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## **Primary Data Documentation**

### **U.S. Agricultural Input, Output, and Productivity Series, 1949–1991**

**(Version 3)**

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## 1. Introduction

Growth accounting approaches to measuring agricultural productivity involves determining the proportion of the growth in outputs that is not accounted for by growth in inputs. As agricultural outputs and inputs are usually comprised of heterogeneous components, aggregates of these heterogeneous components must be formed before measuring productivity growth. Bias from the aggregation procedure can be kept to a minimum by the choice of an appropriate index, the careful selection of value weights for all inputs and outputs, and disaggregating inputs and outputs as finely as possible.

Sectoral growth accounting exercises require drawing together many disparate, not always ideal or complete, data series. These (work in progress) notes document the primary data sources and procedures original used by Craig and Pardey, and augmented by Acquaye, to develop state specific agricultural productivity, input and output price and quantity aggregates for the United States for the period 1949-91.

Earlier and different version of these data were used to form the production and productivity measures reported in the following studies:

Craig, B.J. and P.G. Pardey, "Inputs, Output, and Productivity Developments in U.S. Agriculture." Chapter 4 in J.M. Alston, P.G. Pardey, and M.J. Taylor, eds. *Agricultural Science Policy: Changing Global Agendas*, Baltimore: Johns Hopkins University Press, 2001.

Craig, B.J. and P.G. Pardey. "Productivity Measurement in the Presence of Quality Change." *American Journal of Agricultural Economics* Vol. 78, No.5 (December 1996): 1349-1354.

Craig, B.J. and P.G. Pardey. "Patterns of Agricultural Development in the United States." Department of Agricultural and Applied Economics, Staff Paper P90-72, St Paul: University of Minnesota, December 1990.

Craig, B.J. and P.G. Pardey. "Multidimensional Output Indices." Department of Agricultural and Applied Economics, Staff Paper P90-63, St Paul: University of Minnesota, October 1990.

The present series were used to form the production and productivity measures reported in

Acquaye, A., J.M. Alston, and P.G. Pardey. "A Disaggregated Perspective on Post-War Productivity Growth in U.S. Agriculture." *American Journal of Agricultural Economics* (forthcoming).

and made available on line in the Excel spreadsheet named <US state production and productivity indexes.xls>.

## 2. Outputs

Most output quantity and price data were obtained from various publications of Agricultural Statistics (Ag Stats), and United States Department of Agriculture data reported on the website of Cornell University. Most of the quantity data are the reported quantities produced per state, and the price data are the state-specific prices received on farms. Some quantity data were derived implicitly from value and price data. Table 1 presents a list and description of outputs used in the study. All quantity series and price series are state-specific unless indicated with “N” (national). Price vectors developed from scaled indices are indicated with “S” (scaled index). Unless indicated with an “T” (inferred observation), the data were actual published numbers.

**Table 1: Summary Description of Output Data**

Name	Quantity units	Price units	Source*
<b>Field Crops</b>			
Barley	1000 bushels	\$/bushel	AS
Corn (grain)	1000 bushels	\$/bushel	AS
Cotton	1000 pounds	\$/pound	AS
Flax	1000 bushels	\$/bushel	AS
Hay (all types of hay and alfalfa)	1000 tons	\$/ton baled	AS
Oats	1000 bushels	\$/bushel	AS
Peanuts	1000 pounds	\$/pound	AS
Rice	1000 weights	\$/weight	AS
Rye	1000 bushels	\$/bushel	AS
Sorghum	1000 bushels	\$/bushel	AS
Soybeans	1000 bushels	\$/bushel	AS
Sugar beets	1000 tons	\$/ton	AS
Sugarcane	1000 tons	\$/ton	AS
Tobacco	1000 pounds	\$/pound	AS
Tomatoes, processed	1000 tons	\$/ton	AS
Wheat	1000 bushels	\$/bushel	AS
<b>Fruits and Nuts</b>			
Almonds	1000 tons	\$/ton	AS
Apples, all varieties	1000 pounds	\$/pound	AS
Apricots	1000 tons	\$/ton	AS
Avocados	1000 tons	\$/ton	AS
Cherry (sweet & tart)	1000 tons	\$/ton	AS
Cranberries	1000 barrels barrel = 100lb	\$/barrel	AS
Grapefruit	1000 boxes	\$/box	AS
Grapes	1000 tons	\$/ton	AS
Lemons	1000 boxes	\$/box	AS
Oranges	1000 boxes	\$/box	AS
Peaches	1000 pounds	\$/pound	AS
Pears	1000 tons	\$/ton	AS
Pecans	1000 pounds	\$/pound	AS
Strawberries	1000 weights	\$/weight	AS
Walnuts	1000 tons	\$/ton	AS

Name	Quantity units	Price units	Source*
<b>Vegetables</b>			
Beans	1000 tons	\$/ton	AS
Broccoli	1000 weights	\$/weight	AS
Carrots	1000 weights	\$/weight	AS
Cauliflower	1000 weights	\$/weight	AS
Celery	1000 weights	\$/weight	AS
Cucumber	1000 tons	\$/ton	AS
Lettuce	1000 weights	\$/weight	AS
Onions	1000 weights	\$/weight	AS
Peas	1000 tons	\$/ton	AS
Potatoes	1000 weights	\$/weight	AS
Sweet corn, processed	1000 tons	\$/ton	AS
Sweet corn, fresh	1000 weights	\$/weight	AS
Tomatoes, fresh	1000 weights	\$/weight	AS
Greenhouse and Nursery marketing	1000s of standard chrysanthemums	US PI set to be standard chrysanthemum	Census of Horticulture, and Cornell gopher site
<b>Livestock</b>			
Broilers	1000 pounds	\$/pound	AS
Cattle	1000 pounds	\$/pound I (V/Q)	AS
Eggs	1000 eggs	\$/egg	AS
Hogs	1000 pounds	\$/pound	AS
Honey	1000 pounds	\$/pound	
Milk	1000 pounds	\$/pound	AS
Sheep	1000 pounds	\$/pound I (V/Q)	AS
Turkey	1000 pounds	\$/pound	AS
Wool	1000 pound	\$/pound	AS
Conservation Reserve Program Benefits	1000 acres	SR \$/acre	USDA

Note: AS — Agricultural Statistics. Prices which correspond to annual rental value are indicated with R (rent).

We would have liked to get data for the following items which were not included in this data as they were not available; cabbage, watermelon, honey dew, melon, horses and mules, sunflowers, chili pepper, blueberries, raspberries, maple products, and mushrooms.

## 2.1 Greenhouse and Nursery and Marketing (sometimes erroneously labeled as horticulture)

There was no consistent series on quantities and prices for this output category. We decided to take the current value series and convert it to an implicit quantity with the use of the best price index we could construct. There is no national price series in existence until 1990 for any part of this output and it covers only consumer expenditures on cut flowers and potted plants. Instead, we constructed a Fisher price index for Greenhouse and Nursery that was state specific in that it used national indices for several subcategories and then aggregated them using state-specific value weights for the respective subcategories. Thus a state that produces no bulbs has no bulb

price component in its Greenhouse and Nursery deflator. There was no practical way to construct state-specific subcategory price indices due to lack of data on price, value, or quantities for all but a very few states and a very few products.

### *Value shares*

The state weights for the subcategories (cut flowers, potted flowering plants, foliage plants, bedding and garden plants, cultivated greens, nursery products, bulbs and sod) were calculated based on the value shares of these subcategories in each state from 1949-92. The state shares for total floriculture, nursery products, sod and bulbs for 1949-92 were based entirely on the Census of Agriculture (Ag Census) values for the knots 1949, 1954, 1959, 1964, 1969, 1974, 1978, 1982, 1987 and 1992. The value shares were interpolated between these knots. Additional information on the distribution over the five floriculture subcategories for the years 1984-91 was taken from Table 4, source A as well as the Census of Horticulture in 1979 and 1988. This latter publication was not used for the interpolation of the other four categories as the coverage appeared to be quite inconsistent.

The census shares were run through an interpolation program which converted and scaled the data to yield consistent annual series. The interpolation program first interpolated Floriculture, Nursery and Bulb shares between knots and took sod to be the remainder. After 1969, when Sod was first reported, the knots for sod always include the direct observation on sod. Before 1969, sod's 1969 share of the other undifferentiated total (which included greenhouse vegetables and seed) was used to rescale the shares of all categories so as to exclude everything except Floriculture, Nursery products, Bulbs and Sod. Some states received special treatment either because the algorithm did not work well given their distribution across the big four categories or because selected knots were missing and could not be reasonably estimated.

For some states and census knots, census knots were not usable. Floriculture and Nursery shares were interpolated between neighboring census years. Bulb and Sod shares were found by allocating the remainder: 1969 (WY and ND), 1982 (SD), and 1987 (DE). For two states, OR and NC, sod shares were interpolated first from 1949-59 and 1959-69 leaving bulbs to be the remainder. Using the usual algorithm left them with negative sod shares. Finally, the census data for Nevada was virtually useless since for so many of the knots one or more (all in 1969) of the subcategories was not reported. The average value shares of the Mountain states was used in place of state-specific shares.

### *Prices*

Price series used with these weights were taken from various sources. A catalog of the varieties within each subcategory, the units, and the years of national prices and quantities were used in price index construction. All price indices constructed took 1980 to be the base year and, unless otherwise noted, were Fisher approximations of a Divisia price index.

Nursery products were priced intermittently and interpolated observations were obtained on prices of up to 16 varieties of nursery products. For different periods there were different numbers of products: 1949-59 (16), 1959-79 (16), 1979-88 (13), and 1988-92 (13).

Floriculture prices were taken from various sources and included up to 11 varieties of cut flowers, 13 varieties of potted plants, 9 varieties of bedding plants, 2 varieties of foliage plants and 1 variety of cut greens.

**Sources:**

1949,1954, 1959, 1964, 1969, 1974, 1978, 1982, 1987 and 1992

Johnson, D. C. "Floriculture and Environmental Horticulture Products: A Production and Marketing Statistical Review, 1960-88." United States Department of Agriculture, ERS Stat. Bulletin No. 817

United States Bureau of Census, *Census of Horticultural Specialties*, 1949,1954, 1959, 1964, 1969, 1974, 1978, 1982, 1987 and 1992.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, various issues

and some historical publications of the USDA.

Cut flowers included carnations (standard and mini), roses (hybrid tea and sweetheart), chrysanthemums (standard and pompon), gladioli, snapdragons, daisies, bysophila, iris and other. For different periods the index includes varying subsets of these flowers: 1949-67 (5), 1968-75 (7), 1976-78 (8), 1979-88 (11), 1989-92 (8).

Potted flowers included African violets, chrysanthemums, lilies (Easter and other), poinsettias, hydrangeas, azaleas, roses, begonias, cyclamen, gloxinia, spring bulbs, and other. For different periods the index includes varying subsets of these flowers: 1949-65 (5), 1966-78 (6), 1979-84 (12), 1985-88 (13), 1989- 92 (7).

For cut greens, leatherleaf fern was the only variety priced — data was available from 1966 to 1992. Since there was only one price, there was no need for an aggregation procedure. The price index is simply the price in each year of leatherleaf fern relative to its 1980 price. Cut greens don't show up in any states mix until 19?? (1966?) consequently there was no need to extrapolate this price series.

