR0(LA)   CALC   LAND OUTFLOW
GVFOR0(G)    CALC   GOVT OUTFLOW
LBFOR0
* CNFOR0          COUNTY OUTFLOW
P0(IG)     CALC   PRICE  AGGREGATE PRICES
PD0(I)     CALC   PRICE  DOMESTIC PRICES
PVA0(I)     CALC   PRICE  VALUE ADDED PRICES
PW0(I)     CALC   PRICE  EXOGENOUS PRICES IN EXTERNAL MARKETS
PWM0(I)     CALC   PRICE  IMPORT PRICE
Q0(Z)      DOF    REAL   SOCIAL ACCOUNTING MATRIX TOTALS
Q10(Z)
R0(F,Z)     IMPLAN PRICE  INITIAL SECTORAL RENTAL RATE FOR FACTOR
RA0(F)     IMPLAN AVERAGE RENTAL RATES FOR FACTORS
S0(Z)      DOF    NOMINAL SAVINGS
SPI0      CALC   NOMINAL STATE PERSONAL INCOME
V0(I)      IMPLAN REAL   INTERMEDIATE DEMAND
V0T(I)
TP(H,G)     DOF    NOMINAL GOVERNMENT TRANSFER PAYMENTS
TAUF0(G,F,Z) CALC   SOCIAL SECURITY TAX
YD0(H)     CALC   NOMINAL AFTER TAX TOTAL HOUSEHOLD INCOMES
Y0(Z)      CALC   NOMINAL GROSS HOUSEHOLD INCOME
Y01(H)
YT0(G)          GOV INCOMES
AG0(Z,GN)
SD3(GS)
SD4(GS)
SD5(GS)
SD6(GS)
SD7(GS)
SD10(GS)
SD11(G)
SD12(GX)
SD13(H)
SD14(H)
SD15(H)
SD16(H)
SD17(H)
SD18(H)
SD8
SD9
DDCX(I)
GCP10(I)
GCP0 ;
*-----------------------------------------------------------------------------------------
```

```
* 3.3 CALCULATIONS OF PARAMETERS AND INITIAL VALUES STT1
*---------------------------------------------------------------------------------------------------------------
* ETAIX=ETAI;
* CALCULATE COLUMN AND ROW TOTALS OF SAM TO COMPARE FOR BALANCE
Q10(Z)=SUM(Z1,SAM(Z,Z1) );
Q0(Z)=SUM(Z1,SAM(Z1,Z) );
DQ0(Z) = Q10(Z)-Q0(Z);
DISPLAY Q0, Q10, DQ0;
out(G1,G1) = IOUT(G1,G1);
BETA(I,H)=MISC(I,'ETAY');
*BETAH(HD,H)=MISC(HD,'ETAY');
*DISPLAY BETA, BETAH;
LAMBDA(I,I)=MISC(I,'ETAOP');
*LAMBDAH(HD,HD)=MISC(HD,'ETAOP');
ETAE(I)=MISC(I,'ETAE');
ETAM(I)=MISC(I,'ETAM');
RHO(I)=( 1 - MISC(I,'SIGMA') ) / MISC(I,'SIGMA');
ETARA(H)=MISCH(H,'ETARA');
ETAPIT(H)=MISCH(H,'ETAPIT');
ETAPT(H)=MISCH(H,'ETAPT');
ETAYD(H)=MISCH(H,'ETAYD');
NRPG(H)=MISCH(H,'NRPG');
ETAU(H)=MISCH(H,'ETAU');
*ECOMI(F)=MISCL(F,'ECOMI');
ECOMO(L)=5.0;
EXWGE(L)=1.0;
ECOMI(L)= 1.0;
ETAI(IG)= LANDCAP(IG,'ETAI1');
ETAL1(IG)= LANDCAP(IG,'ETAL1');
ETALB1(IG)= LANDCAP(IG,'ETALB1');
ETAIX('KAP',IG)=ETAI(IG);
ETAL('LAND',IG)=ETAL1(IG);
ETALB('LAB',IG)=ETALB1(IG);
* CALCULATE TAX RATES FROM SAM INFORMATION
TAUQ(GS,I)=SAM(GS,I) /( SUM(J, SAM(I,J) ) + SUM(H, SAM(I,H))+ SAM(I, 'INVEST') + SUM(G,SAM(I,G))
        + SAM(I,'ROW') - SUM(GS1, SAM(GS1,I) ));
TAUC(GS,I)=TAUQ(GS,I);
TAUV(GS,I)=TAUQ(GS,I);
TAUN(GS,I)=TAUQ(GS,I);
TAUG(GS,I)=TAUQ(GS,I);
TAUX(GS,I)=TAUQ(GS,I);
TAUF(G,F,Z)=0;
TAUF(GF,F,I)$(SAM(F,I) AND TAUFF(GF,F))=SAM(GF,I) / SAM(F,I);
TAUF(GF,F,G)$(SAM(F,G) AND TAUFF(GF,F))=SAM(GF,G) / SAM(F,G);
TAUFX(GF,F,Z)=TAUF(GF,F,Z);
TAUFH(GF,F)$(TAUFF(GF,F)) =SAM(GF,F) / SUM(Z, SAM(Z,F));
TAUFL(GF,L)=SAM(GF,L) / SUM(Z, SAM(Z,L));
TAUFLA(GF,LA)=SAM(GF,LA) / SUM(Z, SAM(Z,LA));
TAUFK(GF,K)=SAM(GF,K) / SUM(Z, SAM(Z,K));
TAXS(G,GX)$(IGTD(G,GX) EQ 1)=SAM(G,GX) / SUM(G1$(IGTD(G1,GX) EQ 1), SAM(G1,GX) );

* SET INITIAL INTER GOVERNMENTAL TRANSFERS

IGT0(G,GX)=SAM(G,GX);
DISPLAY TAXS, IGT0;
* SET INITIAL PRICES TO UNITY LESS SALES AND EXCISE TAXES
PW0(I)=1;
PWM0(I)= 1;
P0(I)=1;
PD0(I)=1;
CPI0(H)=1;
* CPIH0(H)=1;

* HOUSEHOLD TRANSFER PAYMENTS AND PERSONAL INCOME TAXES

HH0(H)=MISCH(H,'HH0');

HW0(H)=MISCH(H,'HW0');

HN0(H)= HH0(H) - HW0(H);
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TP(H,G) = 0;
TP(H,G)$(HN0(H))= SAM(H,G) / ( HN0(H) );
* FACTOR RENTALS
JOBCOR(H,L)= JOBCR(H,L);
*HOUSECOR(H,HD) = HOUSCR(H,HD);
R0(F, Z)=1 ;
R0(F ,IG)$EMPLOY(IG,F)=SAM(F ,IG) / (EMPLOY(IG,F)) ;
* R0(L ,G)$MISC(G,L)=SAM(L ,G) / EMPLOY(G,L) * 1000000;
FD0(F,Z)=EMPLOY(Z,F); DISPLAY FD0;
KS0(K,IG)=FD0(K ,IG);
*LAS0(LA)=SUM(IG,FD0(LA ,IG));
LAS0(LA,IG)=FD0(LA ,IG);
A(Z,Z1)=SAM(Z,Z1) / Q0(Z1);
AG(I,G)$(SUM(J, SAM(J,G) ) + SUM(F, SAM(F,G) ) + SUM(GF, SAM(GF,G) ) )
      =SAM(I,G) / ( SUM(J, SAM(J,G) ) + SUM(F, SAM(F,G) )
      + SUM(GF, SAM(GF,G) )+SAM('INVEST',G));

AGFS('LAB',G)=SAM('LAB',G)+ SAM('USSOC',G)+ SAM('UNEMP',G);

AG(F,G)$(SUM(I, SAM(I,G) ) + SUM(F1, SAM(F1,G) ) + SUM(GF, SAM(GF,G) ) )
      =SAM(F,G) / ( SUM(I, SAM(I,G) ) + SUM(F1, SAM(F1,G) )
      + SUM(GF, SAM(GF,G) )+ SAM('INVEST',G));

AG('LAB',G)$(SUM(I, SAM(I,G) ) + SUM(F1, SAM(F1,G) ) + SUM(GF, SAM(GF,G) ) )
      =AGFS('LAB',G) / ( SUM(I, SAM(I,G) ) + SUM(F1, SAM(F1,G) )
      + SUM(GF, SAM(GF,G) )+ SAM('INVEST',G));


* TRADE INTERMEDIATES CONSUMPTION INVESTMENT INITIAL LEVELS

CX0(I)=SAM(I,'ROW')/P0(I) /( 1 + SUM(GS, TAUQ(GS,I) ) );
M0(I)=SAM('ROW',I) / PWM0(I);
V0(I)=SUM(J, SAM(I,J) ) / P0(I) /( 1 + SUM(GS, TAUQ(GS,I) ) );
V0T(I)=SUM(J, SAM(I,J) ) / P0(I) ;
CH0(I,H)=SAM(I,H) / P0(I)/ ( 1 + SUM(GS, TAUQ(GS,I) ) );
CH0T(I,H)=SAM(I,H) / P0(I);
CG0(I,GN)=SAM(I,GN) / P0(I)/ ( 1 + SUM(GS, TAUG(GS,I) ) );
CG0T(I,GN)=SAM(I,GN) / P0(I);
DEPR= SUM(IG, SAM(IG,'INVEST') ) / (SUM((K,IG), KS0(K,IG)));
SD8= SUM(IG, SAM(IG,'INVEST'));
SD9= SUM((K,IG), KS0(K,IG));

DISPLAY SD8, SD9;
N0(K,IG)=(KS0(K,IG)) * (DEPR);
CN0(I)=0;
B(I,IG) = BB(I,IG);
CN0(I)=SUM(IG, B(I,IG) * SUM(K, N0(K,IG)) )  / P0(I)/ ( 1 + SUM(GS, TAUN(GS,I) ) );
CN0T(I)=SUM(IG, B(I,IG) * SUM(K, N0(K,IG)) )/P0(I)   ;
DD0(I)= SUM(H, CH0(I,H) ) + SUM(G, CG0(I,G) ) + CN0(I) + V0(I);
D0(I)= 1 - (M0(I) / DD0(I));

* CORRECT IMPORT ELASTICITY TO DOMESTIC SHARE ELASTICITY

ETAD(I)= - ETAM(I) * M0(I) / ( DD0(I) * D0(I) );

