A Comparison of Capital Measures in U.S. Agriculture

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Abstract

This study compares two panel data sets that measure capital input at the state-level in U.S. agriculture. Despite a number of similarities between the data sets, such as the composition of assets, aggregation procedures, and time frame, an examination of the final estimates of capital service flows reveals that they are drastically different for all 48 contiguous states. We examine the methods used to construct the capital series for each data set, consider some important differences in data sources and the types of data used to construct the capital measures, and outline the main assumptions concerning depreciation, service lives, interest rates, aggregation, and the scope of goods included in each of the data sets. The analysis indicates that an important statistic in the index of capital services in U.S. agriculture is the stock of buildings on farms. We conclude that the primary difference between the measures of capital input in the data sets relates to differences in estimates of the stock of buildings on farms. Given the apparent importance of the measure of the stock of buildings in the aggregate index of capital services in U.S. agriculture, more research is needed to ensure that the measure of the stock of buildings is accurate and meaningful. Once this has been accomplished there should be more agreement on an accurate measure of capital services in U.S. agriculture.

Introduction

An accurate measure of the annual flow of capital inputs in U.S. agriculture is important for policy makers and researchers who are interested in agricultural production and productivity. However, data limitations and a myriad of assumptions required to construct such estimates make their calculation difficult and vulnerable to significant measurement errors. If measurement errors are significant, and the capital measures are used by policy analysts and researchers, they will lead to erroneous conclusions about the structure of agricultural production and the rate of productivity growth in agriculture. The importance of an accurate measure of capital for empirical studies of agricultural production and productivity cannot be overstated, yet there is wide variation among accepted methods to measure capital for such purposes. Estimates of the flow of capital services are highly sensitive to the assumptions used when constructing these measures, and therefore more agreement is needed on the appropriate assumptions to apply when measuring capital in U.S. agriculture.

The study begins by reviewing a common method of measuring capital service flows and outlines a number of important assumptions required to construct such measures. Next, we examine two recently constructed data sets that measure capital inputs in U.S. agriculture at the state level. The first data set comes from the United States Department of Agriculture, Economic Research Service (USDA – ERS) and details about the data can be found in Ball, Butault, and Nehring (2001). The second data set is from Acquaye, Alston, and Pardey (2003), which is a revised data set from earlier work by Craig and Pardey (1996). For the remainder of this paper we use "USDA" to refer to the Ball, Butault, and Nehring data, and "AAP" for Acquaye, Alston, and Pardey. We examine the methods used to construct the capital series for each data set and compare the resulting estimates. We also consider some important differences in data

sources and the types of data used to construct the capital measures, and outline assumptions concerning depreciation, service lives, interest rates, aggregation, and the scope of goods included in each of the capital series for each data set. Despite a number of similarities between the data sets, such as the composition of assets, aggregation procedures, and time frame, an examination of the final estimates of capital service flows reveals that they are drastically different for all 48 contiguous states.

A Brief Description of Procedures for Calculating Capital Input Indexes

The measurement of capital inputs is problematic for two general reasons. The first is that capital is purchased in one time period and its use is spread over a number of time periods thereafter. This raises the issue of exactly how much of the initial investment is used in each time period, which among other things requires assumptions about physical deterioration, obsolescence, replacement, and durability. These assumptions are required to define the accumulated stock of capital as well as the flow of services from the stock, which is the relevant measure to be used in studies of production or productivity. The second reason why capital inputs are difficult to measure relates to the fact that the consumer of capital services is also the supplier, implying that the entire transaction occurs within the internal accounts of the economic unit making the investment (Griliches and Jorgenson 1966). Consequently, scant data are available on either the rental rate of capital or how a capital purchase is actually used during its service life.

In the case of capital, a measure of the flow of services must be constructed from data on the current stock of capital goods, measured in physical units, or alternatively from a long time series on investment in capital goods. The first approach, based on counts of assets, is called the physical inventory method. The second approach, based on investment data, is called the perpetual inventory method. The first approach is more

direct but data limitations often make the perpetual inventory method the only available alternative. A combination of the two methods can be used when a geometric rate of depreciation is assumed for the stock of capital. This is accomplished using a benchmark measure of the capital stock (such as a census knot) and a series on capital investment thereafter. This type of mixed approach is necessary when a long historical series on capital investment is not available to convert into an estimate of the current stock.

An important note about measuring capital concerns the actual (latent) flow of capital services, which is unobservable to the researcher because the data are typically not available. Consider the example of agricultural machinery. Ideally we would have data on the number of machine hours used in production each period for each class of machinery, and an hourly rental rate for each class. An index of the quantity of machine services could then be calculated for the different classes of machines with the hourly rental rates as weights. Since such data are not typically available, a measure of the stock of machinery is substituted in the indexing procedure under the assumption that the flow of machine services is proportional to the stock of machines (each additional machine provides a fixed number of machine hours per period). If the proportionality assumption is correct, then the observable stock can be used as an accurate proxy for the latent quantity of capital services in the indexing procedure, since the stock and flow will grow at the same rate when they are in proportion to one another.

The perpetual inventory method can be used to estimate a stock of capital each period using data on real investment over time. Denoting the service life of an asset, L, and the annual rate of capital depreciation, δ, the current stock of capital can be defined by the following capital accumulation equation:

$$K_t = I_t + (1-\delta)I_{t-1} + (1-\delta)^2 I_{t-2} + \ldots + (1-\delta)^L I_{t-L} \qquad (1)$$

Equation (1) is just the moving sum of current and past investments, truncated according to the assumed service life of the asset. Past investments are reduced by the annual rate of depreciation of the asset. In this manner annual estimates of the stock of capital for each class can be estimated.

The rental rate for each class of asset is a function of the price of a new asset, P_t, the (assumed) constant rate of depreciation of the asset, δ, and the real interest rate, r_t.[1]

$$\rho_t = f(P_t, r_t, \delta) \tag{2}$$

The rental rate estimates serve as weights in the calculation of the index of capital services. These weights are intended to represent the relative marginal products of the different classes of capital. Many different functional forms exist for the rental rate estimates. See Coen (1975) for a formal derivation of the rental rate expression under different depreciation patterns. The most common specific form for the rental rate calculation is:

$$\rho_t = P_t\left(r_t + \delta\right). \tag{3}$$

Assuming that there are i = 1, 2, …, N capital classes, a time series of rental rates for each class of capital can be combined with a time series of stocks for each class of capital to form an index of the quantity of capital services. Commonly, a discrete approximation to a Divisia index, such as a Fisher Ideal index, is used for aggregation. The Fisher Ideal index of the quantity of capital services, qk_t, for i =1, … , N classes of capital is:

[1] We have assumed a constant geometric rate of depreciation; however, many other forms of depreciation exist and the appropriate depreciation method to use in practice is the topic of an extensive literature. The only other form of depreciation discussed in this study is hyperbolic.

$$\frac{qk_t}{qk_{t-1}} = \left(\frac{\sum_{i=1}^{N} \rho_{i,t-1} K_{i,t}}{\sum_{i=1}^{N} \rho_{i,t-1} K_{i,t-1}} \right)^{\frac{1}{2}} \left(\frac{\sum_{i=1}^{N} \rho_{i,t} K_{i,t}}{\sum_{i=1}^{N} \rho_{i,t} K_{i,t-1}} \right)^{\frac{1}{2}} \tag{4}$$

where $\rho_{i,t}$ is the rental rate of capital class *i* in period *t*, and $K_{i,t}$ is the stock of capital class *i* in period *t*. The aggregate rental rate is then calculated as an implicit price index, by dividing the total rental value each period, $\sum_{i=1}^{N} \rho_{i,t} K_{i,t}$, by the quantity index of service flows for that period.

