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ABSTRACT

Measures of capital services are used in studies of production and to inform policies related to growth and development. A variety of methods have been used to measure capital stocks and service flows. We briefly review the methods commonly used to measure capital service flows, and the main assumptions. We then quantify the substantial differences between our newly constructed InSTePP series on capital use in U.S. agriculture and a comparable USDA series. We show that measures of capital services are sensitive to the treatment of interest rates, notably the use of fixed versus variable market rates, and we demonstrate the implications for measures of the quantity and productivity of agricultural capital in the United States. We conclude that when calculating capital usage in U.S. agriculture the use of a fixed rate of interest will generate more plausible estimates than the use of an annual market rate that varies from year to year.

Capital Services in U.S. Agriculture: Concepts, Comparisons, and the Treatment of Interest Rates

"The capital time series is one that will really drive a purist mad."

Robert Solow (1957, p. 314)

An accurate measure of the annual flow of capital inputs is valuable for policy makers and researchers who are interested in production and productivity. However, estimates of capital stocks and service flows are difficult to calculate and vulnerable to significant measurement errors because of data limitations and the myriad of assumptions required. Estimates of the flow of capital services are especially sensitive to underlying assumptions. Information about the implications of the alternatives provides a basis for making better-informed choices about the appropriate approaches and assumptions to apply when measuring capital stocks and flows.

This article begins with a review of methods used commonly to measure capital stocks and service flows, making explicit a number of important assumptions required to construct such measures. Next, we examine and compare the measures of capital inputs in U.S. agriculture from two contemporary, state-specific panel data sets. We compare the methods used to construct the capital series, and we reveal and discuss differences in data sources, the types of data used to construct the capital measures, and the resulting estimates. We also outline some assumptions about depreciation, service lives, interest rates, aggregation methods, and the scope of goods included in each of the capital series for each data set. Finally, we examine and illustrate the extent to which certain choices made regarding data and measurement methods have implications for measures of and findings about the productivity of agricultural capital.

Both sets of estimates examined here are based on the use of modern index number procedures and appropriate economic theory. Even so, our examination of the estimates of capital service flows reveals dramatic and statistically significant differences between the two data sets in the majority of the 48 contiguous states. These results demonstrate how seemingly innocuous choices about methods can have significant consequences for measures of capital service flows, resulting in differences that are likely to have substantial implications for findings from studies that treat the measures simply as data.

In particular, we find that measures of capital services are sensitive to the treatment of interest rates. The use of a market interest rate that varies substantially from year to year imparts volatility into measures of capital services that is unlikely to reflect changes in the actual use of those services. A common alternative is to use a fixed interest rate. In this article we show that different treatments of interest rates significantly influence the estimated flow of capital services in U.S. agriculture. The differences matter for studies that use the measures of capital to describe changes in agricultural input use, to estimate productivity, or as data in models of production.[1]

In his Waugh lecture to the American Agricultural Economics Association, Bruce Gardner (1992) discussed the importance of both the activity of creating data and of the point that data users should know how the data they use were created.

> "Agricultural economists and other social scientists tend to take data as facts. . . . The problem is the data are not facts. Facts are what is really there. Data are

quantitative representation of facts, which statistical workers and economists concoct." (Gardner 1992, p. 1074)

"I call the study of how primary statistical information is made into economic data "factology." The neglect of factology risks scientific ruin." (p. 1067)

Gardner drew specific attention to the measurement of agricultural inputs (especially capital), outputs, and productivity as instances where substantial effort and judgment goes into the creation of the "data," such that the data themselves are very much transformed from the raw material used to make them, and consequently areas where factology matters more than most. Our findings reinforce Gardner's point that it is incumbent on researchers who use "data" on capital from any source to know how the measures were made and what is implied for the measures and estimates based on them.