*  PRODUCTION DATA
DS0(I)=DD0(I) + CX0(I) - M0(I);
AD(I,J)= SAM(I,J) / P0(I) /(1 + SUM(GS, TAUQ(GS, I)))/ DS0(J)   ;
PVA0(I)= PD0(I) - SUM(J, AD(J,I) * P0(J)*(1 + SUM(GS, TAUQ(GS, J))));
RA0(F)=1;
TEST20(F,I) =  SUM(GF$TAUFF(GF,F), SAM(GF,I) ); DISPLAY TEST20;
 ALPHA(F,I)  =   ( SAM(F,I)          + SUM(GF$TAUFF(GF,F), SAM(GF,I) ) )
             / ( SUM(F1, SAM(F1,I) ) + SUM(GF, SAM(GF,I)          ) );
 GAMMA(I)    = DS0(I) / ( SUM(F, ALPHA(F,I) * FD0(F,I) ** ( - RHO(I) ) ) ) ** ( -1 / RHO(I) );
 DELTA(I) = DS0(I)/ (PROD(F$ALPHA(F,I),FD0(F,I)**ALPHA(F,I)));

SPIN(I) = 1;
OWNRD(I) = 1;
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* OTHER DATA

*CMI0(F)=MISCL(F,'COMIN');

*CMO0(F)=MISCL(F,'COMOT');

*SCALEI(F)$EXWGE(F)=CMI0(F)/(((SUM(I, R0(F,I)) / EXWGE(F)))** ECOMI(F));

*SCALEO(F)=CMO0(F)/((EXWGE(F) / (SUM(I, R0(F,I))))** ECOMO(F));

PRIVRET(H) = MISCH(H,'ROWM');
DISPLAY PRIVRET;

Y0(F)= SUM(IG, SAM(F,IG) );

KPFOR0(K)=SAM('KAP', 'ROW');

LNFOR0(LA)=SAM('LAND', 'ROW');

GVFOR0(G) = SAM(G, 'ROW');

A(H,'LAB')=SAM(H,'LAB') / HW0(H) /
        (Y0('LAB')+ SAM('LAB','ROW'))*( 1 - SUM(G, TAUFL(G,'LAB') ) );

A(H,'KAP')=SAM(H,'KAP') / HW0(H) /
        (Y0('KAP') + SAM('KAP','ROW'))*( 1 - SUM(G, TAUFK(G,'KAP') ) );

A(H,'LAND')=SAM(H,'LAND') / HW0(H) / (Y0('LAND') + SAM('LAND', 'ROW'))* ( 1 - SUM(G, TAUFLA(G,'LAND')) );

TAUH(GH,H)=SAM(GH,H) / HH0(H);

S0(H)=SAM('INVEST',H);

YD0(H)=SUM(I, SAM(I,H) ) + S0(H);

Y0(G) = SUM(Z, SAM(G,Z));

* - SAM(G,'ROW' );

Y0(GT)= SUM(Z, SAM(GT,Z));

S0(G)=SAM('INVEST',G);

CMI0(L) = 10952;
CMIWAGE(L) = SAM('LAB', 'ROW')/ CMI0(L);
* CNFOR0 = SAM('CNPRP', 'ROW');

LFOR(LA)=LNFOR0(LA)/(SUM(IG, SAM('LAND', IG)));

KFOR(K)=KPFOR0(K)/(SUM(IG, SAM('KAP', IG)));

GFOR(G)$(Y0(G))=GVFOR0(G)/(Y0(G));

OPTION DECIMALS=8;

DISPLAY GFOR;
*  CFOR=CNFOR0/(Y0('CNPRP'));
NKI0 = SUM(I, M0(I) * PWM0(I) ) - SUM(I, CX0(I) * PD0(I)*(1+SUM(GS,TAUQ(GS,I))) )
     - SUM(H, PRIVRET(H)*HN0(H)) - SUM(LA, LNFOR0(LA))
     - SUM(K, KPFOR0(K)) - SUM(G, GVFOR0(G)) - SUM(L,CMIWAGE(L)*CMI0(L));
* - SUM(L,CMOWAGE(L)*CMO0(L))
Y0(H)=  SUM(L,  A(H,L) * HW0(H) / SUM(H1, A(H1,L) * HW0(H1) )
      * (Y0(L)+ CMIWAGE(L)*CMI0(L))* ( 1 - SUM(G, TAUFL(G,L) ) ))
      + SUM(LA,  A(H,LA) * HW0(H) / SUM(H1, A(H1,LA) * HW0(H1) )
      * (Y0(LA)+ LNFOR0(LA))* ( 1 - SUM(G, TAUFLA(G,LA) ) ))
      + SUM(K,  A(H,K) * HW0(H) / SUM(H1, A(H1,K) * HW0(H1) )
      * (Y0(K)+ KPFOR0(K))* ( 1 - SUM(G, TAUFK(G,K) ) ));

SPI0= SUM(H, Y0(H) ) + SUM((H,G), TP(H,G) * HN0(H) )+ SUM(H, PRIVRET(H)*HN0(H));
```

```
TESTY(H) = PRIVRET(H)*HN0(H);

DISPLAY Y0, "YES", TESTY;
PIT(GI,H) = SAM(GI,H) / (HH0(H));

MI0(H)=HH0(H) * 0.05;

MO0(H)=HH0(H) * 0.05;

GCP0 =SUM((I,H), (CH0(I,H)))+ SUM(I, CN0(I))+ SUM((I,GN), (CG0(I,GN)))+ SUM(I, CX0(I))-SUM(I, M0(I));

GCP10(I) = SUM(H, CH0(I,H))+ CN0(I)+ SUM(GN, CG0(I,GN))+ CX0(I)-M0(I);

Y0(GX)=SUM(I, TAUV(GX,I) * V0(I) * P0(I) )
   + SUM(I, TAUX(GX,I)* CX0(I) * PD0(I))
   + SUM((H,I), TAUC(GX,I) * CH0(I,H) * P0(I) )
   + SUM(I, TAUN(GX,I) * CN0(I) * P0(I) )
   + SUM((GN,I), TAUG(GX,I) * CG0(I,GN) * P0(I) )
   + SUM((F,I), TAUFX(GX,F,I) * RA0(F) * R0(F,I) * FD0(F,I) )
   + SUM((F,GN), TAUFX(GX,F,GN) * RA0(F) * R0(F,GN) * FD0(F,GN) )
   + SUM(L, TAUFH(GX,L) * (Y0(L) + CMIWAGE(L)*CMI0(L)))
   + SUM(K, TAUFH(GX,K) * (Y0(K)+KPFOR0(K)) )
   + SUM(LA, TAUFH(GX,LA) * (Y0(LA)+LNFOR0(LA)) )
   + SUM(H, PIT(GX,H) * HH0(H) )
   + SUM(GX1, IGT0(GX,GX1))
   + GVFOR0(GX);

OPTION DECIMALS=8;

*  SD TESTING


* IGT(G,GX) =E= TAXS(G,GX) * ( Y(GX)- SUM(H, (TP(H,GX) * HN(H)) ));

SD3(GS)= SUM(I, TAUV(GS,I) * V0(I) * P0(I) );
SD4(GS)= SUM(I, TAUX(GS,I)* CX0(I) * PD0(I));
SD5(GS)= SUM((H,I), TAUC(GS,I) * CH0(I,H) * P0(I) );
SD6(GS)= SUM(I, TAUN(GS,I) * CN0(I) * P0(I) );
SD7(GS)= SUM((GN,I), TAUG(GS,I) * CG0(I,GN) * P0(I) );
SD10(GS) =  SUM(LA, TAUFH(GS,LA) * (Y0(LA)));
SD11(G) =   SUM(GX1, IGT0(G,GX1));
SD12(GX) = SUM(H, PIT(GX,H) * HH0(H)) ;

SD13(H)=   SAM(H,'LAB');
SD14(H)=   SAM(H,'KAP');
SD15(H)=   SAM(H,'LAND');
SD16(H)=  SAM(H,'LAB') / HW0(H) *
      ((Y0('LAB')+ SAM('LAB','ROW'))*( 1 - SUM(G, TAUFL(G,'LAB') ) ));
SD17(H)=   SAM(H,'KAP') / HW0(H) * ((Y0('KAP') + SAM('KAP','ROW')));
SD18(H)=   SAM(H,'LAND') / HW0(H) *( (Y0('LAND') + SAM('LAND', 'ROW'))* ( 1 - SUM(G, TAUFLA(G,'LAND')) ));


DISPLAY SD3, P0, PD0;

DISPLAY SD7, SD4, SD6, SD10, SD11, SD12, SD13, SD14, SD15, SD16, SD17, SD18, Y0;

*----------------------------------------------------------------------------------------------------------
* 4. VARIABLES
*----------------------------------------------------------------------------------------------------------
* 4.1 VARIABLE DECLARATION
*----------------------------------------------------------------------------------------------------------
VARIABLES
CG(I,G)  PUBLIC CONSUMPTION
DFCG(I,G)
CH(I,H)  PRIVATE CONSUMPTION
DFCH(I,H)
*CMO(L)   COMMUTING OUT
CMI(L)
CN(I)   GROSS INVESTMENT BY SECTOR OF SOURCE
DFCN(IG)
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CPI(H)   CONSUMER PRICE INDEX
DFCPI(H)
* CPIH(H)   HOUSING PRICE INDEX
CX(I)   EXPORT DEMAND
DCX(I)
D(I)   DOMESTIC SHARE OF DOMESTIC DEMAND
DFD(I)
DD(I)   DOMESTIC DEMAND
DFDD(I)
DS(I)   DOMESTIC SUPPLY
DFS(I)
FD(F,Z)   SECTORAL FACTOR DEMAND
DFFD(F,Z)
DRR(F,Z)
DM(I)
DY(Z)
DDS(I)
DDD(I)
DCH(I,H)
DLAS(LA,IG)
TAUTST(F,GN)
SD1(GN)
SD2(F,GN)
GCP
DGCP
GCP1(I)
DGCP1(I)
HH(H)   NUMBER OF HOUSEHOLDS
DFHH(H)
HN(H)   NUMBER OF NONWORKING HOUSEHOLDS
DFHN(H)
HW(H)   NUMBER OF WORKING HOUSEHOLDS
DFHW(H)
IGT(G,G1) INTER GOVERNMENTAL TRANSFERS
* ITC(I)   INVESTMENT TAX CREDIT AMOUNT
KS(K,IG)   CAPITAL FLOW
*LAS(LA)   LAND FLOW
LAS(LA,IG)
M(I)   IMPORTS
N(K,IG)   GROSS INVESTMENT BY SECTOR OF DESTINATION
NKI   NET CAPITAL INFLOW
LNFOR(LA)   LAND OUTFLOW
KPFOR(K)   CAPITAL OUTFLOW
GVFOR(G)   GOVT OUTFLOW
LBFOR
* CNFOR        COUNTY OUTFLOW
P(I)   AGGREGATE DOMESTIC PRICE PAID BY PURCHASERS
PD(I)   DOMESTIC PRICE RECEIVED BY SUPPLIERS
* PIT(G,H)  PER HOUSEHOLD INCOME TAXES
PVA(I)   VALUE ADDED PRICE
RA(F)   ECONOMY WIDE SCALAR RENTAL RATES OF FACTORS
R(F,Z)   SECTORAL RENTAL RATES
S(Z)   SAVINGS
SPI   STATE PERSONAL INCOME
* TP(H,G)  GOVERNMENT TRANSFER PAYMENTS
V(I)   INTERMEDIATE GOODS
Y(Z)   GROSS INCOMES
YD(H)   AFTER TAX TOTAL HOUSEHOLD INCOMES
YT(G,G1)   GOV INCOME;