Bedding plants included vegetable bedding plants (pots and flats), geranium bedding plants (flats, pots from cuttings and pots from seeds), garden chrysanthemums, and other flowering bedding plants (hanging baskets, pots and flats). For different periods, only a subset of these were available: 1976-78 (3), 1979-84 (4), and 1985-92 (9). For the price index before 1976, the trend in cut flowers and potted flowering plants was used to extrapolate the price index for bedding plants.

Foliage plants included square footage devoted to potted foliage plants, potted foliage plants, hanging baskets with foliage plants. For the period 1966-78 only the price per square foot was available; from 1979-89 potted foliage plants were also priced, from 1989-92 only the value per square foot and the price for hanging baskets were available. Prior to 1966, the index values are extrapolated based on the trend in cut flower and potted flower prices.

Sod prices are national values per acre in production for the census knots 1969 through 1992. Prices between knots were interpolated and the index was calculated as the year's price relative to the estimated price in 1980. Earlier prices were extrapolated based on ?

In 1949, bulb prices and quantities were available at the national level only. For that year we calculated the value share of six bulb types: gladiolus, iris, lily, narcissus, tulip and other — taken to be hyacinth, crocus, lily of the valley and begonia. Import prices for those same bulbs were used to construct a fixed- base Laspeyres index of bulb prices from 1949 to 1972 using 1949 value shares as weights. The annual rates of price change from this index were used to backcast national value per acre of bulbs, corms and rhizomes taken from the census knots from 1969 through 1992. The census knot values were interpolated and put on a 1980 base.

The final price index for each state combined the price index for nursery products, sod, bulbs, and the five floriculture subcategories using state-specific value weights to yield a state-specific Fisher Divisia price index. It had 1980 as its base, so it was scaled in 1980 with the price of standard chrysanthemums (cut flower).

The quantity series was then inferred by dividing total value by the price series. Its units are thousands of standard chrysanthemums.

***Additional Sources:*** (not part of Agriculture or Horticulture Census):

Johnson, D. C. "Floriculture and Environmental Horticulture Products: A Production and Marketing Statistical Review, 1960-88." USDA ERS SB No. 817.

United States Department of Agriculture, "Floriculture Crops." National Agricultural Statistics Service, 1990, 1991, and 1992.

Federal-State Market Service "Marketing California Ornamental Crops 1969-90."

Fossum, M. Truman, 'Trade In Horticultural Specialties, 1890-1950,' United States Department of Agriculture, Marketing Research Report No. 33, 1953.

United States Department of Agriculture, "Horticulture Specialty Crops, Production and Marketing Trends, 1948-65." Economic Research Service, SB 422, April 1968.

United States Department of Agriculture, "Cut Flowers, Production, Sales and Intentions." Agricultural Marketing Service, Crop Reporting Board, annual 1957-1967 except 1960.

United States Department of Agriculture, "Flowers and Foliage Plants, production and Sales in selected states, 1956-68." SRS, Crop Reporting Board, SB 442, June 1969.

United States Department of Agriculture, "Commercial Ornamental Horticulture." Agricultural Marketing Service, Marketing Research Report No. 96, June 1955.

1949-1959.

**Table 2: Summary Description of Greenhouse and Nursery Data**

<b>Commodity</b>	<b>Quantity units</b>	<b>Price units</b>
Mini carnation	1000 bunches	bunch
Pompom chrysanthemums	1000 bunches	bunch
Potted chrysanthemums	1000 pots	pots
Standard chrysanthemums	1000 blooms	bloom
Hybrid tea rose	1000 blooms	bloom
Gladioli	1000 spikes	spike
Sweatheart rose	1000 blooms	bloom

These prices and quantities were used to construct state-specific Divisia price indices for some states [names ?] which were scaled in the base year with the state's own price of potted chrysanthemums. For states that did not produce these chrysanthemums [names ?] but which otherwise had disaggregated production data, the national unit value was used to scale the price index. The resulting scaled price indices were then used to construct implicit quantities (units are numbers of potted chrysanthemums) using the corresponding total value series for each state. This was done for these states because even these disaggregated data do not cover all of the commodities in the total greenhouse and nursery marketing. For the remaining states [names ?] value data was available, but there was no disaggregated production or price data. Consequently a substitute price index was developed and used to derive an implicit quantity series (units of potted chrysanthemums).

[Some price data may have come from Eldon Ball for 1960-68, to be checked]

To construct quantities and prices at the state-level from 1949-1967 for all states, we needed both to create a price index and then use that with the observed state-level value series to create implicit quantities. The pre-1968 price series were found by constructing a Divisia price index of nursery and greenhouse imports using the following commodities

**Table 3: Summary Description of Greenhouse and Nursery Data, earlier years**

<b>Commodity</b>	<b>Quantity units</b>	<b>Price units</b>	<b>Years</b>
Hyacinths	1000 bulbs	per bulb	1949-72
Tulips	1000 bulbs	per bulb	1949-72
Narcissus	1000 bulbs	per bulb	1949-72
Lily	1000 bulbs	per bulb	1949-72
Crocus	1000 corms	per corm	1949-72
Lily of the Valley	1000 pips	per pip	1949-72
Other bulbs/roots/clumps	1000's	per plant	1949-72

<b>Commodity</b>	<b>Quantity units</b>	<b>Price units</b>	<b>Years</b>
Orchids	1000's	per plant	1949-72
Flower seeds	1000's of pounds	per pound	1949-72
Seedlings & cuttings (fruit stock)	1000's	per stalk	1949-72
Seedlings & cuttings (rose stock)	1000's	per stalk	1949-72
Iris	1000's	per bulb	1964-72
Begonia	1000 tubers	per tuber	1964-72
Gladiolus	1000 corms	per corm	1964-72
Live plants for planting	1000's	per plant	1964-72

Source: United States Department of Agriculture, "Ornamentals Production and Marketing Trends, 1948-72." Economic Research Service, SB 529, Tables 35-39.

## **2.2 Fruits and Nuts**

Almonds: For 1949 to 1963 almonds are weighed in the shell. To make these quantities comparable to the out of shell weights used in the rest of the sample, the weight given is multiplied by 0.60 on the advice of Jason Christian. This number is almost exactly what one would get by averaging the ratio calculated from the years in which both in shell and out of shell weights are available that was (1/1.75) as calculated by Steve Trost.

Broccoli: There was no data available for broccoli for 1949. The data used for 1966 was preliminary.

Cranberries: No price or value series are available for states in 1959. The national price for that year was used and then state quantity times national price gave state values.

## **2.3 Conservation Reserve Program**

Farm Service Agency (FSA) administers the Conservation Reserve Program (CRP) which protects the most fragile farmland by encouraging farmers to stop growing crops on highly erosion- and other environmentally- sensitive acreage. In return for planting a protective cover of grass or trees on vulnerable property, the owner receives a rental payment each year of a multi-year contract. Cost-share payments are also available to help establish permanent areas of grass, legumes, trees, windbreaks, or plants that improve water quality and give shelter and food to wildlife.

Participants enroll contracts for 10 to 15 years and, in some cases, easements, in exchange for annual rental payments and cost share assistance for installing certain conservation practices. In determining the amount of annual rental payments to be paid, CCC considers, among other things, the amount necessary to encourage owners or operators of eligible cropland to participate in the program. Applicants submit bids in such a manner as the Secretary prescribes. Bids offered by producers who request rental payments greater than the amount which CCC is willing to pay for their acreage are automatically rejected by CCC. Except for the continuous sign up process implemented in September 1996, remaining bids are evaluated for possible acceptance based on a comparison of environmental benefits indicators with the rental payment cost. The continuous sign up process does not include an evaluation based on environmental benefits

indicators because only those practices designed to obtain high environmental benefits will be eligible. Acreage determined eligible for continuous sign up by the Secretary is automatically accepted in the program providing all other eligibility requirements are met.

Rent received from, and acreage of land set aside for the (CRP) were treated as output for which producers receive revenue equal to the CRP payments from the government. Quantity are the number of acres set aside under the CRP contract signed. Prices are the rent received per acre of the land set aside under CRP. Annual CRP acreage and state-specific rents from 1986 to 1993 were available for all 48 states.

**Source:** 1986-1989

<http://usda.mannlib.cornell.edu/>

1990-1993

<http://www.econ.ag.gov/epubs/pdf/sb925/>

**Other sources:**

<http://www.usda.gov/mission/ffas.htm>

<http://www.fsa.usda.gov/dafp/cepd/conserva.htm>

## **2.4 Miscellaneous**

Honey: For 1991 and 1992, five states' production, value, and average price were reported collectively. Using a 5 year average share of each in value and production, the collective total was allocated to the states. The price was then inferred from the estimated value/estimated quantity. The five states were CT, DE, MA, NH and RI.

### 3 Inputs

Table 4 presents a list and description of inputs used in the study. All input quantity and price series are state-specific unless indicated with N (national). Price vectors developed from scaled indices are indicated with S (scaled index). Prices which correspond to annual rental value are indicated with R (rent).

**Table 4:** *Summary Description of Input Data*

Name	Quantity units	Price units	Value units
Labor			
Family labor	1000 hours	S \$/hour	1000\$
Hired labor	1000 hours	S \$/hour	1000\$
Operators age (25-34) ed (0-7)	1000 hours	N \$/hour	1000\$
Operators age (25-34) ed (8)	1000 hours	N \$/hour	1000\$
Operators age (25-34) ed (HS1-3)	1000 hours	N \$/hour	1000\$
Operators age (25-34) ed (HS4)	1000 hours	N \$/hour	1000\$
Operators age (25-34) ed (C1-3)	1000 hours	N \$/hour	1000\$
Operators age (25-34) ed (C4+)	1000 hours	N \$/hour	1000\$
Operators age (35-44) ed (0-7)	1000 hours	N \$/hour	1000\$
Operators age (35-44) ed (8)	1000 hours	N \$/hour	1000\$
Operators age (35-44) ed (HS1-3)	1000 hours	N \$/hour	1000\$
Operators age (35-44) ed (HS4)	1000 hours	N \$/hour	1000\$
Operators age (35-44) ed (C1-3)	1000 hours	N \$/hour	1000\$
Operators age (35-44) ed (C4+)	1000 hours	N \$/hour	1000\$
Operators age (45-54) ed (0-7)	1000 hours	N \$/hour	1000\$
Operators age (45-54) ed (8)	1000 hours	N \$/hour	1000\$
Operators age (45-54) ed (HS1-3)	1000 hours	N \$/hour	1000\$
Operators age (45-54) ed (HS4)	1000 hours	N \$/hour	1000\$
Operators age (45-54) ed (C1-3)	1000 hours	N \$/hour	1000\$
Operators age (45-54) ed (C4+)	1000 hours	N \$/hour	1000\$
Operators age (55-64) ed (0-7)	1000 hours	N \$/hour	1000\$
Operators age (55-64) ed (8)	1000 hours	N \$/hour	1000\$
Operators age (55-64) ed (HS1-3)	1000 hours	N \$/hour	1000\$
Operators age (55-64) ed (HS4)	1000 hours	N \$/hour	1000\$
Operators age (55-64) ed (C1-3)	1000 hours	N \$/hour	1000\$
Operators age (55-64) ed (C4+)	1000 hours	N \$/hour	1000\$
Operators age (65+) ed (0-7)	1000 hours	N \$/hour	1000\$
Operators age (65+) ed (8)	1000 hours	N \$/hour	1000\$
Operators age (65+) ed (HS1-3)	1000 hours	N \$/hour	1000\$
Operators age (65+) ed (HS4)	1000 Hours	N \$/hour	1000\$
Operators age (65+) ed (C1-3)	1000 Hours	N \$/hour	1000\$
Operators age (65+) ed (C4+)	1000 Hours	N \$/hour	1000\$
Land			
Cropland	1000 acres	SR \$/acre	1000\$ $r*Q$
Irrigated cropland	1000 acres	SR \$/acre	1000\$ $r*Q$
Grassland, pasture, range and grazed forest	1000 acres	SR \$/acre	1000\$ $r*Q$
Capital			