Review of Production Accounts in U.S. Agriculture

A number of statistical databases of inputs and outputs in U.S. agriculture have been constructed over the past 50 years, none of which used exactly the same methods to construct their capital input series. Over the years, significant refinements in data construction methods have increased the accuracy of measures of capital on U.S. farms. Some of these improvements include refinements to indexing procedures, the incorporation of quality changes, utilization adjustments, and the use of disaggregated data.

The U.S. Department of Agriculture (USDA) published Laspeyres indexes of inputs, outputs, and productivity annually in *Changes in Farm Production and Efficiency* until the early 1990s. The details of the data construction are outlined in Agricultural Handbook no. 365 (1970). In 1980, an American Agricultural Economics Association (AAEA) task force reviewed the USDA's data construction procedures and recommended several changes in a publication entitled, *Measurement of U.S. Agricultural Productivity: A Review of Current Statistics and Proposals for Change*.

One of the recommendations of the panel was to switch to the use of discrete approximations to Divisia indexing procedures, instead of the Laspeyres indexes the USDA was publishing.

Brown (1978) was the first researcher to compile (approximate) Divisia indexes of inputs and outputs in U.S. agricultural production. After the AAEA task force published its recommendations, a number of researchers incorporated suggestions from the task force into the construction of their own databases. Modified data sets were constructed by Ball (1985) for 1948-79, and by Capalbo, Vo, and Wade (1986) for 1948-1983. Craig and Pardey (1996) were the first to compile state-level indexes of inputs, outputs, and productivity in U.S. agriculture, which they did for the 48 contiguous U.S. states for 1949-91. Ball, Butault, and Nehring (2001) recently finished constructing a database of U.S. state and national indexes of inputs, outputs, and productivity in U.S. agriculture for 1960-1996. In addition, Acquaye, Alston, and Pardey (2001) recently finished constructing a database of U.S. state and national input, output, and productivity indexes for 1949-91, which is a modified version the Craig and Pardey (1996) data set.

Acquaye, Alston, and Pardey (2001) presented a preliminary comparison of productivity measures between the AAP and USDA data sets for the United States as a whole, and for the 48 contiguous states. They identified very large discrepancies between the two estimates at the level of individual states, though not for the nation as a whole, and concluded that the main source of differences was in the measures of inputs rather than outputs. Further, their analysis suggested that differences in the measures of capital contributed significantly to the differences in measures of total input use. Our further work with the two data sets has reinforced the view that differences in measures of capital are likely to be the primary source of the substantial differences in measures of productivity between AAP and USDA.

A Comparison of the Capital Measures

In the comparisons that follow, a subset of the AAP and USDA data sets (1960-1991) is used that represents the years in which the two data sets overlap. Each data set is invariant to choice of base period, and both of the indexes of capital service flows were standardized with 1960 as the base period. A summary of the methods used to construct each capital series is provided in table 1.

Table 1

The composition of assets included is similar between the two series. The capital service flow series in each data set are Fisher Ideal indexes that use estimates of the stocks as quantities, and estimates of the rental rates as prices. The main difference between the data sets pertains to the estimation of the stock of capital and the rental rate of capital. Graphs of the indexes of capital service flows from each data set for the 48 contiguous states are provided in figures 1-5**.**

Figures 1-5

The AAP capital series is significantly different from the USDA series in every state. One obvious pattern is evident in each of the USDA measures of capital services. In every state, capital services increased between 1960 and the early 1980s, and declined thereafter. This suggests that these measures are driven more by national than state-specific effects. In the remainder of this section we examine some differences in data construction methods and data sources that could be causing the wide discrepancy in service flow estimates observed between the two data sets.

Value of capital services

The value of capital services (or rental value) is simply the estimate of the aggregate rental rate for capital multiplied by the corresponding estimate of the stock each period.

The rental value for each class of capital is the relevant measure to include in the calculation of the aggregate service flow index. Estimates of the rental value of services from automobiles, non-residential buildings, tractors, and trucks in U.S. agriculture are provided for each of the data sets in figure 6.

Figure 6

The estimates follow similar patterns in the two data sets but their values are significantly different. This is especially true in the case of automobiles, where the AAP measure of the rental value is twice (or more) that of the USDA for the entire sample. Only the truck and tractor estimates are similar over most of the sample; however, even these series are different for most of the 1980s. Next, we examine the two components of the rental value more closely. These are the stock of capital and the rental rate of capital services.

Stocks

The primary difference between the USDA stock data and the AAP stock data is that the USDA used the perpetual inventory method to calculate the capital stocks and AAP used a physical inventory method (except in the case of buildings which is based on a value series). Consequently, the USDA stocks are measured in real dollars and the AAP stocks are measured in physical units. This makes it difficult to compare the estimates directly. The estimates of stocks also differ in the treatment of depreciation, the retirement of capital assets, and the sources of data used.

The USDA used investment data from *Fixed Reproducible Tangible Wealth in the United States, 1925-1994* (U.S. Department of Commerce, Bureau of Economic Analysis

1999) to construct stock estimates using the perpetual inventory method.[2] AAP used a variety of data sources including both publicly available and unpublished data to estimate capital stocks in physical units, using a combination of inventory data and investment data. The main data sources for the AAP stock measures are the National Agricultural Statistics Service (NASS) Census of Agriculture; the Farm and Industrial Equipment Institute (FIEI); and the USDA – ERS. Both groups of researchers used asset price deflators from the Bureau of Labor Statistics (BLS).

In addition to differences in data sources, the stock measures differ in their treatment of depreciation. The USDA assumed a hyperbolic depreciation pattern for capital assets, which implies an increasing rate of depreciation over an asset's life (a concave pattern). Alternatively, AAP assumed a geometric depreciation pattern for durable assets, which implies that assets depreciate rapidly in the early years of life and more slowly in later years (a convex pattern). Although the choice of depreciation pattern differs, each of the methods used to depreciate the capital stocks has been widely used and accepted in the literature on the measurement of capital.[3] Finally, the retirement of assets differs significantly between the two data sets for buildings and tractors, as table 1 indicates. While we do not test the sensitivity of the capital measures to changes in service lives, this is another possible area of discrepancy between the measures. Graphs of the stocks of trucks, tractors, automobiles, non-residential buildings, combines and machinery are shown in figure 7.