*----------------------------------------------------------------------------------------------------------
* 4.2 INITIALIZATION OF VARIABLES AND REMOVING TRACE NUMBERS
*----------------------------------------------------------------------------------------------------------

P.L(I)=P0(I);        PD.L(I)   = PD0(I);
PVA.L(I)=PVA0(I);     RA.L(F)   = RA0(F);
R.L(F,Z)=R0(F,Z);     CPI.L(H)   = CPI0(H);
CMI.L(L)=CMI0(L);
DS.L(I)=DS0(I);       DD.L(I)   = DD0(I);
V.L(I)=V0(I);        FD.L(F,Z)  = FD0(F,Z);
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HH.L(H)=HH0(H);        HN.L(H)    = HN0(H);
HW.L(H)=HW0(H);        KS.L(K,IG)  = KS0(K,IG);
CN.L(I)=CN0(I);        N.L(K,IG)   = N0(K,IG);
D.L(I)=D0(I);          CX.L(I)     = CX0(I);
M.L(I)=M0(I);          NKI.L       = NKI0;
KPFOR.L(K)  = KPFOR0(K);   LNFOR.L(LA)   =LNFOR0(LA);
*CNFOR.L=CNFOR0;
GVFOR.L(G)=GVFOR0(G);
*TP.L(H,G)=TP(H,G);
Y.L(Z) = Y0(Z);
YD.L(H)=YD0(H);
IGT.L(G,GX)=IGT0(G,GX);    CH.L(I,H)  = CH0(I,H);
CG.L(I,G)=CG0(I,G);     S.L(Z)     = S0(Z);
SPI.L=SPI0;
*LAS.L(LA) = LAS0(LA);
LAS.L(LA,IG) = LAS0(LA,IG);
* CPIH.L(H)=CPIH0(H);

* REMOVE TRACE NUMBERS FOR COMPUTATIONAL PURPOSES

P.L(I)$(ABS(P.L(I))          LT 0.00000001)=0;
PD.L(I)$(ABS(PD.L(I))        LT 0.00000001)=0;
PVA.L(I)$(ABS(PVA.L(I))      LT 0.00000001)=0;
RA.L(F)$(ABS(RA.L(F))        LT 0.00000001)=0;
R.L(F,Z)$(ABS(R.L(F,Z))      LT 0.00000001)=0;
CPI.L(H)$(ABS(CPI.L(H))      LT 0.00000001)=0;
CMI.L(L)$(ABS(CMI.L(L))      LT 0.00000001)=0;
DS.L(I)$(ABS(DS.L(I))        LT 0.00000001)=0;
DD.L(I)$(ABS(DD.L(I))        LT 0.00000001)=0;
V.L(I)$(ABS(V.L(I))          LT 0.00000001)=0;
FD.L(F,Z)$(ABS(FD.L(F,Z))    LT 0.0000000001)=0;
HH.L(H)$(ABS(HH.L(H))        LT 0.00000001)=0;
HN.L(H)$(ABS(HN.L(H))        LT 0.00000001)=0;
HW.L(H)$(ABS(HW.L(H))        LT 0.00000001)=0;
KS.L(K,IG)$(ABS(KS.L(K,IG))  LT 0.00000001)=0;
*LAS.L(LA)$(ABS(LAS.L(LA)) LT 0.0000001)=0;
LAS.L(LA,IG)$(ABS(LAS.L(LA,IG)) LT 0.00000001)=0;
CN.L(I)$(ABS(CN.L(I))        LT 0.00000001)=0;
N.L(K,IG)$(ABS(N.L(K,IG))    LT 0.00000001)=0;
D.L(I)$(ABS(D.L(I))          LT 0.00000001)=0;
CX.L(I)$(ABS(CX.L(I))        LT 0.00000001)=0;
M.L(I)$(ABS(M.L(I))          LT 0.00000001)=0;
NKI.L$(ABS(NKI.L)            LT 0.00000001)=0;
LNFOR.L(LA)$(ABS(LNFOR.L(LA)) LT 0.00000001)=0;
KPFOR.L(K)$(ABS(KPFOR.L(K))  LT 0.00000001)=0;
GVFOR.L(G)$(ABS(GVFOR.L(G))      LT 0.00000001)=0;
*CNFOR.L$(ABS(CNFOR.L)        LT 0.0000001)=0;
*TP.L(H,G)$(ABS(TP.L(H,G))    LT 0.0000001)=0;
Y.L(Z)$(ABS(Y.L(Z))          LT 0.00000001)=0;
YD.L(H)$(ABS(YD.L(H))        LT 0.00000001)=0;
IGT.L(G,G1)$(ABS(IGT.L(G,G1)) LT 0.00000001)=0;
CH.L(I,H)$(ABS(CH.L(I,H))    LT 0.00000001)=0;
CG.L(I,G)$(ABS(CG.L(I,G))    LT 0.00000001)=0;
S.L(Z)$(ABS(S.L(Z))          LT 0.00000001)=0;
SPI.L$(ABS(SPI.L)            LT 0.00000001)=0;
*CPIH.L(H)$(ABS(CPIH.L(H))    LT 0.00000001)=0;

*------------------------------------------------------------------------------------------------------------
* 4.2 INITIALIZATION OF VARIABLES AND REMOVING TRACE NUMBERS
*------------------------------------------------------------------------------------------------------------

P.LO(I)=P.L(I)    / 1000;  P.UP(I)    = P.L(I)    * 1000;
PD.LO(I)=PD.L(I)  / 1000;  PD.UP(I)   = PD.L(I)   * 1000;
PVA.LO(I)=PVA.L(I)  / 1000;  PVA.UP(I)  = PVA.L(I)  * 1000;
RA.LO(F)=RA.L(F)   / 1000;  RA.UP(F)   = RA.L(F)   * 1000;
CPI.LO(H)=CPI.L(H)  / 1000;  CPI.UP(H)  = CPI.L(H)  * 1000;
CMI.LO(L)=CMI.L(L)  /1000;   CMI.UP(L)  = CMI.L(L)  *1000;
DS.LO(I)=DS.L(I)   / 1000;  DS.UP(I)   = DS.L(I)   * 1000;
DD.LO(I)=DD.L(I)   / 1000;  DD.UP(I)   = DD.L(I)   * 1000;
D.LO(I)=D.L(I)    / 1000;  D.UP(I)    = D.L(I)    * 1000;
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V.LO(I)=V.L(I)   / 1000;  V.UP(I)   = V.L(I)   * 1000;
FD.LO(F,Z)=FD.L(F,Z) / 1000;  FD.UP(F,Z) = FD.L(F,Z) * 1000;
HH.LO(H)=HH.L(H)   / 1000;  HH.UP(H)   = HH.L(H)   * 1000;
HW.LO(H)=HW.L(H)   / 1000;  HW.UP(H)   = HW.L(H)   * 1000;
HN.LO(H)=HN.L(H)   / 1000;  HN.UP(H)   = HN.L(H)   * 1000;
KS.LO(K,IG)=KS.L(K,IG)   / 1000;  KS.UP(K,IG) = KS.L(K,IG)   * 1000;
LAS.LO(LA,IG)=LAS.L(LA,IG) / 1000;  LAS.UP(LA,IG) = LAS.L(LA,IG) *1000;
M.LO(I)=M.L(I)   / 1000;  M.UP(I)   = M.L(I)   * 1000;
Y.LO(Z)=Y.L(Z)   / 1000;  Y.UP(Z)   = Y.L(Z)   * 1000;
YD.LO(H)=YD.L(H)   / 1000;  YD.UP(H)   = YD.L(H)   * 1000;
CH.LO(I,H)=CH.L(I,H) / 1000;  CH.UP(I,H) = CH.L(I,H) * 1000;
CG.LO(I,G)=CG.L(I,G) / 1000;  CG.UP(I,G) = CG.L(I,G)  * 1000;
CN.LO(I)=0;
CX.LO(I)=CX.L(I)   / 1000;  CX.UP(I)   = CX.L(I)   * 1000;
N.LO(K,IG)=0;
* TP.LO(H,G)=TP.L(H,G) / 1000;
* TP.UP(H,G)  = TP.L(H,G)  * 1000;
R.LO(F,IG)=R.L(F,IG)  / 1000;  R.UP(F,IG)  = R.L(F,IG)  * 1000;
*--------------------------------------------------------------------------------------------------------
* 5. PRE-MODEL CHECK OF PARAMETERS AND INITIAL VALUES OF VARIABLES
*--------------------------------------------------------------------------------------------------------
* 5.1 PRINTING OF CALCULATED PARAMETERS AND EXOGENOUS VARIABLES
*--------------------------------------------------------------------------------------------------------
OPTION DECIMALS=8;
* STT2
DISPLAY  "STT3", GAMMA, DELTA, JOBCOR, TAUF, TAUFH,TAUFL, TAUFLA, TAUFK, TAUQ, TAXS, ALPHA, AG, AD,
A, D0, CX0, M0, DD0,DS0,V0, V0T, FD0,RA0, CN0T, CN0,
DEPR, CG0, CG0T, KS0,N0, RHO, N0,R0, ALPHA, IGT0, TP, PIT, LFOR, KFOR, NKI0, CH0,CH0T, Y0, S0, TAUV, TAUC,
TAUN, TAUFX, TAUH, LNFOR0, KPFOR0, GVFOR0
Y0, HH0, HW0;