Name	Quantity units	Price units	Value units
Buildings and structures	1000s average buildings	N index base90-92	1000\$
Automobiles (units not for personal use)	1000s of Intermediate, 4 door sedans	NR \$/rep	1000\$
Trucks	1000s of 3/4 ton pickups	NR \$/rep	1000\$
Pickers and balers	1000s of pickup balers	NR \$/rep	1000\$
Mowers and conditioners	1000s of mowers	NR \$/rep	1000\$
Tractors	1000s of 55HP 2WD tractors	NR \$/rep	1000\$ $r^*Q$
Combines	1000s of medium capacity combines	NR \$/rep	1000\$ $R^*Q$
Dairy cattle	1000 head	Published S \$/head infer r	1000\$ $r^*Q$
Breeder pigs	1000 head	Inferred S \$/head from V/Q infer r	1000\$ $r^*Q$
Breeder sheep	1000 head	Inferred S \$/head from V/Q infer r	1000\$ $r^*Q$
Breeder cows	1000 head	Inferred S \$/head from V/Q infer r	1000\$ $r^*Q$
Chickens, not broilers	1000s	Inferred S \$/head from V/Q	1000\$
Purchased inputs			
Pesticides	Inferred from V/PI	N index base90-92	1000\$
Seed	Inferred from V/PI	N index base90-92	1000\$
Feed	Inferred from V/PI	N index base90-92	1000\$
Fuels (gas, diesel)	Inferred from V/PI	N index base90-92	1000\$
Repairs	Inferred from V/PI	N index	1000\$
Machine hire	Inferred from V/PI	N index	1000\$
Miscellaneous expenses (insurance, etc)		NR	M
Nitrogen	1000 tons	N \$/ton	1000\$ infer
Phosphorous	1000 tons	N \$/ton	1000\$ infer
Potash	1000 tons	N \$/ton	1000\$ infer
Electricity	1000 KWHS inferred from V/PI	S \$/KWH	1000\$

### 3.1 Labor

The quantity data for labor are the number of hours worked on-farm by the respective class of labor, and the price data are the wage received per hour of employment on the farm. Data for labor are made up of 30 farm operator classes (five age and six education characteristics), family labor, and hired labor.

#### *Farm Operators*

The data for our study identifies 30 classes of farm operators that are a combination of five age and six education classes. The five age classes are 25 to 34, 35 to 44, 45 to 54, 55 to 64, and 65+. The six education classes are 0 to 7 years (0-7), 8 years (8), 1 to 3 years of high school

(HS1-3), 4 years of high school (HS4), 1 to 3 years of college (C1-3), and 4 years or more (C4+) of college education.

### *Hours of Operator Labor*

Census observations provide operators working a particular range of days, e.g., 1-49 days, 50-99 days etc., off-farm. Annual 1949-1992 estimates of operator days per year worked off-farm (assuming 350 work days per year) were obtained as the number of days worked off-farm per operator per year, calculated as

$$\frac{\sum_{i=1}^k m_i n_i}{\sum_{i=1}^k n_i}$$

where k is the number of ranges,  $m_i$  is the midpoint in range  $i$ ,  $n_i$  is the number of operators in range  $i$ , and the total number of operators is equal to the number of farms. These estimates differ substantially from those developed by Ball (1985), in that, we use available data to estimate directly the number of days worked on-farm per year rather than assume this to be invariant over time. The dramatic increase in part-time farming (and the slight reversal of this trend for a temporary period which was observed during the mid-1970's) over the sample period makes it necessary to factor this into the estimation method. Geometric interpolations were used to obtain the 1949-92 inter-census years.

### **Sources:**

For years 1934, 39, 44, 49, 54, 59, 64, 69, 74, 78, 82, 87, 92:

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services, 1934, 39, 44, 49, 54, 59, 64, 69, 74, 78, 82, 87, and 92.

**Exploratory Procedures:** We initially assumed 260 (52 \* 5) days worked in a year and an 8 hour work day which gives an average of 2,080 hours a year for a fulltime farmer. However, comparing this with the average annual hours for a fulltime farmer given in the 1980 and 1990 population census (publication "Earnings by Occupation and Education") this figure seems much too low. We opted to assume that the average annual hours in a year was 2,800 (50 weeks, 7 days, 8 hours a day).

### *Imputed Age-Education Categories of "Farm Operators"*

These were obtained from the number of rural males 25 years and older stratified by age/education classes for the Census of Population years 1950, 1960, 1970, 1980, and 1990. For counts of males by age and education, the data refers to the actual census year, except for the 1990 census which gives number of males by age/education classes for 1989. Also, for the census knots 1950, 1960 and 1970 rural males were divided into farm and non-farm, so rural farm males by age and education group was used. However, for 1980 no breakdown of rural males was reported. To derive farm rural male the 1970 ratio of farm rural male to total rural

male was used. The census of 1990 (census knot 1989) reported farm operators and managers (incl. horticultural). The 1990 census only reported number of farm managers and operators with 1-8 years of elementary school. To derive our group A (1-7 elem) and B (8 elem) the ratio for 1980 was used. Knots for 1950, 1960, 1970, 1980, and 1990 were interpolated to give annual observations for the 1949-89 period. The years 1990-92 haven been extrapolated using the 1980-89 annual growth rate. Knots from farm operator age classes (25-34 yrs, 35-44 yrs, 45-54 yrs, 55-64 yrs, 65 yrs and over) for the agricultural census years 1950, 60, 70, and 80 were interpolated to give implicit annual observations of farm operator age classes for the 1949-1989 period. The years 1990 to 92 were extrapolated using the 1980-89 annual growth rate.

**Sources:**

For years 1950, 60, 70, 80.

U.S. Department of Commerce, "Characteristics of the Population" *Census of Population*, 1950, 60, 70, 80.

For year 1990.

U.S. Department of Commerce, "Earnings by Occupation and Education" *Census of Population*, subject summary tape files on CD-ROM (CD90SSTF22A).

The farm operator age classes and the education data were used to determine number of operators by age and education groups. Total number of hours on-farm per state by age/education group were calculated by multiplying, for each state, the number of operators in each age and education group by the average number of hours worked on-farm by operators.

**Sources:**

For years 1945, 50, 54, 59, 64, 69, 74, 78, 82, 87, and 92

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services, 1934, 39, 44, 49, 54, 59, 64, 69, 74, 78, 82, 87, and 92.

*Wages of Operator Labor*

Wages for operator labor were obtained as implicit wages of farm operators by age/education classification. The same wages apply to operators in all states since the series on income used to generate wages were only available at the national level for the census years 1950 to 1980. The census for 1990 reports incomes of farm operators and managers on a state and national level. The census figures for income are always for the year before the census.

**Exploratory Procedure:** Data included the mean (or median in 1949) income for rural males (if available) and all males by various age/education categories. The categories reported were not consistent from decade to decade so we created our own final set of five age groups. If our set of age groups did not correspond directly with the reported age groupings, a new mean income was calculated using

$$\frac{\sum_{i=1}^m n_i y_i}{\sum_{i=1}^m n_i}$$

where  $y_i$  is the mean income for age group  $i$ ,  $n_i$  is the number of people in that age group, and  $m$  is the number of census groups combined to get our age grouping.

**Problems encountered:** 1960 and 1970 census separated rural males into farm and non-farm but the others did not. The 1950 census did not report rural incomes separately.

In the original version of this series that we constructed, we put all figures on a rural male basis to make them comparable. This involved combining the farm and non-farm incomes in 1959 and 1969 figures. For 1949, we took the ratio of rural to all male income in 1959 and assumed that rural male income in 1949 bore the same relationship to all male income

**Revision:** For the census years 1960, 1970, and 1980 we found a better source of earnings: "Earnings by Occupation and Education". They give mean earnings by age and education and by farmers and farm manager (instead of incomes of rural (farm) males as used in the earlier procedure). However, for all the three census years it did not have earnings by state. We also encountered some other problems which were solved using the census data on rural and rural farm males we had available for the respective censuses:

- For the 1959 (1960 census) no information was available for the age group 65-plus. We used the 1960 census ratio of 65-plus rural farm males to rural farm males between 25-64 years to derive the number of farmers and farm managers in this age group.
- For 1969 (1970 census) also no information was available for the age group of 65 plus and the same procedure used for the year 1959 was adapted. The data did not split out elementary education into 0-7 and 8 years which we were using. Since we had those categories for all rural males of the relevant age groups, we took the ratio of mean farmer & manager income to mean income of all rural farm males for each age/education class overlap for an age cohort and applied the average ratio to our existing farmer & manager male mean income from these 2 education classes. Also, the data did not split out the age groups 35-45 years and 45-54 years. Again we used the ratio from total rural farm males for the two age groups.
- For 1979 (1980 census) the occupation categories were split out into 4 groups: (1) farmers, except horticultural specialty farmers, (2) horticultural specialty farmers; (3) managers, farms, except horticultural specialty farms, and (4) managers, horticultural specialty farms. Again the elementary education data were not split out into the 0-7 and 8 categories which we were using. The same procedure was adapted as for these age groups for 1969. Because total earnings by rural males was not split out in farm and non-farm groups, the ratio used is the mean income of all farmers & managers to mean income of all rural males.
- The 1950 census reported only total males. Therefore, we reconstructed the 1949 earnings for rural farm males by using the 1959 ratio of mean income of rural farmers & managers to all male income. We took the movements in the aging pattern into consideration (e.g., all males in the age group 25-34 in 1949 will be in the age group 35-44 in 1959).

For the 1990 census, we found information on aggregate and mean income per worker for the four relevant occupation groups ("farmers, except horticultural", "horticultural specialty farmers," "managers, farms, except horticultural", and "managers, horticultural specialty farms") at the state level and for the total U.S. For the 1990 census, we encountered the same problem as with the 1980 census data—data on elementary education were not split out into 0-7 and 8. We used the same ratio as for the 1979 earnings—the 1979 ratio of mean income of total farmers & managers to mean income of all rural males for each education class overlap for an age cohort and apply the average ratio to our existing farmers & managers mean income from these 2 education classes. As we only had detailed income information for total US in 1979 the average ratio for total US is applied to our existing farm & managers mean income on a state level. We took the movements in the aging patterns into consideration.

**Sources:**

For years 1950, 60, and 70.

U.S. Department of Commerce, "Detailed Characteristics of the Population, US Summary" *Census of Population*, 1950, 60, and 70. Section A.

For year 1980.

U.S. Department of Commerce, "Earnings by Occupation and Education" *Census of Population*, 1980.

For year 1990.

U.S. Department of Commerce, "Earnings by Occupation and Education" subject summary tape files on CD-ROM (CD90SSTF22A).