Figure 7

[2] This is true for the national capital input series; however, it is not clear at this time if the same data source is used to construct the state-level estimates of stocks.

[3] An extensive literature exists on the appropriate treatment of depreciation when measuring capital, including studies by Jorgenson (1996), Hulten and Wycoff (1981), and Penson, Hughes, and Nelson (1977).

The rental rate of capital is typically a function of the price of a new unit of capital, the real interest rate, and the rate of depreciation.[4] The rental-rate estimates are used as proxies for the relative marginal products of the different classes of capital. If the rental rates do indeed reflect the relative marginal products, they will be the appropriate weights to use when calculating the aggregate index of capital services. A number of different formulations of the rental rate are possible. The USDA used a variable real interest rate and a variable rate of depreciation to estimate asset rental rates. AAP used a constant real interest rate and a constant rate of depreciation to estimate asset rental rates. Obviously, these differences result in different estimates of rental rates and thus different weights in the final step of the indexing procedure.

In general, the choice of weights can have a significant impact on any indexing procedure. However, the weights are not important if the different quantities (stocks) in the index procedure are growing at the same rate: if all the quantities (stocks) are growing at the same rate, the quantity index is invariant to any choice of price (rental rate) weights. Table 2 shows the average annual rates of growth of the different stocks for each data set over 1960-1991.[5] Table 2 indicates that the average annual growth rates of the different classes of capital in each of the data sets are not significantly different from zero. Only the growth in the stock of automobiles is statistically significantly different from zero at the 5 percent level of significance. Since most of the stocks are growing at a rate that is not significantly different from zero in each of the data sets, the importance of the rental rate weights in the index procedure is negligible. Therefore, the different construction methods and the different sources used to construct the rental rate estimates in each data set are not the cause of the observed differences between the two sets of

[4] The tax rate is sometimes included in the rental rate expression as well.

[5] Growth rates are calculated as the natural log of the ratio of current and lagged stock, $\ln(K_t / K_{t-1})$.

indexes of capital services. The differences in the service flow indexes must be the result of differences in the measures of one or more of the stocks.

Table 2

A Closer Look at the Stock Measures

The previous section indicated that differences in the estimates of capital stocks for one or more of the different classes of capital are the likely source of discrepancy between the USDA and AAP indexes of capital services. None of the classes of capital stocks grew by much (either positively or negatively) over the sample period. This is consistent with the low growth or negative growth of total inputs in U.S. agriculture over this period.

Refer again to figure 7, which depicts the different stock estimates for each data set. While a direct comparison of the magnitude of the measures is not possible because they are measured in different units, we can examine differences in the paths of the annual estimates of stocks over the sample. A brief examination of the different classes of capital stocks indicates that the stock of non-residential buildings shows the most variation between the USDA and AAP measures. This is also the class of capital with the largest stock in terms of value. The USDA data indicate that, on average, non-residential buildings represent approximately 35 percent of the real value (in 1996 dollars) of all capital on farms in the United States (excluding land). The class of non-residential buildings in the AAP data is also the largest class of capital in terms of value of the stock and the value of the annual service flow.

The prominence of the non-residential building series in each data set, coupled with the fact that significant variation exists between the measures of buildings in the two data sets, led us to suspect that the primary cause of differences in the USDA and AAP indexes of capital services may be differences in their measures of stocks of non-

residential buildings. Figure 8 shows the stock of buildings and the index of the quantity of capital for each data set for the period 1960-1991. The importance of the building series in the estimates of capital services is apparent in figure 8.

Figure 8

The AAP estimates of the stock of non-residential buildings are based on value data from *Farm Real Estate, Historical Series Data, 1950-92* (USDA-ERS, Jones and Canning 1993). The annual values of buildings in this publication are estimates based on a handful of census knots, and a model of the relationship between the rate of inflation and the ratio of the value of land to the value of buildings. The model of the relationship between the rate of inflation and changes in building and land values is based on a theoretical argument by Feldstein (1980), who postulated that land would be a comparatively good hedge against inflation owing to the differential tax treatment of current income and capital gains.

The basic idea behind the procedure used to forecast the value of buildings is that the rate of inflation can be used to partition data on the value of real estate (land and buildings).[6] Jones and Canning (1993, p. 2) wrote,

> The basic premise is that heightened inflationary expectations by investors will cause the stock of land (which is in relatively fixed supply) to gain in value relative to the stock of buildings. The more elastic supply of building materials precludes the same rate of building value inflation as that of land. Thus, land should gain in value relative to buildings in periods of accelerated inflation, and fall in value relative to buildings during declines in inflationary expectations.

The ratio of the value of land to the value of buildings was regressed against the rate of inflation and the rate of inflation squared for a sample of seven census knots, 1921, 1926, 1931, 1941, 1971, 1980, and 1989. Estimation was by restricted least

[6] Additional details of the procedure used to calculate building values are available in Canning (1992).

squares with no intercept term to preserve degrees of freedom. The resulting parameter estimates were then used to forecast the ratio of the value of land to the value of buildings for all years between 1950 and 1992 except the census knot years of 1971, 1980, and 1989. Figure 9 shows the estimated (L/B) series for U.S. agriculture for the period 1960-1991. The forecast of building values is simply the real estate value series (land and buildings) multiplied by the inverse of the (L/B) forecasts.

Figure 9

This procedure for forecasting building values is suspect for a number of obvious reasons including the simplicity of the model and the small sample size used in estimation. Moreover, other information calls the whole concept into question: the Feldstein hypothesis was tested directly by Alston (1986) and Burt (1986), both of whom concluded that increases in inflation did not have the hypothesized positive effect on the real value of farm land.[7] In addition, it is important to recall that we are trying to measure the quantity of buildings. New investment in buildings might depend on the rate of inflation, but the use of existing buildings should not. Hence, it is probably a bad idea to use inflation to forecast the value of buildings, as a measure the stock of buildings used in production on U.S. farms each year. A more sensible approach might be to measure the value of buildings as a constant share of the value of real estate, which might be a better proxy to the actual stock of building used in production.