*--------------------------------------------------------------------------------------------------------
* 5.2 SAVING OF INITIAL VALUES FOR VARIABLES
*--------------------------------------------------------------------------------------------------------
R1('SPI',T)=SPI.L;
R1('HH',T)=SUM(H, HH.L(H) );
R1('HN',T)=SUM(H, HN.L(H) );
R1('HW',T)=SUM(H, HW.L(H) );
R1('W',T)= RA.L('LAB');
R1('R',T)=SUM(Z, R.L('KAP',Z));
R1('RL',T)= RA.L('LAND');
R1('L',T)=SUM(Z, FD.L('LAB',Z) );
R1('K',T)=SUM(Z, FD.L('KAP',Z) );
R1('LAND',T)=SUM(IG, FD0('LAND',IG) );
*R1('LAS',T)=LAS.L('LAND');
*R1('LAND2',T)=SUM(Z, FD.L('LAND2',Z) );
*  R1('GFSAV',T)=S.L('CALGF');
*--------------------------------------------------------------------------------------------------------
* 6. EQUATIONS
*--------------------------------------------------------------------------------------------------------
* 6.1 EQUATION DECLARATION
*--------------------------------------------------------------------------------------------------------
EQUATIONS

* HOUSEHOLDS
CPIEQ(H)   CONSUMER PRICE INDICES
YEQ(H)     HOUSEHOLD GROSS INCOMES
YDEQ(H)    HOUSEHOLD DISPOSABLE INCOMES
CHEQ(I,H)  PRIVATE CONSUMPTION
SHEQ(H)    HOUSEHOLD SAVINGS

* PRODUCERS
PVAEQ(I)   VALUE ADDED
PFEQ(I)    PRODUCTION FUNCTION
FDEQ(F,I)  FACTOR DEMAND
VEQ(I)     INTERMEDIATE DEMAND
YFEQL(L)   LABOR FACTOR INCOME
YFEQK(K)   CAPITAL FACTOR INCOME
YFEQLA(LA) LAND FACTOR INCOME
```

```
LANFOR(LA)  LAND INCOME OUTFLOW
KAPFOR(K)   CAPITAL INCOME OUTFLOW
GOVFOR(G)   GOVT OUTFLOW
*CONFOR     COUNTY OUTFLOW

* TRADE
XEQ(I)      EXPORT DEMAND
DEQ(I)      DOMESTIC SHARES
MEQ(I)      IMPORT DEMAND
PEQ(I)      AGGREGATED PRICES
NKIEQ       NET CAPITAL INFLOW

* INVESTMENT
NEQ1(K,I)
NEQ2(K,IG2)
CNEQ(I)     GROSS INVESTMENT BY SECTOR OF SOURCE
KSEQ(K,IG)  CAPITAL STOCK
* ITCEQ(I)  INVESTMENT TAX CREDIT

* FACTOR SUPPLY
LSEQ1(H)    LABOR SUPPLY
LSEQ3(L)    COMMUTING OUTSUPPLY
LASEQ1(LA,I)    LAND SUPPLY1
LASEQ2(LA,IG2)  LAND SUPPLY1

* MIGRATION
POPEQ(H)    POPULATION
ANEQ(H)     NUMBER OF NON WORKING HOUSEHOLDS

* TAXATION
* PITEQ(GI,H) HOUSEHOLD TAXES

* GOVERNMENT
YGEQ(GX)    GOVERNMENT INCOME
CGEQ(I,GN)  GOVERNMENT ENDOGENOUS PURCHASES OF GOODS AND SERVICES
GFEQ(F,GN)  GOVERNMENT ENDOGENOUS RENTAL OF FACTORS
GSEQL(G)    GOVERNMENT SAVINGS
GSEQJ1(G)   GOVERNMENT SAVINGS
GSEQJ1A(G)  GOVERNMENT SAVINGS
*GSEQJ2(G)  GOVERNMENT SAVINGS
GSEQ(G)     GOVERNMENT SAVINGS
TDEQ(G,G1)  DISTRIBUTION OF TAXES
YGEQ1(GN)
YGEQ1A(GN)
YGEQ2(GT)
* STEDEQ    ENDOGENOUS DISTRIBUTION OF STFED TO EDUCATION
* HWIGTEQ   ENDOGENOUS HEALTH AND WELFARE TRANSFER
* TPEQ(H,GWN) ENDOGENOUS TRANSFER PAYMENTS

* MODEL CLOSURE
SPIEQ       STATE PERSONAL INCOME
LMEQ(L)     LABOR MARKET CLEARING
*HHEQ(H,HD)   HOUSEHOLD L CLEARING
KMEQ(K,IG)  CAPITAL MARKET CLEARING
* KMEQ1(K)  AGG. CAPITAL MARKET CLEARING
LAMEQ(LA,IG) LAND MARKET CLEARING
* LAMEQ1(LA) AGG. LAND MARKET CLEARING
GMEQ(I)     GOODS MARKET CLEARING
DDEQ(I)     DEFINITION OF DOMESTIC DEMAND ;

*-------------------------------------------------------------------------------------------------------
* 6.2 EQUATION ASSIGNMENT
*-------------------------------------------------------------------------------------------------------

* HOUSEHOLDS

CPIEQ(H).. CPI(H)=E= SUM(I, P(I) * ( 1 + SUM(GS, TAUC(GS,I) ) ) * CH(I,H) )
              / SUM(I, P0(I) * ( 1 + SUM(GS, TAUQ(GS,I) ) ) * CH(I,H) );

YEQ(H).. Y(H)=E= SUM(L, A(H,L) * HW(H) / SUM(H1, A(H1,L) * HW(H1) )
```

```
     * (Y(L)+ CMIWAGE(L)*CMI(L))* ( 1 - SUM(G, TAUFL(G,L) ) ))
     + SUM(LA,  A(H,LA) * HW(H) / SUM(H1, A(H1,LA) * HW(H1) )
     * (Y(LA)+ LNFOR(LA))* ( 1 - SUM(G, TAUFLA(G,LA) ) ))
     + SUM(K,  A(H,K) * HW(H) / SUM(H1, A(H1,K) * HW(H1) )
     * (Y(K)+ KPFOR(K))* ( 1 - SUM(G, TAUFK(G,K) ) ));

YDEQ(H).. YD(H)=E=  Y(H) + (PRIVRET(H) * HN(H))+ SUM(G, TP(H,G) * HN(H) )
            - SUM(GI, PIT(GI,H)  * HH(H));

CHEQ(I,H).. CH(I,H)=E= CH0(I,H)
              * ( ( YD(H)  / YD0(H)  ) / ( CPI(H) / CPI0(H) ) ) ** (BETA(I,H)*1.0)
              * PROD(J, ( ( P(J)  * ( 1 + SUM(GS, TAUC(GS,J) ) ) )
                   / ( P0(J) * ( 1 + SUM(GS, TAUQ(GS,J) ) ) ) )** (LAMBDA(J,I)*1.0) ) ;

SHEQ(H).. S(H)=E= YD(H) - SUM(I, P(I) * CH(I,H) * ( 1 + SUM(GS, TAUC(GS,I) ) ));

* PRODUCERS

PVAEQ(I).. PVA(I) =E= PD(I) - SUM(J, AD(J,I) * P(J) * (1 + SUM(GS, TAUQ(GS, J) )) );
PFEQ(I)..DS(I) =E= DELTA(I)*SPIN(I)**1.0*OWNRD(I)**1.0*
           PROD(F$ALPHA(F,I),FD(F,I)**ALPHA(F,I));
FDEQ(F,I).. R(F,I) * RA(F) * ( 1 + SUM(GF,TAUFX(GF,F,I) ) ) * FD(F,I)
        =E= PVA(I) * DS(I) * ALPHA(F,I);
VEQ(I).. V(I) =E= SUM(J, AD(I,J) * DS(J) );
YFEQL(L).. Y('LAB') =E= SUM(IG, R('LAB',IG) * RA('LAB') * FD('LAB',IG));
YFEQK(K).. Y('KAP') =E= SUM(IG, R('KAP',IG) * RA('KAP') * FD('KAP',IG));
YFEQLA(LA).. Y('LAND') =E= SUM(IG, R('LAND',IG) * RA('LAND') * FD('LAND',IG));
LANFOR(LA).. LNFOR(LA) =E= LFOR(LA)*Y(LA);
KAPFOR(K).. KPFOR(K) =E= KFOR(K)*Y(K);


* TRADE

XEQ(I).. CX(I) =E= CX0(I)*( (PD(I)*(1+SUM(GS,TAUX(GS,I))))
           /(PW0(I)*(1+SUM(GS,TAUQ(GS,I))))) **(ETAE(I)*1.0);

DEQ(I)$PWM0(I).. D(I) =E= D0(I) * ( PD(I) / PWM0(I)) ** (ETAD(I)*1.0);

MEQ(I).. M(I)=E= ( 1 - D(I) ) * DD(I);

PEQ(I).. P(I)=E= D(I) * PD(I) + ( 1 - D(I) ) * PWM0(I) ;

NKIEQ.. NKI =E= SUM(I, M(I) * PWM0(I) ) - SUM(I, CX(I) * PD(I)*(1+SUM(GS,TAUQ(GS,I))))- SUM(H,
PRIVRET(H)*HN(H))
     - SUM(LA, LNFOR(LA))- SUM(K, KPFOR(K)) - SUM(G, GVFOR(G)) - SUM(L,CMIWAGE(L)*CMI(L)) ;

* INVESTMENT

 NEQ1(K,I).. N(K,I)=E= N0(K,I)*( R(K,I)/R0(K,I)) ** (ETAIX(K,I)*1.1)
              * ( DS(I) / DS0(I))**(ETAIX(K,I)*1.1);
 NEQ2(K,IG2).. N(K,IG2)=E= N0(K,IG2)*( R(K,IG2)/R0(K,IG2)) ** (ETAIX(K,IG2)*1.1)
              * ( Y(IG2)/ Y0(IG2) )**(ETAIX(K,IG2)*1.1);
CNEQ(I).. P(I)* ( 1 + SUM(GS, TAUN(GS,I) ) )  * CN(I) =E= SUM(IG, B(I,IG) * (SUM(K, N(K,IG))) );
KSEQ(K,IG).. KS(K,IG)=E= KS0(K,IG) * ( 1 - DEPR) + N(K,IG) ;