## **3.2 Land**

### *Quantity of Land in Agriculture*

Numerous production function studies (e.g., Davis 1981) and productivity studies (e.g., Ball 1985) have used "land in farms" as their measure of the land input in agriculture. For various reasons this is an inappropriate measure. It does not allow for a consistent (and economically meaningful) treatment of the cross-sectional, temporal variation in land quality and, equally importantly, significantly mismeasures the actual number of acres in agriculture. In various northeastern states, for instance, upward of 50 percent of the land in farms is not in agriculture, but takes the form of non-grazed forest and woodland acreages. By contrast, many of the drier southwestern states have twice as much land in agriculture as there is land in farms. Substantial tracts of federally owned (Bureau of Land Management) land is rented or leased for rangeland grazing purposes. The methods adopted in our study attempt to overcome both the mismeasurement and quality problem.

### *Grassland, Pasture, Range, and Grazed Forest*

We used state level estimates of the acreage of "forest land grazed". This data include forested pasture and range consisting of forest, brush grown pasture, arid woodlands and other areas within forested areas that have grass or other forage growth. It includes woodland pasture in

farms and rough estimates of forested grazing land not in farms. Some of the latter may be grazed only lightly or sporadically.

**Sources:**

For years 1945, 50, 54, 59, 64, 69, 74, 78, 82, 87 and 92.

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services, 1945, 50, 54, 59, 64, 69, 74, 78, 82, 87 and 92.

Cornell United States Department of Agriculture gopher site, Table 6.

Inter-census years obtained by geometric interpolation.

We also used state level estimates of the acreage of "other grassland pasture and range" which includes all open land used primarily for pasture and grazing, including shrub and brush land types of pasture, grazing land with sagebrush and scattered mesquite, and all tame and native grasses, legumes, and other forage used for pasture or grazing. This data should not include cropland pastured (doesn't count the same acre in both places) but is not always clearly distinguished. It counts acres both in and out of farms (using Bureau of Land Management, Forest Service, etc. to supplement data on pastureland in farms) but does not count acres in the Federal Conservation Research Program (CRP).

**Sources:**

For years 1945, 50, 54, 59, 64, 69, 74, 78, 82, 87 and 92.

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services, 1945, 50, 54, 59, 64, 69, 74, 78, 82, 87 and 92.

Cornell United States Department of Agriculture gopher site, Table 5 (didn't include data for 1992).

Inter-census years obtained by geometric interpolation.

The sum of these two data provided the state-level estimates of total "grassland pasture, range and grazed forest land". Here we make note that the subcomponents were interpolated and then summed.

*Cropland*

We used state-level estimates of total cropland acreage. This includes cropland harvested, crop failure, cultivated summer fallow, cropland used only for pasture, and idle cropland. No distinction is made between irrigated and non-irrigated cropland in this measure, so data for state-level irrigated cropland were used to obtain the total non-irrigated cropland acreage. These figures are based upon the Census of Agriculture (Ag Census) measures but are modified by Economic Research Service in light of annual information they have on actual crop planting practices. Data for inter-census years were interpolated before being adjusted to account for irrigated cropland.

**Sources:**

For years 1949, 54, and 59.

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services, Chapter 1, Table 12, 1949, 54, and 59.

For years 1964, and 69.

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services, Chapter 1, Table 13, 1964.

For year 1974.

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services, Table 2, 1974.

For year 1978.

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services, Table 2, 1978.

For year 1982.

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services, Table 1, 1982.

For years 1987 and 92.

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services, CD Rom.

*Irrigated land*

We used state level estimates of total irrigated acres. These include both irrigated cropland and irrigated pastureland. The latter is unlikely to be important except for (as many as 27) states for which independent information on the breakdown was used to distinguish which types of land were irrigated.

**Sources:**

For years 1949, 54.

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services, Chapter 1, Table 22, 1954

For years 1959, 64.

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services, Chapter 9, Table 2, 1964

For years 1969, 74.

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services. in Volume 4, Irrigation, Table 2, 1978.

For years 1978, 82.

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services, Table 4, 1982

For years 1987, 92.

United States Department of Agriculture, "Major Uses of Land in the United States", *United States Census of Agriculture*, Economic Research Services (CD Rom), 1992

For 1979, 84 and 88 the "Farm and Ranch Irrigation Survey" reported the breakdowns for 20 to 27 states. This was a special report which pulled out information from the Census of Agriculture to then survey actual irrigation practices in a subsequent year, not the census year. All other years are either Ag Census knots or are interpolated.

The Ag Census volumes which gave a breakdown of irrigated land types in 1974 did so only for farms with sales of \$2,500 or more. To keep the series consistent, the total irrigated acres used were based on all farms (published in the 1978 Ag Census).

The state level estimates of total irrigated cropland acreage was calculated in two steps. First we interpolated two shares—the share of irrigated, harvested cropland in total irrigated acres and (2) the share of other types of cropland in the remainder (total irrigated acres-harvested irrigated cropland). These shares were then applied to the interpolated series on total acres under irrigation to get an estimate of irrigated cropland of all types. Only irrigated, harvested cropland was consistently reported for all states. For all but 27 states, total irrigated cropland was set equal to total irrigated acres.

In 1974, the irrigated harvested cropland was for farms with sales of \$2,500 or over. The share was calculated as a percentage of irrigated land in farms with sales of \$2,500. This share was then applied to total irrigated acres from all farms.

State level estimates of total irrigated pastureland acreage. This series was calculated as the difference between total irrigated acres and irrigated cropland acres of all types. This series is zero for all but 27 states.

### *Land Rental Rates*

The sources for data on rents paid for agricultural land differ by land type (see discussion below). The sampling method changed in 1984 to a preferred method: possibly, there are some breaks in the data in that year.

### *Pastureland rents*

New published pastureland rents were published by United States Department of Agriculture (and taken from the Cornell gopher site) for 1960-93 for 33 of 48 states. There were no observations for CT, MA, NH and RI; only 1984 was available for AZ, NV and NM. For 8 other

western states (CA, CO, ID, MT, OR, UT, WA, and WY) there were only observations for 1984-93. Even with this data there were holes in selected series, particularly for 1982 and 1983 and for much of New Jersey in virtually every year after 1982. Additional unpublished rents came from John Jones on diskette for years 1936 to 1990 with some holes. These were used to plug some holes.

Old rents for this series come from Dougherty's report and Doll and Widdows (see citations below). Dougherty had the 1982 rents and land values not found in the Cornell set for FL, LA, MD, MI, NJ, and WV so they were used to fill in the 1982 gaps. Doll and Widdows was the source for 1960-79 on the western states. An old Farm Real Estate publication supplied observations on CT 1976-79. Remaining gaps were filled (if less than one or two years) using Method B,C or D.

**Method B:** This method uses information on rents, values and their ratios. First we constructed estimates of the state ratio of rent to value in the year with the missing rent using the average for 2 years on either side of the missing observations. Then we constructed an estimated value of pastureland in that state for that same year (if needed) using the ratio of state to average regional pastureland value (where the regional average excluded the state in question) for 2 years on either side of the missing observation. The estimated rent was then calculated as the product of the estimated ratio of rent to value and the estimated value. For selected states and observations the formula had to be slightly modified.

**Method C:** When rent to value ratios or value series behave especially erratically a method other than B is called for. In this method, the state's rent relative to the regional average rent is used to construct missing rents. The state's ratio is averaged over the surrounding years and then applied to the regional average rent in the year for which a state's rent is missing.

For Nevada, method C was modified. A smoothed ratio of Nevada rent to the regional average was applied to the regional average to fill in gaps and replace some unpublished and suspicious observations. It is possible that rents reported are sometimes for irrigated and sometimes for non-irrigated pasture, but there is no way to tell.

**Method D:** When there is no information for any neighboring states or regions, a gap was filled with the geometric average of the rents on either side. This was used only to fill in the missing pasture rent for 1983 for all Mountain states (except Nevada) and all Pacific states.

#### *Non-irrigated cropland rents*

New cropland (non-irrigated) rents were reported for 1967-93 for 33 of 48 states. For 7 western states (CO, ID, MT, OR, UT, WA, and WY) the observations covered only 1984-93. There were no observations at all for CT, MA, NH, or RI. For AZ, CA, NV and NM only 1984 was reported.

Old cropland rents were largely replaced. For 9 western states (CO, ID, MT, OR, UT, WA, WY, CA, and NM) plus MA and NH, Doll and Widdows supplied cropland rents for 1960-79. These were kept to fill in gaps in the Cornell series. Remaining gaps were filled (if less than one or two years) using Methods B, C, and D (all described under pastureland rents) as well as some regressions (Method E described below) to backcast.

**Method E:** To backcast cropland rents, the relationship between cropland and farm rents per acre over the overlapping years in the sample was used. A regression for each state of current cropland rent on current farm rent and future cropland rent was run to generate coefficients to estimate current cropland rent.

**Method G:** This method is identical to E except that pasture land rents were the basis of backcasting the cropland rents for western states for which to farm rents were available.

*Irrigated cropland rents:*

Irrigated cropland rents are reported for only a few states. The largest possible set includes 15 states (AZ, CA, CO, ID, KS, MT, NE, NV, NM, OK, OR, TX, UT, WA and WY). For other states, irrigated cropland rents are taken to be equal to cropland rates. The Cornell data provided updates for 1984-93 for all 15 states with longer time series for Kansas (1976-93), Nebraska (1971-93), Oklahoma (1982-85,1987-93)and Texas (1967-93). Doll and Widdows provided irrigated cropland rents from 1960-79 for 11 states. Data from this source did not include KS or OK and observations on NE and TX start only in 1967. Doll and Widdows was used to fill in from 1960 to the earliest observation from Cornell's set. Data from John Jones on irrigated rents and values were used to fill in gaps only for the states in the Mountain and Pacific region and then only for 1981 and 1982. Remaining gaps were filled (if less than one or two years) using Method B described under pastureland rents. The gap in western states for 1982 and 1983 was filled with Method D—geometric interpolation between 1981 and 1984 observations. Backcasting the rents to 1949 involved regressions (Method E) of irrigated cropland rents on cropland rents or pasture rents. For three states (AZ, NV, and NM), Model G was used to backcast to 1949.

**Source:**

For years 1960–1992.

United States Department of Agriculture "Cash Rents for Farms, Cropland, and Pasture, 1960-93," Economic Research Service, data from Cornell University's United States Department of Agriculture gopher site.

**Document sources:**

1960–1979 for CO, ID, MT, OR, UT, WA, WY, CA, NM, MA, and NH.

Doll, John P., and Richard Widdows. "A Comparison of Cash Rents and Land Values for Selected U.S. Farming Regions" United States Department of Agriculture, Economic Research Service, 1982.

1982 for FL,LA,MD,MI,NJ, and WV.

Daugherty, Arthur B., "U.S. Grazing Lands: 1950-82," Economic Research Service, United States Department of Agriculture, SB771 1989.

**Other sources:**

United States Department of Agriculture "Farm Real Estate Market Developments," ESCS, CD-84, August 1979.

United States Department of Agriculture "Agricultural Land Values and Markets, Situation and Outlook Report" Economic Research Service, AR-2, June 1986.

United States Department of Agriculture "Farm Real Estate Market Developments," ESCS, CD-89, August 1984.

John Jones supplied unpublished rents and values from United States Department of Agriculture for pastureland. Preference was given to published data (whenever available) over these unpublished figures. These data covered the eastern states beginning in 1936 and the mountain and Pacific states beginning in 1925. All series ran to 1990, but there were gaps.