The USDA estimate of the stock of non-residential buildings is based on investment data from the U.S. Department of Commerce, Bureau of Economic Analysis (BEA). The series shows a steady gradual increase from 1960 to 1982, and a steady

[7] Subsequent work has yielded a mixture of results on this issue. For instance, see Falk (1991) who found some evidence of short-run speculative bubbles but no long-run relationship between inflation and real land values; and Just and Miranowski (1993) who found a real effect of inflation – but did so by construction and erroneously.

gradual decrease from 1982 until 1991. The same pattern is apparent in most states and this result does not seem plausible. One possible reason why each state is exhibiting the same pattern of capital input is that some national data were used in calculating the state measures, and the national influences are dominating each of the state-level series. We are currently working on uncovering more details about the estimates of the stock of building used by each group of researchers. More details about the buildings data and some additional conclusions about the appropriate measure of the stock of buildings to include in a capital service flow index will be prepared by the time of the conference.

Conclusion

This study has reviewed common methods used to obtain measures of capital, intended to represent an annual flow of services. A careful examination of two data sets that measure capital services in U.S agriculture for the 48 contiguous states has revealed that the measure of the stock of buildings is important in the calculation of the index of capital service flows, and that differences in this index are the likely cause of large differences between the indexes of capital services in the two data sets. Given the apparent importance of the measure of the stock of buildings in the aggregate index of capital services in U.S. agriculture, more research is needed to ensure that the measure of the stock of buildings is accurate and meaningful. Once this has been accomplished there should be more agreement on an accurate measure of capital services in U.S. agriculture. We are currently examining the building series from each data set in more detail, and additional details will be ready by the time of the conference.

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Table 1: A Comparison of the Capital Service Flow Measures

Comparison of capital service flow measures	***AAP*** (Sample period 1949-1991)	***USDA*** (Sample period 1960-1996)
Composition	Automobiles, trucks, tractors, combines, mowers/conditioners, pickers/balers, non-residential buildings, and biological capital (breeding cows, chickens, ewes, milking cows, and sows).	Automobiles, motor trucks, tractors, other machinery, non-residential buildings, inventories (of crops and livestock).
Depreciation (δ) L = service life of asset	Declining balance with a geometric rate of depreciation, δ, for equipment and buildings. See rates in the *cell* below. Depreciation rates are either estimated from 'blue book' price data or taken from USDA estimates.	Hyperbolic decline in productive efficiency of buildings and equipment. The relative efficiency of an asset t years old is $d_t = (L-t)/(L-\beta t)$ with β = 0.5 for equipment, β=0.75 for buildings, and β=1 (one-hoss shay) for inventories.
Service Lives (L)	Satisfies the relationship $(1-\delta)^L = 0.1$ for the assumed depreciation rates. *Class* — δ — *L* Automobiles 0.22 9 Buildings 0.05 45 Combines 0.14 15 Forage eq. 0.10 22 Tractors 0.12 18 Trucks 0.21 10 Biological 0.00 1	Normally distributed around a mean service life (by class). See text for reference to data. *Class* — *L* Automobiles Na Buildings 38 Inventories 1 Machinery 14 Tractors 9 Trucks 9 Na = not available
Interest rate (r)	r = 0.04 for all capital classes and all time periods.	Annual rates are calculated as the nominal yield on Moody's BAA corporate bonds minus the rate of inflation.
Aggregation	Fisher indexes. Prices are the user cost of capital estimates, and quantities are the productive stock estimates.	Fisher indexes. Prices are the user cost of capital estimates, and quantities are the productive stock estimates.

Table 2: Average Annual Growth in Capital Stocks, 1960-1991

	Average Annual Growth Rate	
Capital Class	AAP	USDA
Automobiles	-0.0216	-0.0428
	(0.0060)	(0.0047)
Buildings	-0.0004	0.0061
	(0.0146)	(0.0030)
Combines	0.0083	0.0000
	(0.0097)	(0.0061)
Tractors	-0.0022	-0.0051
	(0.0072)	(0.0099)
Trucks	0.0001	0.0113
	(0.0033)	(0.0069)
Inventories		0.0070
		(0.0081)

Note: Standard errors in parentheses.

Figure 1: The USDA and AAP Indexes of Capital Service Flows for the Mountain and Pacific Regions, 1960-1991 (1960=1)