* FACTOR SUPPLY

LSEQ1(H).. HW(H)/HH(H) =E= HW0(H)/HH0(H)
           * ( SUM(L, RA(L) / RA0(L))/ ( CPI(H) / CPI0(H) ) )** (ETARA(H)*1.2)
           * ( SUM(G, TP(H,G) / CPI(H) )
           / SUM(G, TP(H,G) / CPI0(H) ) ) ** ETAPT(H);

LSEQ3(L).. CMI(L)=E= CMI0(L)* ((RA(L) / EXWGE(L))** (ECOMI(L)*1.1));

LASEQ1(LA,I)..  LAS(LA,I) =E=  LAS0(LA,I)*(R(LA, I)/R0(LA, I))**(ETAL(LA,I)*1.0)
                        * ( DS(I) / DS0(I))**(ETAL(LA,I)*1.0);

LASEQ2(LA,IG2)..  LAS(LA,IG2) =E=  LAS0(LA,IG2)*(R(LA, IG2)/R0(LA, IG2))**(ETAL(LA,IG2))
                        * ( Y(IG2)/ Y0(IG2) )**(ETAL(LA,IG2));
```

```
* MIGRATION
 POPEQ(H).. HH(H)=E= HH0(H) * NRPG(H)
                  + MI0(H) * ( ( YD(H)  / HH(H)  )
                       / ( YD0(H)  / HH0(H)  )
                       / ( CPI(H)  / CPI0(H) ) ) ** (ETAYD(H))
                       * ( ( HN(H)  / HH(H)  )
                       / ( HN0(H)  / HH0(H)  ) ) ** (ETAU(H))
                  - MO0(H) * ( ( YD0(H)  / HH0(H)  )
                       / ( YD(H)  / HH(H)  )
                       / ( CPI0(H) / CPI(H)  ) ) ** ETAYD(H)
                       * ( ( HN0(H)  / HH0(H)  )
                       / ( HN(H)  / HH(H)  ) ) ** ETAU(H);

ANEQ(H).. HN(H)=E= HH(H) - HW(H);

* TAXATION

* GOVERNMENT


YGEQ(GX).. Y(GX)=E=  SUM(I, TAUV(GX,I) * V(I) * P(I) )
              + SUM(I, TAUX(GX,I)* CX(I) * PD(I))
              + SUM((H,I), TAUC(GX,I) * CH(I,H) * P(I) )
              + SUM(I, TAUN(GX,I) * CN(I) * P(I) )
              + SUM((GN,I), TAUG(GX,I) * CG(I,GN) * P(I) )
              + SUM((F,I), TAUFX(GX,F,I) * RA(F) * R(F,I) * FD(F,I) )
              + SUM((F,GN), TAUFX(GX,F,GN) * RA(F) * R(F,GN) * FD(F,GN) )
              + SUM(L, TAUFH(GX,L) * (Y(L) + CMIWAGE(L)*CMI(L)))
              + SUM(K, TAUFH(GX,K) * (Y(K)+KPFOR(K)) )
              + SUM(LA, TAUFH(GX,LA) * (Y(LA)+LNFOR(LA)) )
              + SUM(H, PIT(GX,H) * HH(H) )
              + SUM(GX1, IGT(GX,GX1))
              + GVFOR(GX);

YGEQ2(GT).. Y(GT)=E= SUM(GX, IGT(GT,GX))+GVFOR(GT);

GOVFOR(G).. GVFOR(G) =E= GFOR(G)*Y(G);

CGEQ(I,GN).. P(I) * ( 1 + SUM(GS, TAUG(GS,I) ) ) * CG(I,GN)
          =E= AG(I,GN) * (Y(GN));

YGEQ1('FEDGOV').. Y('FEDGOV')=E=Y('CYGFF');

YGEQ1A('STAGOV').. Y('STAGOV')=E=Y('CYGFS');

GFEQ(F,GN)..  FD(F,GN) * R(F,GN) * RA(F)*( 1 + SUM(GF, TAUFX(GF,F,GN)))
          =E= AG(F,GN) * (Y(GN));

GSEQL(GN).. S(GN)=E= (Y(GN)) - SUM(I, CG(I,GN) * P(I) * ( 1 + SUM(GS, TAUG(GS,I) ) ) )
          - SUM(F, FD(F,GN) * R(F,GN) * RA(F) * ( 1 + SUM(GF, TAUFX(GF,F,GN))));

GSEQ(GX).. S(GX)=E= (Y(GX)) - SUM(H, (TP(H,GX) * HN(H)) ) - SUM(G,IGT(G,GX) );

GSEQJ1('CYGFF').. S('CYGFF')=E= Y('CYGFF') -  Y('CYGFF');

GSEQJ1A('CYGFS').. S('CYGFS')=E= Y('CYGFS') -  Y('CYGFS');

TDEQ(G,GX)$(IGTD(G,GX) EQ 1).. IGT(G,GX) =E= TAXS(G,GX) * ( Y(GX)- SUM(H, (TP(H,GX) * HN(H)) ));


* MODEL CLOSURE

SPIEQ.. SPI =E=  SUM(H, Y(H) )+ SUM((H,G), TP(H,G) * HN(H)  ) + SUM(H, PRIVRET(H)*HN(H));

LMEQ(L).. SUM(H, HW(H)* JOBCOR(H,L)) + CMI(L) =E= SUM(Z, FD(L ,Z) );

* LMEQ(L,IG).. SUM(H, HW(H)* JOBCOR(H,L))=E= FD(L ,IG);

*HHEQ(H,HD).. SUM(H, HH(H) * HOUSECOR(H,HD)) =E= SUM(LA, LAS(LA,HD));
```

```
KMEQ(K,IG).. KS(K,IG) =E= FD(K,IG);

*  LAMEQ(LA).. LAS(LA) =E= SUM(IG, FD(LA,IG)) ;

* KMEQ1(K).. SUM(IG,KS(K,IG)) =E= SUM(IG,FD(K,IG));

LAMEQ(LA,IG).. LAS(LA,IG) =E= FD(LA,IG) ;

* LAMEQ1(LA)..  SUM(IG,LAS(LA,IG)) =E= SUM(IG, LAS0(LA,IG));

GMEQ(I).. DS(I)=E= DD(I) + CX(I) - M(I);

DDEQ(I).. DD(I)=E= V(I) + SUM(H, CH(I,H) ) + SUM(G, CG(I,G) ) + CN(I);

*-----------------------------------------------------------------------------------------------------------
* 6.3 MODEL CLOSURE
*-----------------------------------------------------------------------------------------------------------
*  P.FX(FG)= P0(FG);
* FIX PIT FOR NON INCOME TAX UNITS TO ZERO
* PIT.FX(G,H)$(NOT GI(G))=0;

* FIX INTER GOVERNMENTAL TRANSFERS TO ZERO IF NOT IN ORIGINAL SAM
 IGT.FX(G,GX)$(NOT IGT0(G,GX))=0;

* FIX EXOGENOUS INTERGOVERNMENTAL TRANSFERS
IGT.FX(G,GX)$(IGTD(G,GX) EQ 2)=IGT0(G,GX);

* FIX GOVERNMENT DEMAND FOR EXOGENOUS GOVERNMENT UNITS
* CG.FX(I,GX)=CG0(I,GX);
* FD.FX(F,'STFED')=FD0(F,'STFED');

* FIX INTER SECTORAL WAGE DIFFERENTIALS
 R.FX(L,Z)=R0(L,Z);
*   R.FX(LA,Z)=R0(LA,Z);
*   R.FX(K,Z)=R0(K,Z);


* FIX GOVERNMENT RENTAL RATE FOR CAPITAL TO INITIAL LEVEL
* R.FX(K,G)=R0(K,G);

* FIX ECONOMY WIDE SCALAR
*  RA.FX(L)=RA0(L);
 RA.FX(LA)=RA0(LA);
 RA.FX(K)=RA0(K);

* FIX EXOGENOUS TRANSFER PAYMENT LEVELS
*TP.FX(H,GWX)=TP0(H,GWX);
*TP.FX(H,G)$(NOT TP0(H,G))=0;

*FIXING THE AMOUNT OF LAND
*LAS.FX(LA,IG) = LAS0(LA,IG);

*-----------------------------------------------------------------------------------------------------------
* 7. SOLVE AND OUTPUT PREPARATION
*-----------------------------------------------------------------------------------------------------------

MODEL FTC0 /ALL/;

* TAX EXPERIMENT LOOP


 LOOP(T$(ORD(T) GT 1),
  IF (
(ORD(T)) >2,

MI0(H)=MI0(H)*1.08;
NRPG(H) = NRPG(H)*1.01;
PW0('MPP') = PW0('MPP')*0.900063;
PW0('BEF') = PW0('BEF')*0.9;
PW0('DFD') = PW0('DFD')*0.9;
```

```
* SPIN('BEF')=1.83;

* I ran these changes to approximate basic research -- which is
* where the high 80 % retunrs occur.  It simulates these easily.

SPIN('BEF')=1.36;
SPIN('DFD')=1.5;
* SPIN('PAG')=1.4;
* SPIN('MIL')=1.4;
* SPIN('FEG')=1.2;
* SPIN('HOG')=1.4;

*  The above were used as basci research

* SPIN('MPP')=1.38;
* SPIN('FDK')=1.4;
* PW0('BEF') = PW0('BEF')*1.0004;
* PW0('WAT') = PW0('WAT')*1.0004;
* PW0('MAN') = PW0('MAN')*1.0004;
* PW0('PRF') = PW0('PRF')*1.0004;
* PW0('SER') = PW0('SER')*1.0004;
*change the Etara and Ecomi and Etau and Etayd elasticities if needed
*HN.FX(H)=HN0(H);


* CX.L('CMANF') = 1170.0;
* CX0(I) = CX0(I)*1.003;
* LAS0(LA,IG)=LAS0(LA,IG)*1.00;