John Jones supplied unpublished rents and values from United States Department of Agriculture for irrigated and dry land for 11 western states. Preference was given to published data (whenever available) over these unpublished figures. The data begins only in 1960, so adds little to Doll and Widdows except after 1979. No observations were available for 1982 or 1983.

John Jones supplied unpublished rents and values from United States Department of Agriculture for entire farms in states outside the Mountain and Pacific regions. The data were from 1921-90 for most states, but were discontinued for many states before 1990: KS (76), NE (67), OK (82), TX (67), FL (82), LA (82), WV (82), NY (82).

#### *Total Expenditures "Value" Of Land*

This should more properly be called total expenses for land. The "value" is inferred from the product of annual rent (in dollars) and quantities of land, so the units are in dollars spent. Comprised of state-level estimates of land expenses for all three types of land.

### **3.3 Capital**

In general, to get from a stock figure to service flow, we employed basic principles to infer the rental value of the capital stock. This rental value per unit multiplied by the units in place gave the value of capital services, i.e., its service flow. The real purchase price of a unit of capital in any year  $k$ ,  $\tilde{\delta}_k$  was taken to reflect the expected discounted flow of real rents in year  $k$ ,  $\tilde{r}_k$ , from that same unit of capital, i.e.

$$\delta_k = \left[ \tilde{n}_k + \frac{(1-\ddot{a})\tilde{n}_k}{R} + \frac{(1-\ddot{a})^2 \tilde{n}_k}{R^2} + \dots + \frac{(1-\ddot{a})^{L-k} \tilde{n}_k}{R^{L-k}} \right] = \tilde{n}_k \sum_{s=0}^{L-k} \left[ \frac{1-\ddot{a}}{R} \right]^s = \frac{\tilde{n}_k}{\ddot{e}(L, k, r, \ddot{a})}$$

$$\text{where } R = 1+r, \text{ and } \ddot{e}(L, k, r, \ddot{a}) = \frac{r+\ddot{a}}{1+r} \left[ 1 - \left( \frac{1-\ddot{a}}{1+r} \right)^{(L-k+1)} \right]^{-1}$$

$r$  is the real discount rate,  $L$  is the life span of the capital input, and  $\ddot{a}$  is the rate at which capital depreciates. Two forms of this service profile were used. The Light bulb service profile ( $\ddot{a} = 0$ ) was used for biological capital, and the declining balance with a geometric rate of depreciation ( $1 > \ddot{a} > 0$ ) was used for physical capital. Table 5 defines the different parameters that were used for estimating the real purchase prices per unit of capital.

**Table 5: Parameters Used for Estimating Real Purchase Prices Per Unit of Capital**

Capital Class	$\ddot{a}$	L	R	$\ddot{e}(L, 1, r, \ddot{a})$
Automobiles	0.22	9	1.04	0.2702950
Trucks	0.21	10	1.04	0.2568114
Tractors	0.12	18	1.04	0.1618481
Combines	0.14	15	1.04	0.1836957
Forage equipment	0.10	22	1.04	0.1404516
Service buildings	0.05	45	1.04	0.0880372
Biological capital	0.00	1	1.04	1

### (i) Livestock Inventory and Biological Capital

Ideally it would be desirable to differentiate between livestock which is in essence biological capital (e.g., breeding stock, milking cows, sheep for wool, chickens for eggs, etc.) and the year-to-year carryover of livestock inventory. Given, inter alia, information on the service flow profile of the various classes of biological capital, it would be possible to develop a service flow measure in an analogous way to other capital input variables. Where possible, we have separated livestock into two types. Livestock with service lives in excess of one year are treated as biological capital (beef and milking cows and heifers that have calved, ewes over one year, sows that have farrowed, and chickens not counting broilers). For those livestock that do not have such service lives we have already captured them in livestock production since (at least for cattle) change in inventories from January in year  $t$  and  $t+1$  is counted as period  $t$  production.

This approach requires annual price and quantity data relating to the year-to-year carryover of all livestock inventories (breeding plus non-breeding livestock) because the total value and quantity of inventories is our only source of price (really a unit value) for the breeder livestock. In the case of dairy cattle, we have a direct state price observation, but for sows, ewes, and breeder cows they are only priced per cwt—not per head. The inventory data contained in our files relates to a January 1 (or January 1 equivalent) for all classes of livestock for the 1949-1991 period except where noted.

#### *Cattle*

We attempt to distinguish between cattle inventories which include animals with only a one year service life and those cattle on farms which are likely to have a longer service life. From all cattle and calves on farm plus in-shipments we subtract the cows and heifers that are used to breed (beef cows) and those kept for milk (milk cows). The latter two types of cows are assumed to have a service life longer than one year. The imputed unit values of all cattle and calves are based on the value of inventory taken on January 1 of year, 1949-91. This total includes cows and heifers kept for milk.

**Source:**

For years 1949 –1991.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, various issues.

Rents, our price series, for cattle were taken to be a particular fraction of the unit value calculated with data on all cattle and calves. The rent to value proportion was based on an assumed light bulb service profile, a lifespan of 5 years, an average age of 2 years, and a real interest rate of 0.04. The rent series based on a single year's observation on unit values was fairly erratic. Since it included the value of other types of cattle, a three year moving average of the rent centered on the year in question was used in its place.

*Milking Cows*

We used number of cows and heifers kept for milk. From 1970-91 these totals counted just cows and heifers that had calved. Before 1970 these counted all cows and heifers 2 years old and older. The series are quite similar but the total of 2 year-olds and older is always larger. We used the average of the two values in 1970, the only year for which there was an overlap in the series. In 1973, New England states were reported jointly; the total was allocated to the states based on state average shares of the regional total in 1971, 72, 74 and 1975.

**Source:**

For years 1949 –1991.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, various issues.

Total rental expenses, our value series for dairy cows, were calculated using the simple product of the rent per head and the number of dairy cows. Data was available for price per head of cows kept for milk from 1961-91. It's not clear what was done prior to 1961. For 1961-81 we used the price observed in January for dairy cows sold for dairy herd replacement. Beginning in January 1982, prices were estimated only quarterly and then only for some (a majority of the) states. Yearly averages were used for the states for which there was no monthly or quarterly data from 1985-91. These states were AZ, CT, DE, ME, MA, MT, NV, NH, NJ, NM, RI, SC, SD, WV, and WY. The published average price in Ag Stats was for all cows and heifers 2 years old and older which were kept for milk, but it seems like the figures from NASS on the monthly/quarterly/ annual average price per milk cow did not include the value of heifers.

**Sources:**

For years 1961-1991.

United States Department of Agriculture "Agricultural Prices, Annual Summary,"  
National Agricultural Statistics Service, annual summaries.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural  
Statistics Service, various issues.

Rents for milk cows, our price series, were taken to be a particular fraction of their value based on an assumed light bulb profile, a lifespan of 5 years, an average age of 2 years, and a real interest rate of 0.04.

### *Breeder Cows*

Number of beef cows and heifers is our quantity measure for breeder cattle. For 1970-91 these totals counted just cows and heifers that had calved. From 1954-70 these counted all cows and heifers 2 years old and older. The series are quite similar but the latter gives a larger total. For 1949-53 no data on these beef cows and heifers were published directly. From the calf crop statistics the total population of cows 2 years old and older could be inferred for 1949-53. The known milk cows that fit this description were subtracted from the total to leave only breeder cows. The method resulted in some negative values. For those states and years, the numbers of breeder cows were extrapolated using the average geometric growth rates from the first nonnegative observation to the first published observation. States for which some extrapolation was needed were

1949 only: CT, ME, and VT.

1949-50: MI, NH, NJ, NY, PA, and WI.

1949-53 was set to zero for RI (matching the rest of the 1950s)

### **Sources:**

For years 1949-1991.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural  
Statistics Service, various issues.

The resulting state totals were then adjusted so that the sum of the states would be consistent with published US totals since dropping out negative values in these states led to a mismatch.

All scaling took into account the service profile of breeder cows, and was concentrated on the rental rate. Each cow or heifer counted was taken to be a cow of the average age and quality.

Total rental expenses, our value series for breeder cows, were also calculated using the simple product of the rent per head and the number of breeder cows.

### *Sheep and Lambs*

As with cattle we attempt to count separately sheep with one year or more of service life and ewes which are used for breeding. We have taken the breeders to be identical with ewes one year old or older and ewes that have successfully lambed.

Our quantity figures are the total number of ewes, 1949-91. Total ewes combines data of two forms — ewes one year old and older from Ag Stats 1964-91, and the number of lambs, and the ratio of lambs to ewes were used to infer totals of ewes for years 1950-1963. The 1949 inventory

was inferred by allocating the reported US total to states based on the 1950-52 average state share in US total ewes.

**Sources:**

For years 1949-1991.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, various issues.

All scaling took into account the service profile of ewes, and was concentrated on the rental rate. Each ewe counted was taken to be an ewe of the average age and quality. Unit values of stock and on-feed sheep and lambs on farm, 1949-3, were imputed. From 1988 on, this was derived by dividing total value by total quantity of all sheep. NASS estimates the total value of sheep and lambs. Before 1988, we found that NASS publishes a regular bulletin (No. 800 in Jan. 1990, No. 719 in Jan. 1985) entitled *Sheep and Goats, Final Estimates* (generally with five years covered). This bulletin has total value as well as inventory figures from which unit values were derived.

Total value of stock and on-feed sheep and lambs on farm, 1949-1 was our quantity series. A total for "other states" was allocated across AR, DE, FL, GA, MS, RI, and SC for 1991 and for the same group plus AL for 1988-90. Each of these states' value shares in total group value for 1974-78 were used to allocate among states because there were no sheep reported in any of these states from 1979-87.

Rents for ewes, our price series, were taken to be a particular fraction of the unit value calculated with data on all sheep. The rent to value proportion was based on an assumed light bulb service profile, a lifespan of 6 years, an average age of 3 years, and a real interest rate of .04. The rent series based on a single year's observation on unit values was fairly erratic. Since it included the value of other types of sheep, a three year moving average of the rent centered on the year in question was used in its place. Total rental expenses, our value series for sheep and lambs, were calculated using the simple product of the rent per head and the total number of ewes.

*Hogs and Pigs*

As with cattle and sheep, we distinguish between breeding stock and stock of hogs with a one year service life or less. Average number of sows farrowing for 2 consecutive 6 month periods provides our quantity series. These figures are themselves the average of 2 published averages. The published figures come from various issues of *Ag Stats*.

**Sources:**

For years 1949-1991.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, various issues.

Our unit value series for all hogs and pigs on farm was imputed using the total value of all hogs and pigs on farm, 1948-91, and number of all hogs and pigs (including farrowing sows) on farm.<sup>1</sup> They are also published as value per head in *Ag Stats*.

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<sup>1</sup> From 1948-68, these were January 1 inventories. From 1969-92, the inventory is taken as of December 1 of the previous year.

Rents for sows, our price series, were taken to be a particular fraction of the unit value calculated with data on all pigs. The rent to value proportion was based on an assumed light bulb service profile, a lifespan of 3 years, an average age of 1.5 years, and a real interest rate of .04. The rent series based on a single year's observation on unit values was very erratic. Since it included the value of other types of pigs, a three year moving average of the rent centered on the year in question was used in its place.