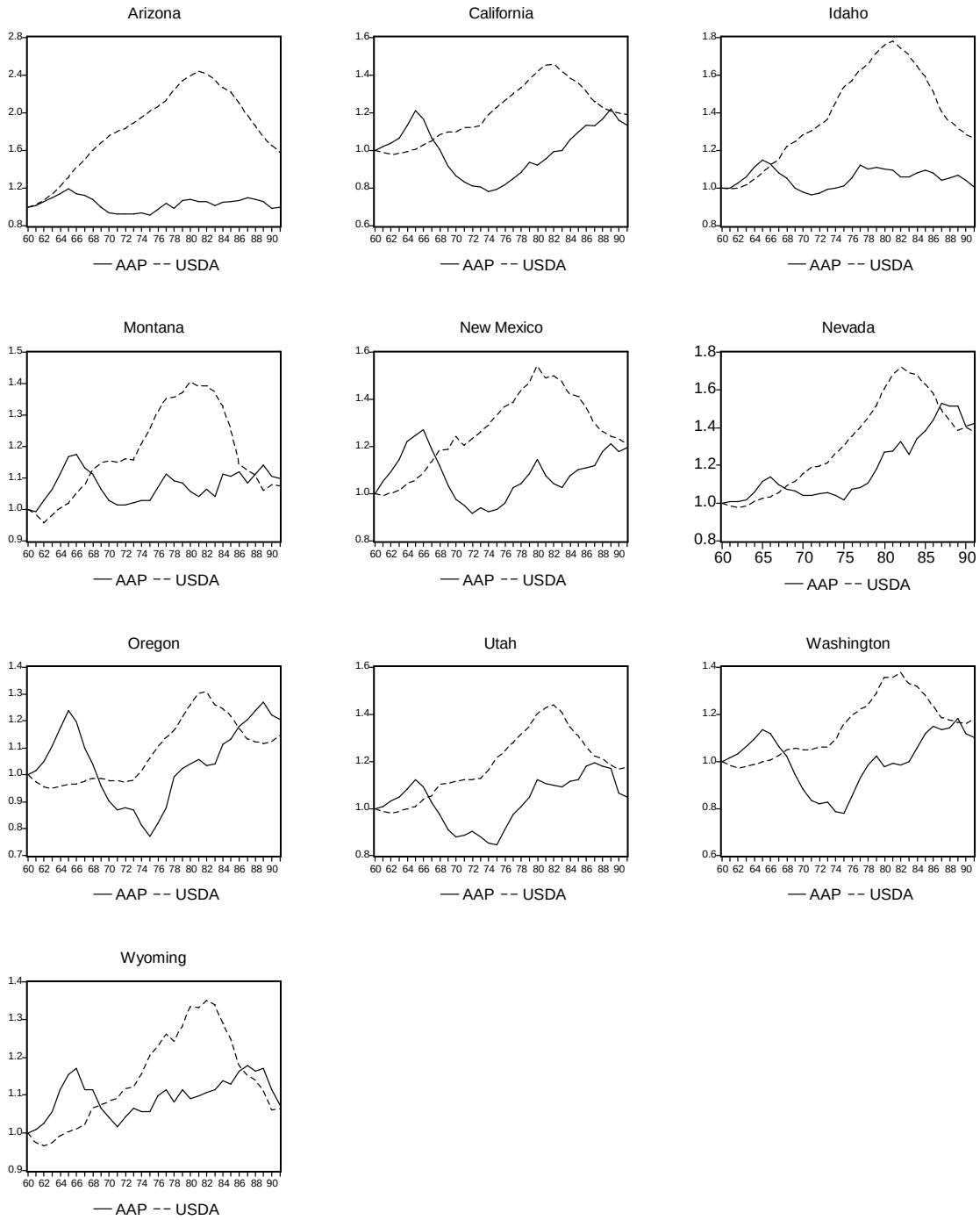

Figure 2: The USDA and AAP Indexes of Capital Service Flows for the Northern Plains, Southern Plains, and Delta Regions, 1960-1991 (1960=1)

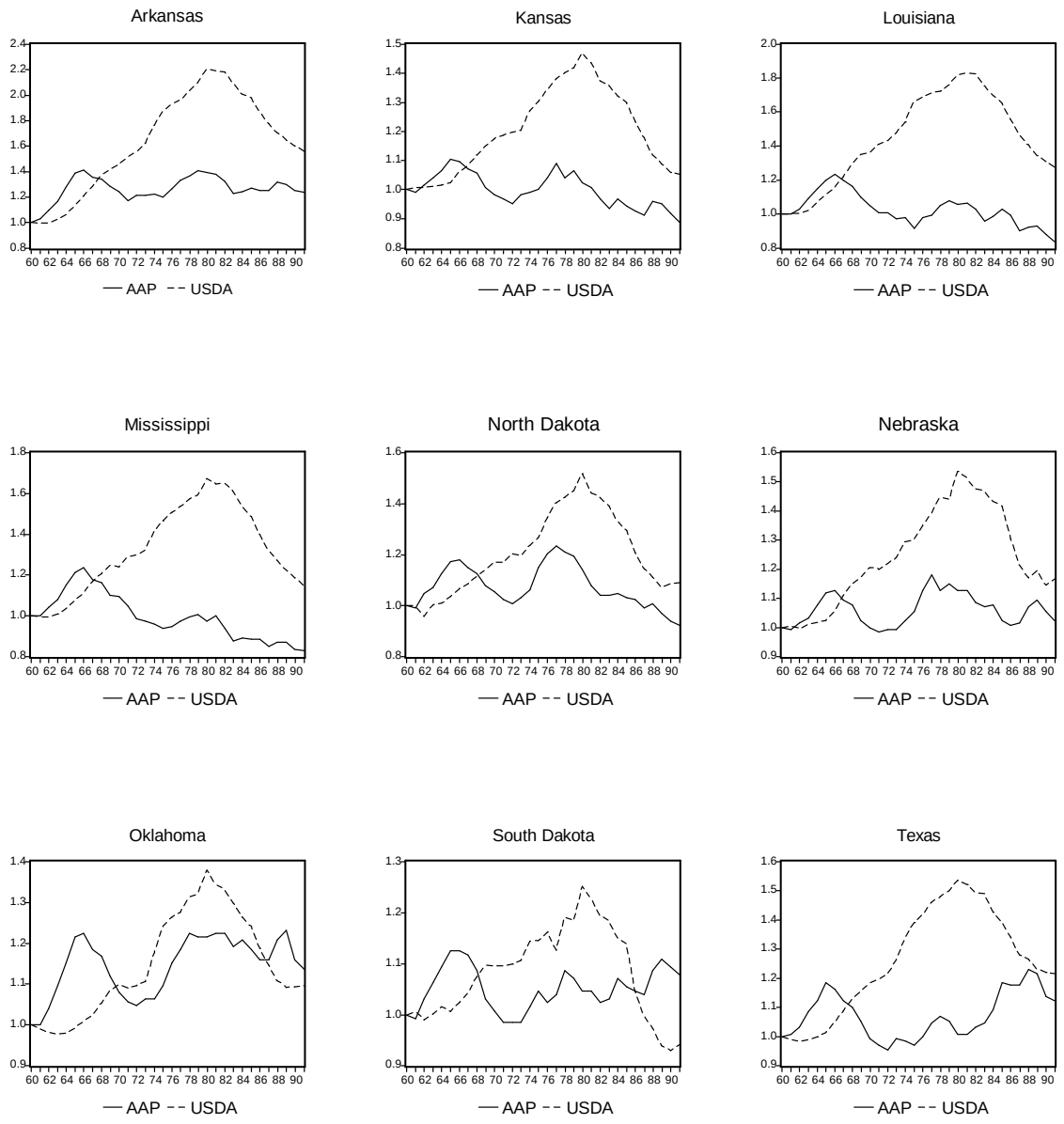

Figure 3: The USDA and AAP Indexes of Capital Service Flows for the Apalachian and Southeast Regions, 1960-1991 (1960=1)