*  CX0('LODGE') = CX0('LODGE')*1.04;
*   CX0('RETAL') = CX0('RETAL')*1.053;
*  CX0('EATING') = CX0('EATING')*1.017;
*   HH0(H) = HH0(H)*1.01;
* FD.FX('LAB', 'STFED')=FD.L('LAB', 'STFED');
*      PD.FX('MANUF')=1.0;
*   TAUC('CYSTX', I)=  TAUC('CYSTX', I)*1.167; DISPLAY TAUQ, TAUC;
*    TAUX('CYSTX', I)=  TAUX('CYSTX', I)*1.167;
*   TAUV('CYSTX', I)=  TAUV('CYSTX', I)*1.167;
*   TAUN('CYSTX', I)=  TAUN('CYSTX', I)*1.167;
*  TAUG('CYSTX', I)=  TAUG('CYSTX', I)*1.167;
*  PW0('MANUF') = PW0('MANUF')*1.04;
*   PW0('RETAL') = PW0('RETAL')*1.01;
*   DELTA('RETAL')=DELTA('RETAL')*1.0028;
*  PW0('LODGE') = PW0('LODGE')*1.05;
*  DELTA('LODGE') = DELTA('LODGE')*1.017;
*  PW0('eating') = PW0('eating')*1.03;
*  ALPHA('LAB','LODGE') =  ALPHA('LAB','LODGE')+.004;
*  ALPHA('KAP','LODGE') =  ALPHA('KAP','LODGE')-.002;
*  ALPHA('LAND','LODGE') =  ALPHA('LAND','LODGE')-.002;
*  LAS0(LA,IG) =  LAS0(LA,IG)*1.0021;
*  KS0(K,'RETAL') =  KS0(K,'RETAL')*1.01;

 )


OPTION NLP=MINOS5;
FTC0.scaleopt = 1;
FTC0.OPTFILE = 0;
OPTION SYSOUT = ON;
SOLVE FTC0 MAXIMIZING SPI USING NLP;

R1('GFREV',T)=DS.L('BEF')/(DELTA('BEF')*PROD(F$ALPHA(F,'BEF'),FD.L(F,'BEF')**ALPHA(F,'BEF')));
R1 ('SPI',T) = SPI.L;
R1('SSC',T)= SUM(IG, R.L('LAND',IG) * RA.L('LAND') * FD.L('LAND',IG));
R1('HH',T)=SUM(H, HH.L(H) );
R1('HN',T)=SUM(H, HN.L(H) );
R1('HW',T)=SUM(H, HW.L(H) );
R1('W',T)= RA.L('LAB');
R1('R',T)=SUM(Z, R.L('KAP',Z));
R1('RL',T)= RA.L('LAND');
```

```
R1('L',T)=SUM(Z, FD.L('LAB',Z) );
R1('K',T)=SUM(Z, FD.L('KAP',Z) );
R1('LAND',T)=SUM(Z, FD.L('LAND',Z) );
R2('M-STAT',T)=FTC0.MODELSTAT;
R2('S-STAT',T)=FTC0.SOLVESTAT);
DFCG.L(I,G)=CG.L(I,G)-CG0(I,G);
DFFD.L(F,Z) = FD.L(F,Z)-FD0(F,Z);
DY.L(Z) = Y.L(Z)-Y0(Z);
DM.L(I) =M.L(I)-M0(I);
DDS.L(I) = DS.L(I)-DS0(I);
DDD.L(I) =DD.L(I) - DD0(I);
DCX.L(I) =CX.L(I) -CX0(I);
GCP1.L(I) =SUM(H, CH.L(I,H))+ CN.L(I)+ SUM(GN, CG.L(I,GN))+ CX.L(I)-M.L(I);
DGCP1.L(I) = GCP1.L(I) - GCP10(I);
DCH.L(I,H) = CH.L(I,H) - CH0(I,H);
GCP.L =SUM((I,H), (CH.L(I,H)))+ SUM(I, CN.L(I))+ SUM((I,GN), (CG.L(I,GN)))+ SUM(I, CX.L(I))-SUM(I, M.L(I));
DGCP.L=GCP.L-GCP0;

OPTION DECIMALS=6;
DISPLAY
CG0,CG.L,CH0,CH.L,CN0,CN.L,CPI0,CPI.L,CX0,CX.L,D0,D.L,DD0,DD.L,DS0,DS.L,FD0,FD.L,HH0,HH.L,HN0,HN.L,HW0,H
W.L
,IGT0,IGT.L,KS0,KS.L,LAS0,LAS.L,M0,M.L,N0,N.L,NKI0,NKI.L,LNFOR0,LNFOR.L,KPFOR0,KPFOR.L,GVFOR0,GVFOR.L,
P0,P.L,PD0,PD.L,PVA0,PVA.L, PWM0, RA0,RA.L,R0,R.L,S0,S.L,SPI0,SPI.L,TP,V0,V.L,Y0,Y.L,YD0,YD.L,DFCG.L, DFFD.L,
DY.L, DM.L, DDS.L, DDD.L, DCX.L, DGCP1.L, GCP1.L, dgcp.L, GCP.L, GCP0, cmi0, CMI.L;


* PUT RESULTS INTO OUTPUT FILE
* results.pc=5;
PUT 'FTCO          ';
LOOP(T, PUT T.TL);
PUT /;

PUT '                    ',' MODEL   ','       ';
    LOOP(T$(ORD(T) GT 1), LOOP(MS$(R2('M-STAT',T) EQ ORD(MS) ), PUT MS.TL ) );
    PUT /;

PUT '                    ',' SOLVER  ', PUT '       ';
    LOOP(T$(ORD(T) GT 1), LOOP(SS$(R2('S-STAT',T) EQ ORD(SS) ), PUT SS.TL ) );
    PUT /;