Total rental expenses, our value series, were also calculated using the simple product of the rent per head and the total number of sows.

### *Poultry items*

#### *i) Broilers*

Number of broilers and other meat-type chickens on farms, 1949-85 not updated since the total chicken count excludes them and the output figure includes them.

Imputed unit value of broilers and other meat-type chickens.

#### *ii) Chickens*

Number of chickens (other than broilers) on farm, 1949-91, in thousands, is our quantity series.

Imputed unit value of chickens in dollars per head, 1949-91, is the direct observation of price and/or rent since we take the chickens to have a lifespan of only one year. We may want to reconsider this after a conversation with someone who knows better.

Total value of chicken inventory, 1949-91, in thousands.

#### *iii) Turkeys*

Number of breeder plus non-breeder turkeys on farm.

Imputed unit value of all turkeys.

*Sources:* See background notes.

## **(ii) Physical Capital**

### *Combines*

Different types of data are available for different periods and there was some work done to ensure broad consistency. Census inventories of undifferentiated combines (self-propelled and pull-type totals) were available prior to 1964. The 1964 Census broke the total down into the two types, but all subsequent census observations contain self-propelled combines only. Sales figures from unpublished Farm and Industrial Equipment Institute (FIEI) files broke down by annual sales of combines for all states from 1964 to 1989 into several categories (including a breakdown of self-propelled versus pull-type through 1973). To get consistency of the sales figures, the inventories they would imply, and published census inventories it would appear that 0.03 of

combines on farms disappear annually. There was substantial difference across states and time periods, but this figure helped graft sales numbers onto inventories in a way that lets us preserve what we know about quality (from the FIEI) without totally ignoring what we know about stocks on farms (from the Ag Census). The last three Census knots (1982, 1987, and 1992) report the number of combines on farms manufactured in the last 5 years. This information was used to scale up (if necessary) the state sales figures from FIEI in the years 1978-89. The sales figures never purported to cover all purchases of combines, but they evidently only failed to capture 12% from 1978-82. In subsequent five year periods, Census counts exceed FIEI counts by 42% (1983-87) and 25% (1988-92). In some Northeastern states, the census figures imply sales where FIEI reports none. Because FIEI data are unavailable for states in 1990 and 1991, total US sales were apportioned to states based on past shares of total sales. In all years between 1978-92, FIEI data were never scaled down since it was reasoned that these numbers represent the lower bound and that the Census could be lower for sampling problems. Only the total of self-propelled combine sales was scaled. That modified total was then used to go back and scale combines in all classes reported for the state. If no sales were reported in FIEI but were implied by the Census observations on machines manufactured in the last 5 years, a guess based on past purchases was used to allocate the Census reported new combines on farms. For three states, the Ag Census implied sales were not captured by FIEI. These were allocated to classes using past year's sales and distribution in the following way:

<b>State</b>	<b>Implied sales</b>	<b>Based on reported sales</b>
MA	1978-87	1971-77
NH	1983-87	1971-82
CT	1983-87	1971-82

Sales for 1990-92 were inferred from published totals for total sales for the U.S. and state-level sales implied by the 1992 Census. The allocation of combine sales across combine classes was based on the state's distribution of purchases in 1987-89. The only exception is for Nevada which had no reported sales in those years, so the historical distribution from 1983-85 was used instead.

The price series in this case is a national rent based on the price of one medium capacity, self-propelled combine. The price and rent series were based on the BLS price index on combines that began in 1971 and was extrapolated to 1949 using the BLS index of farm machinery and equipment. Both these series had December 1982 as a base, so the price index was scaled by the base year price of the numeraire combine as reported in Agricultural Statistics. The value series for combines is just the total rental expenses implied by the imputed rent and quality adjusted quantity series.

**Sources:**

For years 1949-1991.

United States Department of Agriculture "Agricultural Prices, Annual Summary," National Agricultural Statistics Service, 1987.

United States Department of Labor, "Producer Price Index" from Bureau of Labor Statistics web site.

Data for number of combines on farms were taken from Ag Census. Data for 1945, 45, 54 and 49 were for total grain combines, and 1964, 69, 74, 78, 82 figures were for self-propelled grain and bean combines only. Annual inventories are found by geometric interpolation. Data for

numbers of pull-type combines on farms for 1964 come directly from Ag Census—they were no longer counted after 1964. Sales figures from FIEI were used to infer total pull-type combines,  $Q$ , in each state for 1965-74 using the following formula:

$$Q_t = Q_{t-i}(1-d) + S_{t-1}$$

Starting with a base of 1964 and taking  $d = 0.11142$  left us with a total for the 48 states which matched an inferred total available for the US only in 1969. For the years 1975-91, the stock of pull-type combines was simply drawn down using the same rate for  $d$ ; this is equivalent to setting  $S$  to zero for 1974-90.

### *Tractors*

Our quantity series is the final series of quality adjusted tractor counts in thousands of 55 horsepower, 2WD equivalents for the 1949-91 period. We used some historical farm machinery bulletins to get periodic observations on the average age of tractors on all US farms to use in the quality adjustment of census observations prior to 1964.

The price series in this case was national rent based on the price of one 55 HP, 2 WD tractor. The price and rent series were calculated using a BLS price index on 2WD tractors and the base year price of 2WD tractor between 50 and 59 HP as reported in Agricultural Statistics. The value series for tractors is the total rental expenses implied by the product of imputed rent and the quality adjusted quantity series. Figures for 1969 had to be constructed as the net figure of total (on all farms) less crawlers (on 1 to 5 farms). Annual inventories were found by geometric interpolation.

### **Sources:**

Prices, for years 1949-1991.

United States Department of Agriculture "Agricultural Prices, Annual Summary," National Agricultural Statistics Service, 1987.

United States Department of Labor, "Producer Price Index" from Bureau of Labor Statistics web site.

Values, for years 1940, 45, 50, 54, 59, 64, 69, 74, 78, 82, 87, and 92.

United States Department of Agriculture, "Tractors (wheel tractors on farms)", *United States Census of Agriculture*, Economic Research Services, 1940, 45, 50, 54, 59, 64, 69, 74, 78, 82, 87, and 92.

### **Other sources:**

Cross, T. L., and G. M. Perry. "Depreciation Patterns for Agricultural Machinery." *American Journal of Agricultural Economics* Vol. 77 (February 1995):194-204.

Hansen, L., and H. Lee. "Tractor Depreciation and Technical Change: A Case Study of 60-Horsepower Tractors." Economic Research Service, Technical Bulletin No. 1772, USDA, Washington, DC

Hrubovcak, J. "Measuring Implicit Rental Rates for Farm Capital." *Agricultural Economics Research* Vol. 38, No. 1 (Winter 1986):19-33.

Penson, J. B., D. W. Hughes, and G. L. Nelson. "Measurement of Capacity Depreciation Based on Engineering Data." *American Journal of Agricultural Economics* Vol. 59, No. 2 (May 1977):321-29.

Data on sales of two-wheel drive tractors are available in up to 16 horsepower designations for 1964 to 1989 for all states. Four-wheel drive tractor sales are first reported in 1971 but with no horsepower designations until 1973. For 1990-92, only sales for the total U.S. were available and for only four broad classifications. These sales were allocated to the states and classifications using shares of 18 tractor types in the four classes based on state level sales for the years 1987-89.

Average horsepower of two wheel drive, four wheel drive and combined tractors sold for the period covered by the FIEI/Equipment Manufacturers Institute (EMI) data are calculated and used to infer quality adjusters for tractors purchased in years before 1964. We also infer purchases of 2WD tractors with under 40 horsepower for the years 1977-82. FIEI quit reporting the sales of these tractors in that six year period which resulted in a blip both in total sales and in the calculated average horsepower of tractors sold. Taking the observations of these small tractors to total 2WD tractor sales in 1976 and 1981 as knots, we interpolated the shares that would have been evident for 1977-82.<sup>2</sup> The interpolated shares were used to derive estimates of sales of tractors under 40HP. These estimated shares were not distributed across the possible classifications. Instead, they were taken to be an average of 24 HP whenever they were involved in an average horsepower calculation. The interpolated shares of these small tractors were used to scale up total sales in the 1977-82 period as follows.

Total estimated 2WD tractors = [total reported / (1-n)]

where  $n$  was the share of small tractors with less than 40HP in all 2WD tractors sold.

We checked on the consistency of Census inventories and sales figures. The 1982, 1987, and 1992 Ag Census reported separately the counts of tractors manufactured in the last 5 years. These were compared to sales figures from FIEI/EMI. Without taking disappearance into account, the Census and sales figures matched up pretty well only for tractors of 40HP or more (ratio of census counts to sales counts were 1.03 and 0.99 for 1987 and 1992). The Census counts of tractors of 40HP or less were quite different at the aggregate level (ratios of .46 and .56 for 1987 and 1992).

### *Buildings and Structures*

Using reported total value for each state, we inferred total rental expenses using the method described in the introduction to the capital section. The parameters used to infer rents from values were lifespan,  $L = 45$ ; average age,  $a = 23$ ; depreciation rate,  $\delta = 0.0499$ , and the real interest rate,  $r = 0.04$ . The quantity data were derived from the rental series using the price indices for building and fencing materials based in 1910-14 and 1992 in the place of the value of the new numeraire building. Data from 1975 onwards was based on the 1992 base index of

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<sup>2</sup> For CT and RI, the knots were taken to be the average of 1974-76 and 1983-85 since their sales were small enough to make shares of any kind of tractor erratic.

prices paid by farmers from United States Department of Agriculture—it was spliced to the old by applying the inferred inflation rate from the old to extend the series with the newer base. Once the Q was inferred, the rent was simply taken as the total expenditure divided by the inferred Q.

The value of buildings from Economic Research Service, NASS, Cornell gopher site, 1950-1994, were backcast to 1949 using geometric extrapolation.

### *Trucks and Automobiles*

Data on motor trucks, and automobiles on farms were taken from Ag Census 1940, 45, 50, 54, 59, 64, 69, 74, 78, and 82. The 1987 figures were from unpublished United States Department of Agriculture data. State share of (48 state) total number of trucks, and automobiles on farms annual shares were obtained by geometric interpolation of the shares implied by the census knots.

#### **Sources:**

For years 1940, 45, 50, 54, 59, 64, 69, 74, 78, and 82.

United States Department of Agriculture, "Tractors (wheel tractors on farms)", *United States Census of Agriculture*, Economic Research Services, 1940, 45, 50, 54, 59, 64, 69, 74, 78, and 82.

For year 1987.

Unpublished data from United States Department of Agriculture.

## **3.4 Purchased Inputs**

### *Fertilizers*

The quantity data for fertilizer is broken down into three elements: nitrogen, phosphoric oxide, and potash. These are treated as separate commodities and are measured in thousands of tons applied per state until 1985. The state-level data was discontinued in 1985, but there was still data available from the Ag Census on total acres fertilized in all states in 1982, 1987 and 1992 which together with regional totals on tons applied of particular elements allowed us to extend the series to 1991. The following 5 step process was used to extend nitrogen, phosphoric acid and potash beyond 1985. Exceptions noted under particular elements.

Step 1: Acres fertilized in each state were interpolated between the knots 1982, 1987 and 1992.

Step 2: The average ton/acre applied in the period 1982-85 was calculated using observed total tons of fertilizer (all three elements) per estimated acre.