Calculating Indexes of Capital Input

The measurement of capital inputs is problematic for two general reasons. First, capital is purchased in one time period but the amount of the initial investment used in each subsequent time period is not directly observable. Assumptions about physical depreciation, obsolescence, replacement, and durability 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. Second, and especially in agriculture, the consumer of capital services is also often the supplier, such that the entire transaction occurs within the internal accounts of the economic unit making the investment, and is not observed by the econometrician (Griliches and Jorgenson 1966). Consequently, scant data are available on rental rates and the ex-post usage of most capital assets in U.S. agriculture. In addition, the heterogeneity of capital on farms—which includes assets of different types, different service flow profiles, and different vintages—further compounds the problem of forming estimates of the aggregate stock of capital and the quantity of capital services flowing annually into U.S. agriculture.[2]

A measure of the stock of capital can be constructed either (a) directly, from current data on the stock of capital goods, measured in physical units, or (b) indirectly, from a long time series of data on investment in capital goods. The first approach, based on counts of purchased or in-place assets, is called the physical inventory method; it is often infeasible because of limitations of data and other resources. The second approach, based on investment data, is called the perpetual inventory method, and is used more often.

The perpetual inventory method is commonly used to estimate a stock of capital each period using a time series on investment expressed in real dollars, *I*. Denoting the service life of an asset, *L*, and the annual rate of capital deterioration, 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 the moving sum of the depreciated value of current and past investments truncated at the assumed service life of the asset. In this manner, annual estimates of the stock of capital for each class can be developed.

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

$$\rho_t = f(P_t, r_t, \delta) \qquad (2)$$

The estimates of rental rates serve as weights in the calculation of a quantity index of capital services. These weights are intended to represent the relative marginal products of the different classes of capital. Many different functional forms have been used to compute rental rates. Coen (1975) generalized the rental rate expression to incorporate a range of depreciation patterns. The simplest form for the rental rate calculation assumes a constant interest rate and a constant geometric rate of depreciation.

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

The first term in this expression, $P_t r$, represents the opportunity cost of the invested funds. The second term, $P_t \delta$, represents the cost of physical wear and tear, and any other sources of economic depreciation of the asset as it ages.

The rate of "depreciation" in equation (3) may differ from the rate of "deterioration" in equation (1) if other forms of economic depreciation are important. In practice, both in general and specifically in the work reported in this article, the two concepts are treated as though they are equivalent such that the rate of economic depreciation used in equations for rental rates is identical to the rate of deterioration used in equations for capital stocks.

Assuming $i = 1, 2, \ldots, N$ capital classes, annual time series of the rental rate can be combined with annual time series of the stock for each class of capital (which serves as a proxy for the latent annual service flows under the assumption of proportional service flows) 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 in year t, qk_t for $i = 1, \ldots, N$ classes of capital is computed using:

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

where $\rho_{i,t}$ is the rental rate of capital class i in period t, and $K_{i,t}$ is the stock of capital of class i in period t. Typically the aggregate rental rate is then calculated as an implicit (nominal) 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

State-Specific Capital Measures in U.S. Agriculture

The rest of this article draws on the work of two teams of economists who have compiled state-level measures of inputs, outputs, and productivity in U.S agriculture. In the 1980s a group of researchers at the University of Minnesota led by Philip Pardey and Barbara Craig began compiling production accounts data at the state level in U.S. agriculture. Craig and Pardey (1996a) used state-specific data on prices and quantities to construct Tornqvist-Theil indexes of outputs, inputs, and productivity for the 48-contiguous states for 1949–1991. They included 54 commodities in their output index, as well as 11 classes of purchased inputs, 32 classes of labor, 12 classes of capital, and three classes of land in their input indexes. Subsequently, Acquaye, Alston, and Pardey (2003) performed additional quality adjustments to the data and calculated Fisher Ideal indexes of inputs, outputs, and productivity. Finally, Andersen (2005) further revised and updated the aforementioned production accounts to the year 2002. The database now includes 74 categories of outputs and 58 categories of inputs. The indexes, some of the underlying production data, and an extensive documentation of data sources and specific measurement issues are available through the International Science and Technology Practice and Policy Center (InSTePP) at the University of Minnesota.[3] This data set is referred to here as the InSTePP series.