LOOP(R1H, PUT '      ';
    PUT R1H.TL,
    LOOP(T, PUT R1(R1H,T) );
    PUT / );
```

APPENDIX B

Colorado SAM

DUMMY	DFD	PAG	BEF	SLG	HOG	MIL	FEG	HAP	FOG	MPP
DFD	0.000004	0.000006	0.001505	0.000103	0.00014	0	0	0.000001	0.000026	0.000006
PAG	0.000002	0.000003	0.000008	0.000002	0.000001	0	0	0	0.001193	0.005978
BEF	0.000042	0.000071	0.280925	0.000014	0.000019	0.000001	0.000005	0.000012	0.000912	0.853677
SLG	0.000003	0.000005	0.000013	0.045488	0.000001	0	0	0.000001	0.000032	0.01401
HOG	0.000004	0.000007	0.000019	0.000001	0.016924	0	0	0.000001	0.00015	0.17942
MIL	0.000008	0.000014	0.000041	0.000003	0.000004	0.000168	0.000001	0.000003	0.00022	0.001607
FEG	0.002431	0.000087	0.019413	0.001313	0.001805	0.000051	0.000007	0.000018	0.000097	0.000004
HAP	0.003886	0.000139	0.031033	0.002099	0.002883	0.000081	0.000012	0.000029	0.000156	0.000006
FOG	0.003498	0.005955	0.016913	0.001144	0.001573	0.000082	0.000391	0.000992	0.029398	0.000257
MPP	0.000008	0.000012	0.000135	0.000009	0.000013	0.000003	0.000001	0	0.000056	0.278397
PLP	0	0	0.000001	0	0	0	0	0	0.000179	0.007009
OFM	0.000877	0.001247	0.004973	0.000336	0.000462	0.000148	0.000001	0.000002	0.000055	0.004424
PRF	0.001008	0.002263	0.008422	0.00057	0.000783	0.000058	0	0	0.000074	0.000011
FDR	0.000007	0.000006	0.000066	0.000004	0.000006	0.000001	0	0.000001	0.000232	0.002334
WAT	0.011326	0.00332	0.097447	0.006592	0.009062	0.000327	0.000679	0.001708	0.023084	0.07665
MAN	0.002422	0.003399	0.030536	0.002066	0.00284	0.000355	0.001113	0.002801	0.032173	0.05801
CON	0.001786	0.000989	0.023278	0.001575	0.002165	0.000029	0.000196	0.000493	0.007081	0.010056
SER	0.008715	0.003822	0.117881	0.007975	0.010962	0.000428	0.000866	0.00218	0.031706	0.108977
EDU	0.002905	0.001274	0.039294	0.002658	0.003654	0.000143	0.000289	0.000727	0.010603	0.036326
RAD	0.000001	0.000001	0.000018	0.000001	0.000002	0	0	0	0.000559	0.00425
LAB	0.02325	0.008726	0.130034	0.009297	0.008428	0.015188	0.009284	0.026374	0.349023	0.224857
KAP	0.035325	0.005651	0.199089	0.01643	0.007624	0.003637	0.031021	0.05979	0.125815	0.002357
LAND	0.05182	0.028812	0.400992	0.018498	0.043035	0.015222	0.30229	0.460674	0.62868	0.028914
HH1	0	0	0	0	0	0	0	0	0	0
HH2	0	0	0	0	0	0	0	0	0	0
HH3	0	0	0	0	0	0	0	0	0	0
INVEST	0	0	0	0	0	0	0	0	0	0
USSOC	0	0	0	0	0	0	0	0	0	0
UNEMP	0	0	0	0	0	0	0	0	0	0
USPIT	0	0	0	0	0	0	0	0	0	0
STPIT	0	0	0	0	0	0	0	0	0	0
FEDTX	0.000152	0.000074	0.001222	0.000083	0.000114	0.000007	0.000007	0.000016	0.000474	0.001043
STATTX	0.000399	0.000257	0.004113	0.000278	0.000382	0.000025	0.00003	0.000075	0.001507	0.00478
CYSTX	0.002442	0.001446	0.171577	0.007915	0.018414	0.001743	0.059703	0.090985	0.077966	0.016502
CYGFF	0	0	0	0	0	0	0	0	0	0
CYGFS	0	0	0	0	0	0	0	0	0	0
FEDGOV	0	0	0	0	0	0	0	0	0	0
STAGOV	0	0	0	0	0	0	0	0	0	0
ROW	0.029771	0.021143	0.615209	0.046221	0.090385	0.002886	0.002135	0.005374	0.087293	0.447169

	PLP	OFM	PRF	FDR	WAT	MAN	CON	SER	EDU
DFD	0	0.115001	0.000014	0.000215	0.000088	0.000156	0.000102	0.000384	0.000136
PAG	0.032194	0.001919	0	0.00369	0.000009	0.000045	0.000024	0.00059	0.000198
BEF	0.000001	0.002179	0.000004	0.001611	0.000398	0.001714	0.000724	0.00227	0.000796
SLG	0	0.000143	0	0.000106	0.000026	0.000092	0.000047	0.000149	0.000053
HOG	0	0.0002	0	0.000148	0.000037	0.000206	0.000067	0.000209	0.000074
MIL	0.000027	0.005271	0.00002	0.000136	0.000069	0.002927	0.000137	0.000962	0.000489
FEG	0	0.00457	0.33345	0.000183	0.000088	0.000479	0.001113	0.000514	0.00018
HAP	0	0.007306	0.55321	0.000292	0.000141	0.000766	0.00178	0.000821	0.000289
FOG	0.000016	0.173985	0.000234	0.048781	0.005359	0.07719	0.036564	0.075844	0.026214
MPP	0.000644	0.011593	0.000209	0.101376	0.000283	0.006778	0.000472	0.015184	0.005067
PLP	0.004491	0.003976	0.000003	0.018357	0.000899	0.000414	0	0.002853	0.000951
OFM	0.000037	1.130325	0.02041	0.217176	0.001841	0.016651	0.002136	0.024962	0.008346
PRF	*0.000005*	*0.000072*	*0.000756*	*0.000063*	*0.988678*	*0.000489*	*0.000226*	*0.000229*	*0.000079*
FDR	0.000203	0.018063	0.000366	0.046709	0.041762	0.075515	0.171578	0.15242	0.052387
WAT	0.002915	0.508667	0.016762	0.295052	0.344798	2.924794	1.432346	0.838466	0.294912
MAN	0.002543	0.427957	0.017224	0.120007	0.479192	6.792477	3.272042	2.882931	0.7533
CON	0.000494	0.049632	0.001224	0.060069	0.114674	1.201464	11.029784	1.960606	0.715321
SER	0.004353	0.547518	0.016136	0.772984	1.943166	2.588908	1.872183	10.083263	3.548072
EDU	0.001451	0.182972	0.005379	0.257661	0.728203	0.879293	0.625105	3.411453	1.199479
RAD	0.000164	0.014783	0.00033	0.053513	0.196661	0.150422	0.219049	0.839015	0.296559
LAB	0.032885	0.751762	0.017117	3.130823	8.871236	8.53456	6.612743	20.866097	9.762841
KAP	0.000354	0.007668	0.000184	0.11836	0.675198	0.423961	2.201577	4.364117	1.483592
LAND	0.006429	0.734469	0.005215	0.755456	2.989034	2.860125	2.827478	17.382736	5.832125
HH1	0	0	0	0	0	0	0	0	0
HH2	0	0	0	0	0	0	0	0	0
HH3	0	0	0	0	0	0	0	0	0
INVEST	0	0	0	0	0	0	0	0	0
USSOC	0	0	0	0	0	0	0	0	0
UNEMP	0	0	0	0	0	0	0	0	0
USPIT	0	0	0	0	0	0	0	0	0
STPIT	0	0	0	0	0	0	0	0	0
FEDTX	0.000042	0.009544	0.000247	0.021727	0.117026	0.06167	0.033544	0.492492	0.171264
STATTX	0.000244	0.034642	0.001436	0.033774	0.091155	0.164372	0.078174	0.407368	0.142135
CYSTX	0.001554	0.419238	0.001518	0.749253	3.382072	0.310417	0.559309	4.132682	1.393641
CYGFF	0	0	0	0	0	0	0	0	0
CYGFS	0	0	0	0	0	0	0	0	0
FEDGOV	0	0	0	0	0	0	0	0	0
STAGOV	0	0	0	0	0	0	0	0	0
ROW	0.059252	1.639634	0.114982	1.044746	1.435301	8.309806	4.438437	7.413448	2.587547

	RAD	LAB	KAP	LAND	HH1	HH2	HH3	INVEST	USSOC
DFD	0.000019	0	0	0	0.000597	0.000785	0.001033	0	0
PAG	0.000002	0	0	0	0.004082	0.005223	0.007501	0	0
BEF	0.00008	0	0	0	0.002838	0.003907	0.005715	0	0
SLG	0.000005	0	0	0	0.000186	0.000256	0.000376	0	0
HOG	0.000007	0	0	0	0.000261	0.000359	0.000522	0	0
MIL	0.000488	0	0	0	0.002564	0.005562	0.010545	0	0
FEG	0.000017	0	0	0	0.000377	0.000544	0.000809	0	0
HAP	0.000027	0	0	0	0.000603	0.000869	0.001295	0	0
FOG	0.000326	0	0	0	0.046011	0.062715	0.093025	0	0
MPP	0.000013	0	0	0	0.177395	0.228231	0.328506	0	0
PLP	0	0	0	0	0.025448	0.032854	0.047312	0	0
OFM	0.000061	0	0	0	0.29913	0.398969	0.58497	0	0
PRF	0.00005	0	0	0	0.000376	0.00052	0.000798	0	0
FDR	0.015493	0	0	0	0.910405	1.57724	2.772336	0.079695	0
WAT	0.029111	0	0	0	1.778147	3.232861	5.63244	0.327318	0
MAN	0.09908	0	0	0	1.093362	1.869108	3.383372	7.496828	0
CON	0.01079	0	0	0	0.014361	0.024557	0.036177	1.813352	0
SER	0.435848	0	0	0	5.673512	9.08097	17.060504	0.171275	0
EDU	0.145283	0	0	0	2.083853	3.183177	6.228306	0	0
RAD	0.169539	0	0	0	0.002722	0.003457	0.003975	0	0
LAB	1.413768	0	0	0	0	0	0	0	0
KAP	0.126717	0	0	0	0	0	0	0	0
LAND	0.189564	0	0	0	0	0	0	0	0
HH1	0	3.833467	0.395098	1.960387	0	0	0	0	4.913804
HH2	0	17.56913	1.564935	5.49631	0	0	0	0	3.824274
HH3	0	42.459732	7.397413	15.665454	0	0	0	0	4.104422
INVEST	0	0	0	0	0.042429	0.07689	10.586431	0	0
USSOC	0	9.637174	0	0	0	0	0	0	0
UNEMP	0	1.327659	0	0	0	0	0	0	0
USPIT	0	0	0.531021	0	0.43148	1.112232	2.997352	0	0
STPIT	0	0	0	0	1.381607	5.866763	17.301106	0	0
FEDTX	0.023166	0	0	0	0	0	0	0	0
STATTX	0.017847	0	0	0	0	0	0	0	0
CYSTX	0.016163	0	0	0	0	0	0	0	0
CYGFF	0	0	0	0	0	0	0	0	0
CYGFS	0	0	0	0	0	0	0	0	0
FEDGOV	0	0	0	0	0	0	0	0	0
STAGOV	0	0	0	0	0	0	0	0	0
ROW	0.320489	0	0	0	0	0	0	0	0

	UNEMP	USPIT	STPIT	FEDTX	STATTX	CYSTX	CYGFF	CYGFS	FEDGOV	STAGOV	ROW
DFD	0	0	0	0	0	0	0	0	0.000025	0.000059	0.061687
PAG	0	0	0	0	0	0	0	0	0.000001	0.001041	0.025023
BEF	0	0	0	0	0	0	0	0	0.000513	0.000522	1.035207
SLG	0	0	0	0	0	0	0	0	0.000034	0.000034	0.109615
HOG	0	0	0	0	0	0	0	0	0.000047	0.000047	0.022971
MIL	0	0	0	0	0	0	0	0	0.000023	0.00017	0.009124
FEG	0	0	0	0	0	0	0	0	0.000013	0.000145	0.040323
HAP	0	0	0	0	0	0	0	0	0.00002	0.000232	0.044282
FOG	0	0	0	0	0	0	0	0	0.000777	0.020008	0.681492
MPP	0	0	0	0	0	0	0	0	0.048412	0.019841	1.144393
PLP	0	0	0	0	0	0	0	0	0.002717	0.000761	0.002073
OFM	0	0	0	0	0	0	0	0	0.018529	0.026305	4.040716
PRF	0	0	0	0	0	0	0	0	0.000179	0.000072	0.100649
FDR	0	0	0	0	0	0	0	0	0.012248	0.045401	1.87779
WAT	0	0	0	0	0	0	0	0	0.037775	0.127592	4.353243
MAN	0	0	0	0	0	0	0	0	2.099275	0.468388	3.99289
CON	0	0	0	0	0	0	0	0	0.171026	0.888274	17.277288
SER	0	0	0	0	0	0	0	0	0.411137	0.913082	19.935642
EDU	0	0	0	0	0	0	0	0	0.170095	0.315191	8.761273
RAD	0	0	0	0	0	0	0	0	0.170634	0.09181	0.796488
LAB	0	0	0	0	0	0	0	0	5.332693	8.926188	-0.230012
KAP	0	0	0	0	0	0	0	0	0	0	0
LAND	0	0	0	0	0	0	0	0	1.442235	1.210885	-15.092537
HH1	0.870819	0	0	0	0	0	0	0	0	0	1.998171
HH2	1.699222	0	0	0	0	0	0	0	0	0	-3.385822
HH3	0.732733	0	0	0	0	0	0	0	0	0	-3.275348
INVEST	0	0	0	0	0	0	0	0	1.338417	23.00892	-25.164619
USSOC	0	0	0	0	0	0	0	0	0	0	3.205326
UNEMP	0	0	0	0	0	0	0	0	0	0	1.975115
USPIT	0	0	0	0	0	0	0	0	0	0	0.008069
STPIT	0	0	0	0	0	0	0	0	0	0	0.187825
FEDTX	0	0	0	0	0	0	0	0	0	0	0
STATTX	0	0	0	0	0	0	0	0	0	0	0
CYSTX	0	0	0	0	0	0	0	0	0	0	0
CYGFF	0	5.080154	0	0.933914	0.982993	2.095183	0	0	0	0	2.164581
CYGFS	0	0	24.737301	0	0	9.319357	0	0	0	0	2.00831
FEDGOV	0	0	0	0	0	0	11.256825	0	0	0	0
STAGOV	0	0	0	0	0	0	0	36.064968	0	0	0
ROW	0	0	0	0	0	0	0	0	0	0	0

Misc. File

TABLE EMPLOY(Z,F) FACTOR DEMAND

	LAB	KAP	LAND
DFD	1591.0000000000000000	353.2600000000000000	88.00000000000000000
PAG	597.00000000000000000	56.51000000000000000	49.00000000000000000
BEF	8902.0000000000000000	1990.890000000000000	680.0000000000000000
SLG	636.00000000000000000	164.3000000000000000	31.00000000000000000
HOG	577.00000000000000000	76.24000000000000000	73.00000000000000000
MIL	1040.0000000000000000	36.37000000000000000	26.00000000000000000
FEG	635.00000000000000000	310.2100000000000000	512.0000000000000000
HAP	1805.0000000000000000	597.9000000000000000	781.0000000000000000
FOG	23890.000000000000000	1258.150000000000000	6566.000000000000000
MPP	5138.0000000000000000	23.57000000000000000	49.00000000000000000
PLP	751.00000000000000000	3.540000000000000000	11.00000000000000000
OFM	19177.000000000000000	76.68000000000000000	1245.000000000000000
PRF	491.00000000000000000	1.840000000000000000	9.000000000000000000
FDR	141958.00000000000000	1183.600000000000000	1280.000000000000000
WAT	400575.00000000000000	6751.980000000000000	5066.000000000000000
MAN	275006.00000000000000	4239.610000000000000	4848.000000000000000
CON	237491.00000000000000	22015.77000000000000	4792.000000000000000
SER	1214406.0000000000000	43641.17000000000000	29462.00000000000000
EDU	305765.00000000000000	14835.92000000000000	9885.000000000000000
RAD	39655.000000000000000	1267.170000000000000	321.0000000000000000
FEDGOV	96454.000000000000000	0.0000000000000000000	24140.00000000000000
STAGOV	264165.00000000000000	0.0000000000000000000	110880.0000000000000;

TABLE LANDCAP(IG,*) MISC ELASTICITIES

	ETAL1	ETAI1	ETALB1
DFD	0.500000000000000	1.000000000000000	1.000000000000000
PAG	0.500000000000000	1.000000000000000	1.000000000000000
BEF	0.500000000000000	1.000000000000000	1.000000000000000
SLG	0.500000000000000	1.000000000000000	1.000000000000000
HOG	0.500000000000000	1.000000000000000	1.000000000000000
MIL	0.500000000000000	1.000000000000000	1.000000000000000
FEG	0.500000000000000	1.000000000000000	1.000000000000000
HAP	0.500000000000000	1.000000000000000	1.000000000000000
FOG	0.500000000000000	1.000000000000000	1.000000000000000
MPP	0.800000000000000	2.000000000000000	1.000000000000000
PLP	0.800000000000000	2.000000000000000	1.000000000000000
OFM	0.800000000000000	2.000000000000000	1.000000000000000
PRF	0.800000000000000	2.000000000000000	1.000000000000000
FDR	2.000000000000000	3.000000000000000	1.000000000000000
WAT	1.000000000000000	2.000000000000000	1.000000000000000
MAN	1.000000000000000	2.000000000000000	1.000000000000000
CON	1.400000000000000	2.000000000000000	1.000000000000000
SER	2.000000000000000	2.000000000000000	1.000000000000000
EDU	0.800000000000000	2.000000000000000	1.000000000000000
RAD	0.800000000000000	2.000000000000000	1.000000000000000
FEDGOV	1.500000000000000	1.000000000000000	1.000000000000000
STAGOV	2.000000000000000	1.000000000000000	1.000000000000000;

TABLE MISC(Z,*) MISCELLANOUS TABLE

	ETAM	ETAE	ETAY	ETAOP
DFD	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
PAG	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
BEF	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
SLG	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
HOG	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
MIL	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
FEG	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
HAP	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
FOG	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
MPP	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
PLP	1.000000000000000	-1.650000000000000	1.000000000000000	-1.00000000000000
OFM	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
PRF	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
FDR	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
WAT	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000
MAN	1.000000000000000	-1.650000000000000	1.000000000000000	-1.000000000000000