Step 3: The average from step 2 was applied to the interpolated acre series for 1986-92 to get estimated total tons for each state.

Step 4: The total tons of fertilizer were allocated to the three elements based on 1982-85 average tonnage share in each state.

Step 5: Regional totals of each particular fertilizer element for 1986-90 were then used to adjust state totals estimated in step 4. For 1991 the average ratio of estimated state totals (step 4

results) and regional totals reported over 1986-90 was used to make the final adjustment to state totals.

### *Nitrogenous Fertilizers*

Tonnage of available plant-nutrient content (nitrogen) used on farms for the 1949-1991 period was the quantity series. Exception to step 5: Mountain states regional total was substantially less than published state sum for 1984 and 1985. Reasoning that the regional total was still missing a large fraction in subsequent years (indeed the state estimated totals always exceeded the regional figure), the average percentage difference of state sum and regional total was subtracted from the ratio in 1986-90 before applying the ratio to estimated state totals. The value data was inferred from the product of these quantities with the national level price per ton.

#### **Sources:**

For years 1949–1991.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, various issues.

For years 1949–1991 for regional totals.

Cornell gopher site: Table PETAB28.WK1.

For years 1982, 87, and 92 for state acreage fertilized.

United States Department of Agriculture, "Agricultural Chemicals Used, Including Fertilizer", *United States Census of Agriculture*, Economic Research Services, 1982, 87, and 92.

### *Phosphate Fertilizers*

Tonnage of available plant-nutrient content (phosphoric oxide) used on farms for the 1949-1985 period was the quantity series. Exception to step 5: Both LS and MT states regional total was substantially less than published state sum for 1984 and 1985. Reasoning that the regional total was still missing a large fraction in subsequent years, the average percentage difference of state sum and regional total was subtracted from the ratio in 1986-90 before applying the ratio to estimated state totals. The value data was inferred from the product of these quantities with the national level price per ton.

#### **Sources:**

For years 1949 – 1991.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, various issues.

For years 1949 – 1991 for regional totals.

Cornell gopher site: Table PETAB29.WK1.

For years 1982, 87, and 92 for state acreage fertilized.

United States Department of Agriculture, "Agricultural Chemicals Used, Including Fertilizer", *United States Census of Agriculture*, Economic Research Services, 1982, 87, and 92.

### *Potash Fertilizers*

Tonnage of available plant-nutrient content (potash) used on farms for the 1949-1985 period was the quantity series. The value data was inferred from the product of these quantities with the national level price per ton.

#### **Sources:**

For years 1949–1991.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, various issues.

For years 1949 – 1991 for regional totals.

Cornell gopher site: Table PETAB30.WK1.

For years 1982, 87, and 92 for state acreage fertilized.

United States Department of Agriculture, "Agricultural Chemicals Used, Including Fertilizer", *United States Census of Agriculture*, Economic Research Services, 1982, 87, and 92.

### *Fertilizer Prices*

National level fertilizer related unit price data for the 1948-1988 period were available at the elemental level. After 1988 these individual prices were extrapolated using the trend in annual average prices of Urea (44-46% nitrogen), Triple Superphosphate/Superphosphate (44-46% phosphoric acid), and Muriate of Potash/Potassium Chloride (60% potash) respectively. These were taken from *Agricultural Prices*.

#### **Sources:**

For years 1948-1988.

Unpublished data provided by Eldon Ball, Economic Research Service, United States Department of Agriculture, June 1989.

United States Department of Agriculture *Agricultural Prices*, National Agricultural Statistics Service, annual summary 1991, and 1994.

### *Pesticides*

Available from the United States Department of Agriculture were data on total pesticide expenditures by state for the 1949-1986 period (nominal, millions of dollars). United States Department of Agriculture analysts used the state distribution pattern from the latest Ag Census to distribute annual national estimates to individual states. The quantity data was inferred from the total value of expenditures divided by the price index described below.

#### **Source:**

For years 1949-1986.

Cornell's United States Department of Agriculture gopher site on Farm Income Data.

### *Pesticide Price*

The new NASS price index on agricultural chemicals for 1975-94 with base 1990-92 was spliced onto the existing price series from Eldon Ball with base 1980. The NASS series is based on sales of alachlor, captan, carbaryl, malathion, methyl parathion, and synthetic pyrethroids. Growth rates from the series obtained from Eldon Ball were used to backcast the NASS price index. The Divisia price index provided by Eldon Ball for pesticides had a base of 1982 = 1.0, and was inclusive of herbicides, insecticides and fungicides. Quantity data used to construct the index were derived as total (including multiple applications) treated acres per chemical multiplied by (constant) application rate per chemical. Price data represents cost per treatment per acre per chemical.

#### **Source:**

For years 1975-1994, National Agricultural Statistics Service price index.

United States Department of Agriculture "Agricultural Prices, 1994 Summary," National Agricultural Statistics Service, July 1995.

Eldon Ball's Series.

Unpublished data provided by Eldon Ball of United States Department of Agriculture.

### *Seeds*

We obtained the total nominal value (expenditure) of seed purchases by state for the 1949-1986 period for seed used on farms. Seed grown and used on farms and seed purchased for resale are not included. United States Department of Agriculture analysts use the state distribution pattern for the latest Ag Census to distribute annual national estimates to individual states.

#### **Source:**

For years 1949-1986.

Cornell's United States Department of Agriculture gopher site on Farm Income Data.

A Divisia Törnqvist-Theil price index for seed was constructed for 1948-80 using national level purchased seed prices and quantity data for 13 varieties of seed. Data for rice seed prices were only available through 1980 period other types of seed had data through 1986. The seed categories include were, corn, winter wheat, durum and spring wheat, oats, barley, rye, flaxseed, sorghum, rice, soybean, potato, peanut, and cotton. The price series from NASS on seeds, with base 1990 = 92, was spliced together with this Divisia Törnqvist-Theil index. The NASS series is itself a Divisia index with rolling weight based on 5 year average sales of alfalfa, barley, corn, cottonseed, oats, peanuts potatoes, red clover, ice, ryegrass, sorghum, soybeans, Sudan grass, tall fescue, and wheat. The final series uses our Divisia index from 1949-74 and the NASS from 1975-91. The growth rates from our Divisia are used to cast the NASS series backward. The quantity data was inferred from the total value of expenditures divided by the price index described above.

#### **Source:**

For years 1975-1994, National Agricultural Statistics Service price index.

United States Department of Agriculture "Agricultural Prices, 1994 Summary," National Agricultural Statistics Service, July 1995.

For years 1949-1974, Eldon Ball's Series.

Unpublished data provided by Eldon Ball of United States Department of Agriculture.

### *Purchased Feed*

We obtained the nominal value (expenditure) of total feed purchases by state of various types of feed including grain, hay, silage, and mixed feeds for livestock and poultry. It appears that the value of feed grains or hay that were used on-farm was not included. However, hay purchases were included even though they were predominantly an "inside input". For some purposes we may want to deduct the value of (predominantly) intra-state hay sales. When that is the case, we subtracted the value of hay directly from the value for feed, but the quantity calculation was done more indirectly. The value of hay divided by the price index for feed gave quantity of hay in the same units as feed. This derived quantity was subtracted from the quantity for feed. United States Department of Agriculture analysts use the state distribution pattern for the latest Ag Census to distribute annual national estimates to individual states.

### **Source:**

For years 1949-1986.

Cornell's United States Department of Agriculture gopher site on Farm Income Data.

A Divisia Törnqvist-Theil price index for feed was constructed for 1948-86 using national level purchased feed prices and quantities data for the 1948-1986 period. The 14 feed categories included were, wheat middlings, brewers dried grain, distillers dried grain, gluten feed, tankage and meat meal, alfalfa meal, soybean meal, cottonseed meal, peanut meal, linseed meal, corn feed grain, sorghum feed grain, oats feed grain, barley feed grain. The price series from NASS on feed, with base 1990 = 92, was spliced together with the Divisia index described above. The NASS series is itself a Divisia index with rolling weight based on 5 year average sales of barley, beef cattle concentrate, bran, corn, cornmeal, cottonseed meal, dairy feed, alfalfa hay, other hay, hog feed, liquid molasses, oats, poultry feed, sorghum, soybean meal, and stock salt. Our final series uses our Divisia index from 1949-74 and the NASS from 1975-94. The growth rates from our Divisia are used to cast the NASS series backward. The quantity data was inferred from the total value of expenditures divided by the price index described above.

### **Source:**

For years 1975-1994, National Agricultural Statistics Service price index.

United States Department of Agriculture "Agricultural Prices, 1994 Summary," National Agricultural Statistics Service, July 1995.

For years 1949-1974, Eldon Ball's Series.

Unpublished data provided by Eldon Ball of United States Department of Agriculture.

### *Water Usage*

We used annual estimates of water used on farms for livestock watering and irrigation. Published data covers water usage every five years—we obtained publications for 1950, 1955, 1960, 1965, 1970, 1975, 1980, 1985 and 1990. The intervening years were interpolated using geometric growth rates. 1949 and 1991 were both extrapolated using the average annual geometric growth

rates seen over the nearest five year period. Water irrigation fees are part of inputs in the miscellaneous expenses category.

**Source:**

For years 1950, 1955, 1960, 1965, 1970, 1975, 1980, 1985 and 1990  
United States Department of Interior, United States Geological Survey.

*Other Operating Expenditures*

*Electricity expenditures*

State-level electricity expenditures were taken from Economic Research Service tapes 1949-86

*Fuels and oils expenditures*

State-level expenditures on fuel and oil provide the value series. These expenditure data were taken from Economic Research Service tapes, 1949-81, and the Farm Income and Expenses data, 1982-92, available from the Cornell web site.

National price index of fuel and oil, and electricity prices are used for the price series. The price index from 1948 to 1987 is a Divisia Törnqvist-Theil index based on prices and quantities of 4 fuels: petrol, diesel, liquid petroleum gas, and natural gas. From 1988-91 the price index is taken from the NASS index of fuels which includes diesel, unleaded gasoline, liquid petroleum gas, and electricity. The quantity series of Electricity and Fuels and Oils were inferred from the expenditure series divided by the price index.

**Sources:**

For years 1948-1987.

Unpublished data provided by Eldon Ball, June 1989.

For years 1988-1991.

United States Department of Agriculture "Agricultural Prices, Annual Summary,"  
National Agricultural Statistics Service.

**Table 6: Units of Electricity, Fuels, and Oils:**

	<b>Price</b>	<b>Quantity</b>
Petrol	\$/gallon	Million gallons
Diesel	\$/gallon	Million gallons
Liquid petroleum gas	\$/gallon	Million gallons
Natural gas	\$/100cubic feet	10 <sup>9</sup> cubic feet
Electricity	\$/100 Kilowatt hrs.	10 <sup>8</sup> kilowatt hrs.

*Repair and Maintenance Expenditures*

State-level repair and maintenance expenses are the basis for our value series. As with miscellaneous expenses, we used the series on repair and maintenance that excluded operator dwelling expenses.

**Source:**

For years 1950-1992.

Cornell gopher site, Economic Indicators of the Farm Sector, State Financial Summary.

To construct a price index, we used the NASS price index on Supplies and Repairs from 1975-91, base 1990-92. This series was extrapolated to 1949 using the NASS Prices Paid Index, base 1910-14. The base year price was set equal to 1.00 before inferring quantities in 1000 of unnamed units. Quantity numbers are inferred from the expenses divided by the price series.