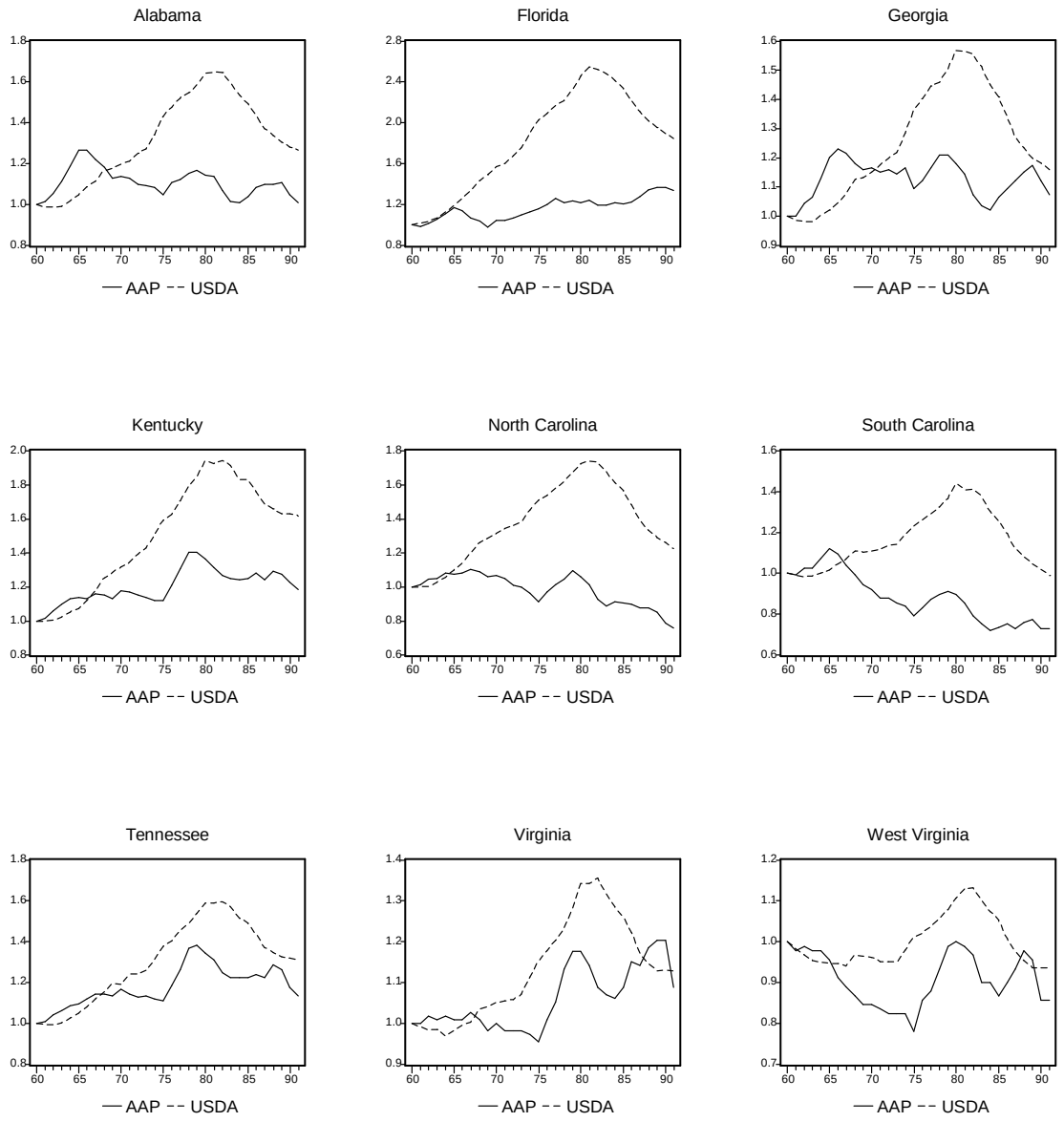

Figure 4: The USDA and AAP Indexes of Capital Service Flows for the Corn Belt and Lake States Regions, 1960-1991 (1960=1)

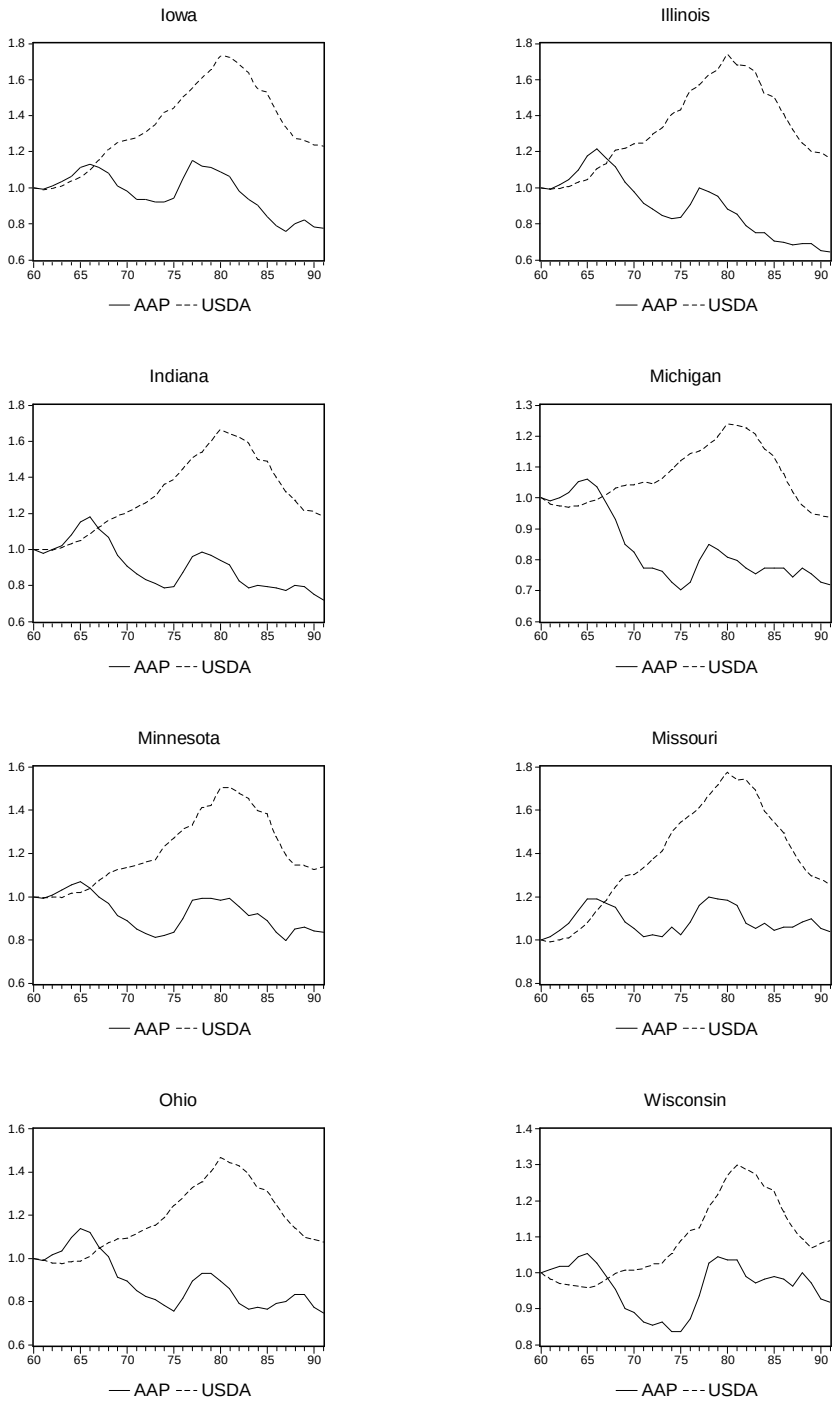

Figure 5: The USDA and AAP Indexes of Capital Service Flows for the Northeast Region, 1960-1991 (1960=1)