Beginning in the 1990s, a group of researchers at the United States Department of Agriculture's Economic Research Service (USDA-ERS) also began constructing state-level production accounts data. Eldon Ball took the lead in developing the USDA's state-level production data.[4] Many of the details about these data can be found in Ball, Butault, and Nehring (2001). They constructed Fisher Ideal indexes of inputs, outputs, and productivity for the 48 contiguous states for the period 1960–1996. These data—from here on referred to as the USDA series—were recently updated to 2004 (USDA 2009). Estimates of the stock of each asset in both the InSTePP and USDA series are state-specific.

A primary difference between the USDA series and the InSTePP series is that the USDA used the perpetual inventory method to calculate the capital stocks whereas InSTePP 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 while the InSTePP stocks are measured in physical units. The USDA and InSTePP estimates of stocks also differ in their treatment of depreciation and the retirement of capital assets, as well as in the sources and categories 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 estimates of capital stocks using the perpetual inventory method. National data on investment were partitioned among states using state-specific data from the Census of Agriculture.[5] InSTePP used a variety of data sources including both publicly available and unpublished private data to estimate capital stocks in physical units using a combination of inventory data and investment data. The main data sources for the InSTePP stock measures are state-specific observations from the National Agricultural Statistics Service (NASS) Census of Agriculture, the USDA–ERS, and unpublished data on machinery sales for each state from the Association of Equipment Manufacturers.[6] The machinery sales data allowed InSTePP to explicitly incorporate state-specific vintage and size (i.e., quality or compositional) effects in their stock estimates. Both groups of researchers used national asset price deflators from the BLS.[7] The InSTePP researchers used the BLS Producer Price Index (PPI) for "Farm Machinery and Equipment Manufacturing."[8]

The USDA method of calculating stocks began with national data on investment. The perpetual inventory method was used to construct estimates of national capital stocks that were subsequently partitioned among states using additional state data from the Census of Agriculture: a 'top-down' approach to constructing the state-level estimates that is consistent with national income accounting in other sectors of the economy. In contrast, InSTePP started with state-specific data on physical inventories and physical counts of different assets to construct their state (and ultimately national) stock estimates: a 'bottom-up' approach. The appropriate choice of method depends on the purpose for which the estimates are being constructed but it is also driven, at least in part, by the availability of data. In turn, each method carries with it implications for the choice and use of data, and differences in the resulting measures of state-specific capital stocks and service flows.[9]

The InSTePP researchers calculated values for twelve separate classes of capital with asset-specific estimates of stocks and rental rates, and the USDA researchers calculated values for six classes of capital with asset-specific estimates of stocks and rental rates. For purposes of comparison, we classified these capital classes into three main categories: machinery; inventories and biological capital; and service structures. The InSTePP capital measure has a more disaggregated basis, for example, including five separate classes of biological capital, whereas the USDA measure includes all livestock and crop inventories in a single class. Furthermore, the InSTePP series treats mowers, combines, and pickers/balers as separate types of machinery, whereas the USDA series includes these in a single category labeled "other machinery." For these reasons, the composition of the assets included differs substantially between the two capital aggregates.

USDA researchers assumed a hyperbolic depreciation pattern for capital assets, along with the assumption of an average service life and a distribution of asset retirement around the average that follows the normal distribution. This combination results in a pattern of depreciation with an inflection point, concave in the early years of the asset and convex in the later years, which implies an increasing rate and then a decreasing rate of depreciation over an asset's life (Ball 2010). In contrast, the InSTePP researchers assumed a geometric depreciation pattern for durable assets, which implies that assets deteriorate rapidly in the early years of life and more slowly in later years (a convex pattern).[10] Although the choice of depreciation pattern differs between the InSTePP and USDA measures, each of the two methods used to depreciate the capital stocks has been widely used in the literature on the measurement of capital. The different assumptions concerning the depreciation of assets imply differences in the estimates of stocks and rental rates. However, it is difficult to determine precisely how much this aspect contributed to the observed differences in the InSTePP and USDA indexes of capital input given the numerous other sources of differences between these measures, particularly the treatment of interest rates, which is the focus of the empirical work in this article.