**Sources:**

For years 1975-1991.

United States Department of Agriculture "Agricultural Prices, 1994 Summary," National Agricultural Statistics Service.

*Machine hire*

State-level expenses for machine hire, millions of dollars, are the basis for our value series. These were converted to thousands of dollars and extrapolated to 1949 based on average annual geometric growth rate over the 1950-54 period. Since there is also a series on income from machine hire, we will want to use both series: expenses as an input and income as an output. We can't just use net expenses since the expenses/income figures are a mixture of inputs we have and have not measured. Capital owned by farmers but used on a farm is already counted as an expense. Net expenses would be most appropriate to use as an input if machine hire were only capital. Unfortunately, the labor component of machine hire has probably NOT been included in our input series since farmers would be likely to report days worked off their own farm as days off farm. The quantity data are inferred from the expenses divided by the price series described under repairs and maintenance.

**Source:**

For years 1950-92.

Cornell gopher site, Economic Indicators of the Farm Sector, State Financial Summary.

*Miscellaneous Expenses*

There are two series on miscellaneous expenses: one includes expenses associated with the operator's dwelling and the other excludes it. We used the series which excluded operator dwelling expenses as our value series.

**Source:**

For years 1950-92.

Cornell gopher site, Economic Indicators of the Farm Sector, State Financial Summary.

This series has a break in 1978. Prior to 1978 it included estimates of insurance, binding materials, dairy supplies, unidentified greenhouse and nursery expenses, grazing fees, harness, saddlery and blacksmithing, hardware and hand tools, telephone, vet fees and supplies. After 1978 it included health and breeding supplies, grazing fees, custom feeding fees, irrigated water fees, farm supplies, tools, non-capital equipment, net insurance, motor vehicle registration and licensing, telephone and water, other farm business management expenses and production expenses.

Note: We need to think about the inclusion of grazing fees. We have imputed land rents on both farm and non-farm grazing lands of western states and so have these grazing fees built into the land expenses. In the case of private grazing land, the fees paid by one farmer is the income of another which we have not measured.

To construct a price index, we used the NASS price index on Supplies and Repairs from 1975-91, base 1990-92. This series was extrapolated to 1949 using the NASS Prices Paid Index, base 1910-14. The base year price was set equal to 1.00 before inferring quantities in 1000s of unnamed units. Quantity numbers are inferred from the expenses divided by the price.

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- United States Department of Agriculture, "Tractors (wheel tractors on farms)", *United States Census of Agriculture*, Economic Research Services, various years.

## Appendix 1: Number of Farms

The final farm numbers used to expand distribution of operators into total operators of each type came from the Cornell gopher site in the Historical Farm Income and Balance Sheets data set. This data set was retrieved in October 1995. This data spanned 1949 to 1993 and included a large drop in the number of farms (in virtually every state) from 1974 to 1975 due to a change in the definition of what constituted a farm. To spread this definitionally induced drop out over many years, it was decided to allocate part of the change to every year from 1975 to 1981.

Taking  $Y(t)$  to be the observed number of farms in year  $t$  and  $g(t)$  to be the observed growth rate of farms from year  $t$  to year  $t+1$ , the allocation formula worked out as follows:

$$Y(82) = \prod_{t=1974}^{1981} (1 + g(t)) Y(74)$$

We wanted to calculate new growth rates  $G(t)$  such that

$$(1 + G(t)) = (1 + x) * (1 + g(t)) \quad t = 1975, \dots, 1982$$

$$(1 + G(74)) = (1 + x) * (1 + \bar{g}(74))$$

$$Y(82) = \prod_{t=1974}^{1982} (1 + G(t)) Y(74)$$

where the growth rate from 1974 was taken from earlier NASS/ERS farm income statistics. Solving these equations for  $(1+x)$  we got

$$(1 + x) = \left[ \frac{1 + g(74)}{1 + \bar{g}(74)} \right]^{(1/8)}$$

Applying this to smooth out the farm numbers left us with new farm number totals  $\bar{Y}$  bar

$$\bar{Y}(75) = Y(75) * (1 + x)^{-7}$$

$$\bar{Y}(76) = Y(76) * (1 + x)^{-6}$$

$$\bar{Y}(77) = Y(77) * (1 + x)^{-5}$$

$$\bar{Y}(78) = Y(78) * (1 + x)^{-4}$$

$$\bar{Y}(79) = Y(79) * (1 + x)^{-3}$$

$$\bar{Y}(80) = Y(80) * (1 + x)^{-2}$$

$$\bar{Y}(81) = Y(81) * (1 + x)^{-1} c$$

For 2 states (California and Nevada) no smoothing was done since there was no drop in farm numbers. For 5 states (Massachusetts, New Hampshire, New Jersey, Rhode Island and Vermont) we instead interpolated geometrically between 1974 and 1978 and again from 1978 to 1982. These states have so few farms that the erratic jumps in numbers from year to year can be caused by rounding error alone. This period seems especially bad for unknown reasons.

The Census definition of a ‘farm’ or ‘establishment’ used for statistical purposes has changed somewhat over time. Lucier et al. (1986:2-3) summarizes the salient features of the various Census definitions which have been adopted as follows:

1974 Census – an establishment which has sales of agricultural products, or potential sales, of \$1,000 or more during the year;

1959 Census – an agricultural operation of fewer than 10 acres with \$250 or more in sales, or 10 or more acres with \$50 or more in sales;

1950 Census – an operations with 3 or more acres, or operations of fewer than 3 acres and \$150 or more in sales;

1945 Census – an operation of fewer than 3 acres and \$250 or more in production (as distinct from sales) or any operation with 3 or more acres.

NOTE: This is more restrictive than the 1950 definition.

According to *Agricultural Census* (1945:4-5), the 1945 definition was essentially the same as that used in the 1940, 1935, 1930 and 1925 Censuses. For the 1920 and 1910 Census, the minimum production requirement for farms of fewer than 3 acres was not applied if the farms had at least one person continually farming the operation.

Although the quinquennial *Census of Agriculture* figures provide a benchmark for deriving state-level farm number estimates, United States Department of Agriculture analysts developed revised estimates which account for under (or over) enumeration problems in the Census figures and include additional information provided by various United States Department of Agriculture surveys. Further, when compiling time series of farm numbers, land in farms, farm production expenses, and farm income and balance sheet statistics, Economic Research Service analysts do not necessarily use the corresponding Census definition of a farm. In many instances, revised estimates are backcast on the basis of the most recent Census definition in order to abstract from definitional changes (at least for a limited time period) in the series of interest.

Appendix 2 records the farm definition used to compile the published United States Department of Agriculture number and land in farms statistics; various ERS state income production expenses and balance sheet statistics; and, farm labor statistics used as primary sources for this study. The definitional changes, particularly the 1959 to 1974 change, cause an apparent loss of farms greater than would have been indicated in the absence of the change in farm definition. Given that the principal causes of reduction in farm numbers in most states were farm consolidations and the discontinuance of *smaller* operating units, USDA (1962:3), these definitional changes appear to have had a relatively minor impact on state-level estimates of land in farms and farm income, production expenses and balance sheet statistics. However, the definitional changes introduce substantial discontinuities in the farm number (and by implication number of farm operators) statistics themselves.

United States Department of Agriculture estimates of the number of farms were published for 1978 using both the 1959 and 1974 Census definitions (see USDA *Agricultural Statistics*, 1977 and 1978), and indicate an 11.5% decline in the number of farms at the national level due simply to a change in definition. To ‘overcome’ this problem a splicing technique was used to adjust USDA, *Agricultural Statistics*, USDA/ NASS farm number data over the 1975-77 period.

(i) *Number of all farms for agricultural census years over the 1850-1982 period*

**Sources:**

1982, and 78.

United States Department of Agriculture, *United States Census of Agriculture*, Economic Research Services, Table 5, 1982.

1974.

United States Department of Agriculture, *United States Census of Agriculture*, Economic Research Services, Table 3, 1978.

1969.

United States Department of Agriculture, *United States Census of Agriculture*, Economic Research Services, Table 1, 1974.

1964.

United States Department of Agriculture, *United States Census of Agriculture*, Economic Research Services, Ch. 2, Table 13, 1969.

1959.

United States Department of Agriculture, *United States Census of Agriculture*, Economic Research Services, Ch. 1, Table 12, 1964.

1954, 50, 45, 40, 35, 30, 25, 20, 10, 1900 1890, and 80

United States Department of Agriculture, *United States Census of Agriculture*, Economic Research Services, Ch. V, Table 13, 1959.

1870, 60, and 50.

United States Department of Agriculture, *United States Census of Agriculture*, Economic Research Services, Ch. I, Table 18, 1945.

(ii) *Number of farms with sales > \$2,500 for agricultural census years 1950- 1982.*

**Sources:**

1982, and 78.

United States Department of Agriculture, *United States Census of Agriculture*, Economic Research Services, Table 3, 1982.

1974.

United States Department of Agriculture, *United States Census of Agriculture*, Economic Research Services, Table 4, 1978.

1969.

United States Department of Agriculture, *United States Census of Agriculture*, Economic Research Services, Table 1, 1974.

1964.

United States Department of Agriculture, *United States Census of Agriculture*, Economic Research Services, Ch. 2, Table 21, 1969.

1959.

United States Department of Agriculture, *United States Census of Agriculture*, Economic Research Services, Ch. 6, Table 12, 1964.

1954, and 50.

United States Department of Agriculture, *United States Census of Agriculture*, Economic Research Services, Ch. XI, Table 3, 1954.

(iii) *Annual estimates of number of all farms for the 1949-1985 period using USDA, NASS/USDA, Ag. Stats sources. See Table? for details on changes in the farm definition over time on which these figures are based.*

**Sources:**

1949-58.

United States Department of Agriculture, "Number of Farms."

1959-68.

United States Department of Agriculture, "Farms: Number of Farms."

1969-75.

United States Department of Agriculture, "Farms and Land in Farms."

1976.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, Table 584, 1977.

1977.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, Table 602, 1978.

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United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, Table 601, 1979.

1979.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, Table 599, 1980.

1980.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, Table 598, 1981.

1981.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, Table 548, 1983.

1982.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, Table 548, 1983.

1983.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, Table 537, 1984.

1984.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, Table 534, 1985.

1985.

United States Department of Agriculture, *Agricultural Statistics*, National Agricultural Statistics Service, Table 535, 1986.

**Appendix 2: Farm Definitions Underlying Various Land in Farms, Number of Farms, Farm Income, Balance Sheet, and Expense Statistics Used to Construct these Data.**

Census Definition	DOC, Census of Agriculture <sup>a</sup>		USDA NASS/Ag Stats <sup>a</sup>		USDA/ERS
	Land in farms	Number of farms	Land in farms	Number of farms	Farm income, expenses, balance sheet statistics
1974	1982, 78, 74	1982, 78, 74	1978-85	1978-85	1977-85
1959	1969, 64, 59	1969, 64, 59	1954-78	1954-78	?
1950	1954, 50	1954, 59	1950-53	1950-53	?
1945	1945, 40, 35, 30, 25	1945, 40, 35, 30, 25	NA	1925-49	?
Other	1920, 10, 1900, 1890, 80, 70, 60, 50	1920, 10, 1900, 1890, 80, 70, 60, 50	NA	1910-24	

<sup>a</sup> See discussion of farm numbers in Appendix 1 data for sources.