```
CON        1.000000000000000   -1.650000000000000   1.000000000000000   -1.000000000000000
SER        1.000000000000000   -1.650000000000000   1.000000000000000   -1.000000000000000
EDU        1.000000000000000   -1.650000000000000   1.000000000000000   -1.000000000000000
RAD        1.000000000000000   -1.650000000000000   1.000000000000000   -1.000000000000000
FEDGOV     0.000000000000000    0.000000000000000   0.000000000000000    0.0000000000000000
STAGOV     0.000000000000000    0.000000000000000   0.000000000000000    0.0000000000000000

+          SIGMA

DFD        0.900000000000000
PAG        0.900000000000000
BEF        0.900000000000000
SLG        0.900000000000000
HOG        0.900000000000000
MIL        0.900000000000000
FEG        0.900000000000000
HAP        0.900000000000000
FOG        0.900000000000000
MPP        0.700000000000000
PLP        0.700000000000000
OFM        0.700000000000000
PRF        0.700000000000000
FDR        0.600000000000000
WAT        0.600000000000000
MAN        0.600000000000000
CON        0.600000000000000
SER        0.600000000000000
EDU        0.600000000000000
RAD        0.600000000000000
FEDGOV     0.000000000000000
STAGOV     0.000000000000000
;

TABLE MISCH(H,*) MISC. HH DATA

      ETAPIT         ETAPT    HH0          HW0
HH1   0.0000000000   -0.05    645.263000   565.226000
HH2   -0.2250000000  0        548.177000   480.183000
HH3   -0.4000000000  0        370.017000   324.121000

+     ETARA               NRPG                ETAYD               ETAU
HH1   1.000000000000000   1.000000000000000   1.000000000000000   -1.000000000000000
HH2   1.000000000000000   1.000000000000000   1.000000000000000   -1.000000000000000
HH3   1.000000000000000   1.000000000000000   1.000000000000000   -1.000000000000000

+     ROWM                 NWORK
HH1   0.02496559091420220  80.037000
HH2   -0.0497958937553314  67.994000
HH3   -0.0713645633606415  45.896000;

TABLE TPC (H,G)
      USSOC               UNEMP
HH1   1.000000000000000   1.000000000000000
HH2   1.000000000000000   1.000000000000000
HH3   1.000000000000000   1.000000000000000
;
TABLE JOBCR(H,L)
      LAB
HH1   321.75979165855800000
HH2   1735.8236339062400000
HH3   6214.8796282869700000;

TABLE TAUFF (G,F) ASSNG OF FACTOR TAX
        LAB                 KAP                 LAND
USSOC   1.000000000000000   0.000000000000000   0.000000000000000
UNEMP   1.000000000000000   0.000000000000000   0.000000000000000
USPIT   0.000000000000000   1.000000000000000   0.000000000000000;


TABLE IOUT(G1,G1) TRANS EXCLUDE
```

	USSOC	UNEMP	USPIT	STPIT	FEDTX
USSOC	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
UNEMP	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
USPIT	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
STPIT	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
FEDTX	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
STATTX	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
CYSTX	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
CYGFF	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
CYGFS	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
FEDGOV	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
STAGOV	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000

+	STATTX	CYSTX	CYGFF
USSOC	0.000000000000000	0.000000000000000	0.000000000000000
UNEMP	0.000000000000000	0.000000000000000	0.000000000000000
USPIT	0.000000000000000	0.000000000000000	0.000000000000000
STPIT	0.000000000000000	0.000000000000000	0.000000000000000
FEDTX	0.000000000000000	0.000000000000000	0.000000000000000
STATTX	0.000000000000000	0.000000000000000	0.000000000000000
CYSTX	0.000000000000000	0.000000000000000	0.000000000000000
CYGFF	0.000000000000000	0.000000000000000	0.000000000000000
CYGFS	0.000000000000000	0.000000000000000	0.000000000000000
FEDGOV	0.000000000000000	0.000000000000000	0.000000000000000
STAGOV	0.000000000000000	0.000000000000000	0.000000000000000

+	CYGFS	FEDGOV	STAGOV
USSOC	0.000000000000000	0.000000000000000	0.000000000000000
UNEMP	0.000000000000000	0.000000000000000	0.000000000000000
USPIT	0.000000000000000	0.000000000000000	0.000000000000000
STPIT	0.000000000000000	0.000000000000000	0.000000000000000
FEDTX	0.000000000000000	0.000000000000000	0.000000000000000
STATTX	0.000000000000000	0.000000000000000	0.000000000000000
CYSTX	0.000000000000000	0.000000000000000	0.000000000000000
CYGFF	0.000000000000000	0.000000000000000	0.000000000000000
CYGFS	0.000000000000000	0.000000000000000	0.000000000000000
FEDGOV	0.000000000000000	0.000000000000000	1.000000000000000
STAGOV	0.000000000000000	1.000000000000000	0.000000000000000;

TABLE IGTD(G,G1) GOV TRANS

	USSOC	UNEMP	USPIT	STPIT	FEDTX
USSOC	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
UNEMP	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
USPIT	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
STPIT	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
FEDTX	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
STATTX	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
CYSTX	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000	0.000000000000000
CYGFF	0.000000000000000	0.000000000000000	1.000000000000000	0.000000000000000	1.000000000000000
CYGFS	0.000000000000000	0.000000000000000	0.000000000000000	1.000000000000000	0.000000000000000

```
FEDGOV          0.000000000000000    0.000000000000000    0.000000000000000    0.000000000000000
0.000000000000000
STAGOV          0.000000000000000    0.000000000000000    0.000000000000000    0.000000000000000
0.000000000000000
+               STATTX               CYSTX                CYGFF                CYGFS
USSOC           0.000000000000000    0.000000000000000    0.000000000000000    0.000000000000000
UNEMP           0.000000000000000    0.000000000000000    0.000000000000000    0.000000000000000
USPIT           0.000000000000000    0.000000000000000    0.000000000000000    0.000000000000000
STPIT           0.000000000000000    0.000000000000000    0.000000000000000    0.000000000000000
FEDTX           0.000000000000000    0.000000000000000    0.000000000000000    0.000000000000000
STATTX          0.000000000000000    0.000000000000000    0.000000000000000    0.000000000000000
CYSTX           0.000000000000000    0.000000000000000    0.000000000000000    0.000000000000000
CYGFF           1.000000000000000    1.000000000000000    0.000000000000000    0.000000000000000
CYGFS           0.000000000000000    1.000000000000000    0.000000000000000    0.000000000000000
FEDGOV          0.000000000000000    0.000000000000000    0.000000000000000    0.000000000000000
STAGOV          0.000000000000000    0.000000000000000    0.000000000000000    0.000000000000000
+               FEDGOV               STAGOV
USSOC           0.000000000000000    0.000000000000000
UNEMP           0.000000000000000    0.000000000000000
USPIT           0.000000000000000    0.000000000000000
STPIT           0.000000000000000    0.000000000000000
FEDTX           0.000000000000000    0.000000000000000
STATTX          0.000000000000000    0.000000000000000
CYSTX           0.000000000000000    0.000000000000000
CYGFF           0.000000000000000    0.000000000000000
CYGFS           0.000000000000000    0.000000000000000
FEDGOV          0.000000000000000    0.000000000000000
STAGOV          0.000000000000000    0.000000000000000;

* ENDOGNOUS =1
* EXOGNOUS = 2
```