The age of retirement of assets also differs significantly between the two data sets. In the case of a geometric decline in efficiency, it is typically assumed that an asset is retired when its productive efficiency falls below a threshold. The threshold and the assumed constant rate of depreciation, δ, jointly determine the service life of the asset. For example, the InSTePP researchers set the threshold at 10 percent, and calculated service lives, *L*, using the expression, $(1-\delta)^{L} = 0.10$. The USDA used estimates of service lives from a 2003 Bureau of Economic Analysis (BEA) publication titled, *Fixed Assets and Consumer Durable Goods, 1925–97*. The USDA estimates of service lives are shorter than the InSTePP estimates for all asset classes. In general, the choice of service lives can have a substantial impact on the resulting estimates of stocks and rental rates. While we did not test the sensitivity of the capital measures to changes in service lives, this is another important difference in the construction of the InSTePP and USDA capital series and another potential source of discrepancy between the measures.

The rental rate of capital is typically modeled as a function of the price of a new unit of capital, the real interest rate, the rate of depreciation, and the service life of the asset. The simplest form for the rental rate calculation assumes a constant geometric rate of depreciation, a constant interest rate, and, implicitly, an infinite service life: i.e.,

$\rho_t = P_t(r + \delta)$.[11] In constructing the quantity indexes of capital services, 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.

Any errors in calculating interest rates will affect the rental rates, $\rho_{i,t}$, in equation (4), and thus the index of the quantity of capital services. If all assets are growing at the same rate, differences among the individual asset-specific rental rates do not matter in that the rate of change in the index of the quantity of capital services is unaffected by the choice of interest rate. However, when the different asset classes (with different service lives) included in the capital aggregate are growing at different rates, the choice of a variable or constant interest rate affects the quantity index in a systematic way. Specifically, assets with relatively longer (shorter) service lives are given relatively more weight in the indexing procedure when interest rates are increasing (decreasing). This is because a variable interest rate affects the rental rates of the different assets disproportionately over time.[12] As the relative rental rates of different assets change over time because of changes in interest rates, the index of the quantity of capital services changes as well. This is true for any chained index, such as a discrete approximation to a Divisia index, like a chained Fisher index.

Recall that the rental rates serve as weights in the indexing procedure and are intended to represent the relative marginal product of each asset. Should these relative marginal products change over time because of changes in interest rates, or should they only change to reflect physical changes in the relative marginal products of the individual assets? We think it is advisable to use a fixed interest rate in the calculation of asset rental rates and the quantity of capital services. Otherwise, changes in interest rates can translate erroneously into changes in the estimated quantity of capital services that flow from a given stock of capital.[13] Obviously, differences in the treatment of interest rates can (and do) result in different estimates of rental rates and thus different weights in the final step of the indexing procedure. At issue is the size of the influence of these assumptions on the resulting measures.

Comparisons of the Capital Series

In this section we examine the empirical consequences of differences between the baseline InSTePP series-and the USDA series. In the section to follow we provide more general insights into the implications of alternative treatments of interest rates in measures of capital use. In the USDA versus InSTePP comparisons we assess differences in both the estimated quantity of capital services and the real value of those services. The value of capital services can be calculated as the rental rate of capital multiplied by the corresponding flow of capital services each period.