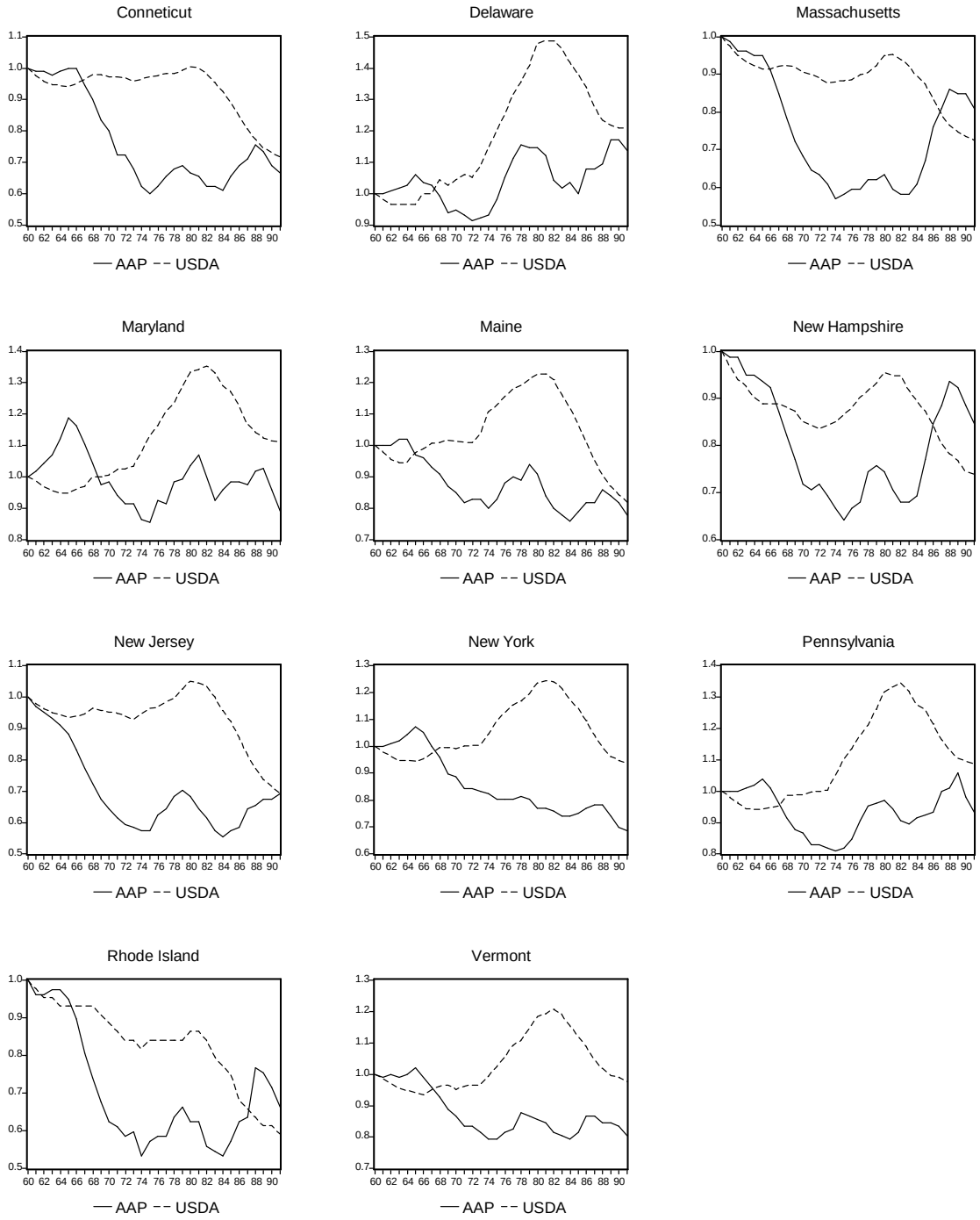

Figure 6: The Annual Rental Value of Capital Services in U.S. Agriculture 1960-1991

(*the rental rate multiplied by the stock*)

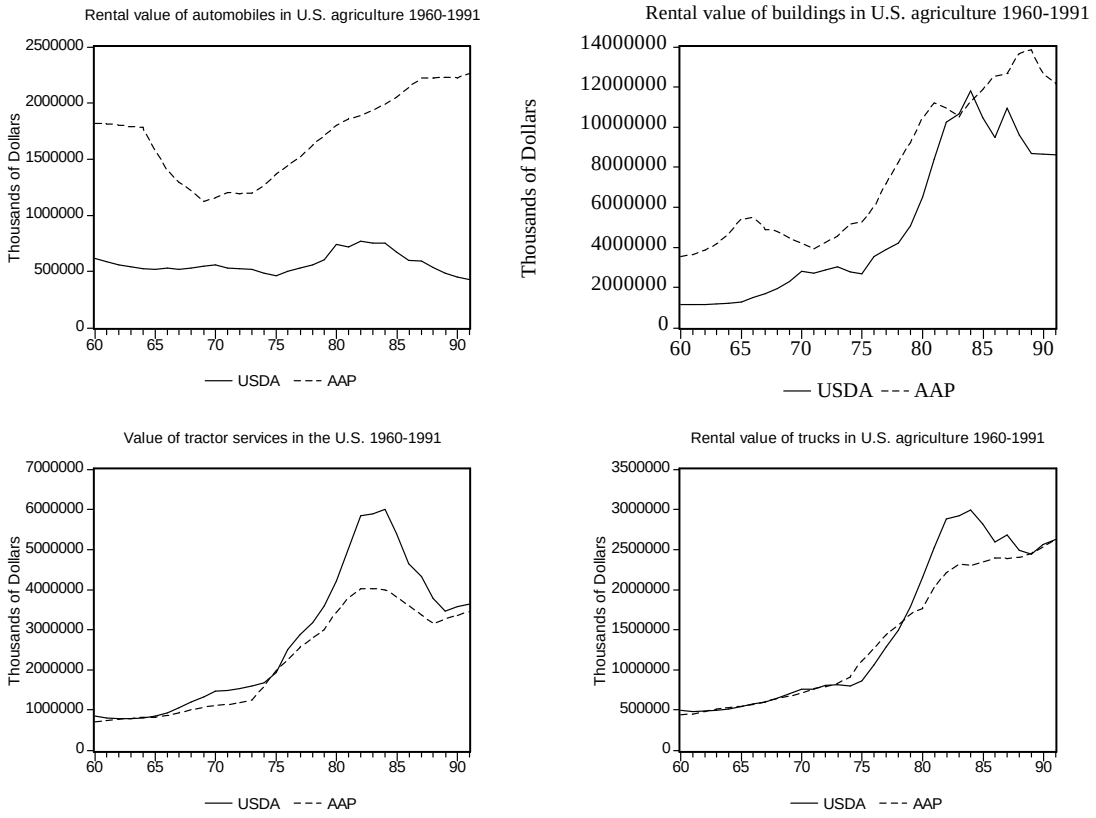

Figure 7: The Stock of Physical Capital in U.S. Agriculture 1960-1991

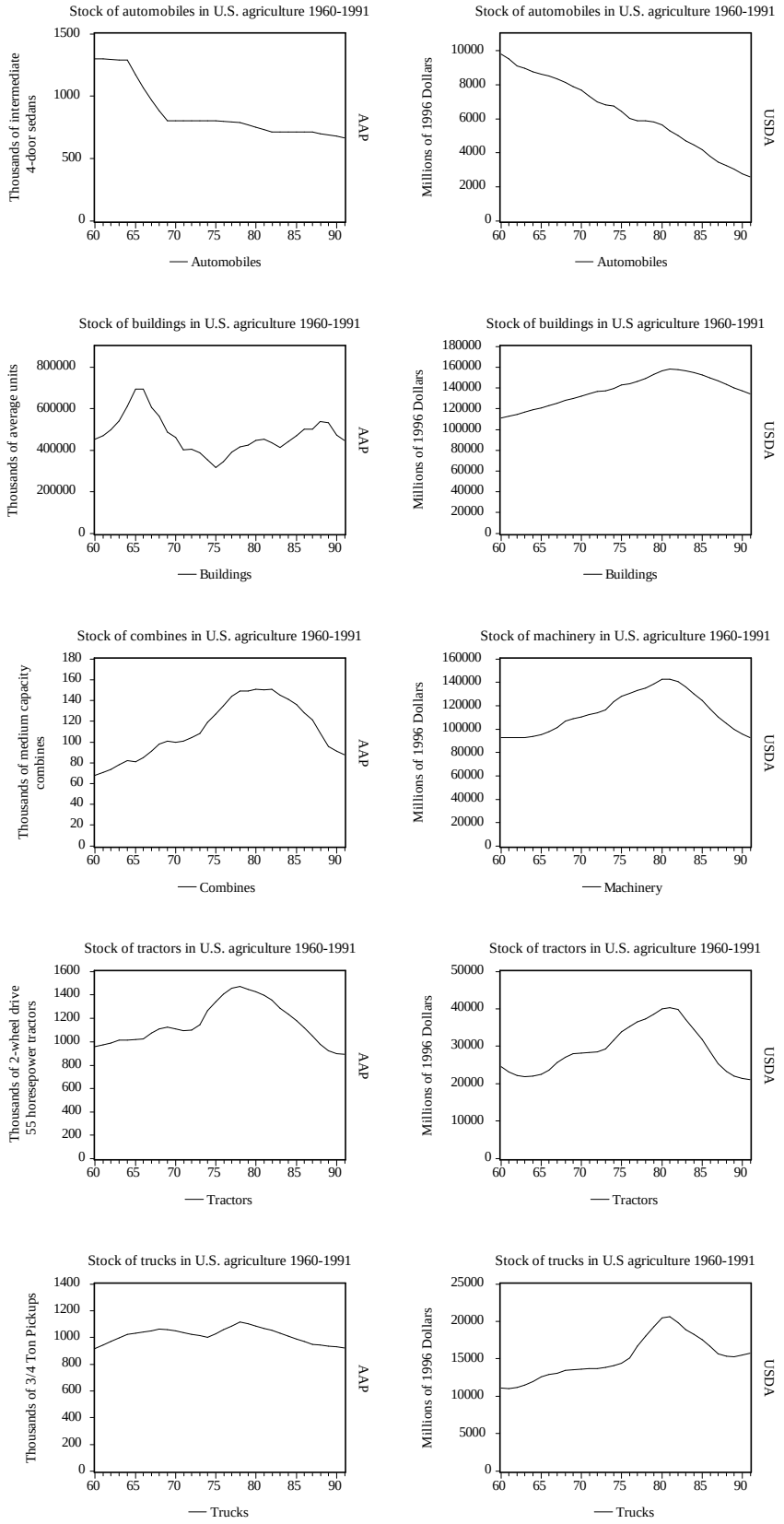

Figure 8: The Stock of Buildings and Index of Capital Services in U.S. Agriculture for each Data Set, 1960-1991

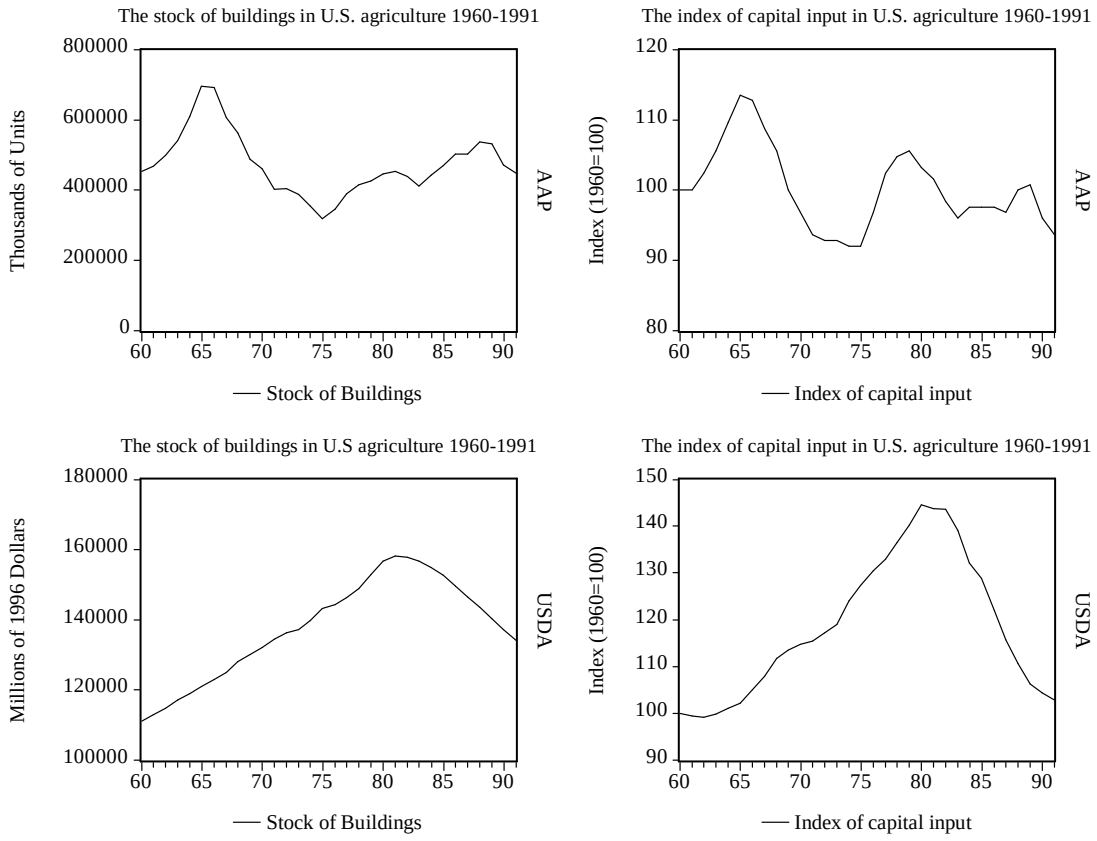

Figure 9: The Forecasted Ratio of Land Value to Building Value 1960-1991