To simplify state-by-state comparisons, in some cases we standardized the InSTePP and USDA indexes to a base period of 1960. Divisia indexes are invariant to the choice of base period; however, differences in the specifics of the data construction procedures should be kept in mind when examining differences in the resulting estimates. In most of the comparisons that follow, a subset of the InSTePP and USDA data sets is used, representing the years in which the two data sets overlap.[14]

Indexes of the quantity of capital services for each of the 48 contiguous U.S. states are plotted in Figure 1. A visual inspection reveals that the InSTePP capital series is substantially different from the USDA series in the majority of states. Using statistical tests we rejected the hypothesis of equality of the means of the state-specific capital series in 30 of the 48 states.[15] We also performed *F*-tests of the equality of the standard deviations for each state and we rejected the hypothesis of the equality of the variances in 39 of the 48 states. Not only are the annual averages and variances of the state-specific measures mostly different, the InSTePP measures of capital services indicate far more state-to-state variation in the overall trend of each capital series compared with the USDA measures. A common pattern is apparent for most states in the USDA data: specifically an upward trend before the early 1980s and a downward trend thereafter. This suggests that the state trends in the USDA series are relatively heavily influenced by the national effects they have in common by dint of their construction rather than individual state-specific effects.

[Figure 1. State-specific indexes of the quantity of capital service flows, 1960 = 100]

National estimates of the real value of services (1949-99) from tractors and trucks, other machinery, service structures, and aggregate physical capital from each of the data sets are shown in Figure 2.[16] The four sets of plots in Figure 2 reveal that for each of these capital classes the USDA and InSTePP value series diverge in the 1970s and early 1980s and then re-converge in the later 1980s and 1990s. The USDA and InSTePP estimates for the value of truck and tractor services follow somewhat similar paths over most of the sample, however even the paths of these series diverge for most of the 1980s.

[Figure 2. The real value of capital services in U.S. agriculture, 1949-99]

In Figure 2, each of the USDA value series increases markedly from around 1975, peaks around 1982, and then declines sharply. This pattern is consistent with movements in real interest rates during this period, suggesting that it reflects the use of variable market interest rates in the calculation of capital services. Figure 2 reveals that the two alternative sets of measures imply very different findings about the patterns of capital use in U.S. agriculture, with very different implications for understanding what happened and when, for findings from models of agricultural production, and for agricultural policy that is based on such measures of agricultural capital and productive performance.

Growth Rates

The entries in Table 1 are average annual rates of growth in the capital service flow estimates of the USDA versus InSTePP series for selected states and periods. The various state-specific USDA estimates grew at a comparatively rapid rate during the 1960s and 1970s followed by a rapid contraction in the estimated use of capital services thereafter; a pattern that carries over to the 48-state average at the bottom of Table 1. For the entire sample period 1960-2002, the USDA capital series declined at an average rate of 0.39 percent per year.

[Table 1. Growth Rates of the USDA and InSTePP Indexes of Capital Services]

The rate and pattern of change in the InSTePP series vary more markedly among the states and imply quite different findings in terms of the 48-state average compared with the USDA series (Table 1). The large bubble in capital services evident in the USDA series is more muted in the InSTePP estimates, indicating much more modest growth in capital services during the 1970s, and a less-dramatic decline in services flows during the 1980s. According to the InSTePP estimates, during the period 1960–2002, the use of capital services contracted at an average rate of 0.27 percent per year when averaged across all 48 states. This overall average rate is, similar to the overall average rate of contraction in the USDA series, albeit with substantial differences the underlying patterns among states and across different sub-periods.

The Treatment of Interest Rates in Computing Capital Services

Some of the differences between the InSTePP and USDA capital series are attributable to the fact that they are based on different treatments of interest rates. In this section we first review some in-principle arguments regarding the alternatives. Then we present some evidence of the effects of the treatment of interest rates alone, holding other aspects constant, using the InSTePP data.

Fixed vs Variable Rates in Principle

What does the prior economic literature have to say about the choice of interest rates when estimating aggregate flows of capital services? Harper, Berndt, and Wood (1989) surveyed some relevant literature on measuring capital inputs, and examined the sensitivity of asset rental rates to the choice of interest rates. In principle, the relevant expected rate of return on capital investment can be assumed to be an exogenous rate or it can be calculated endogenously as an internal rate of return. If an exogenous rate is used, it could be a fixed rate or it could be represented using a market rate such as the yield on a class of corporate bonds.[17] The internal rate of return approach relies on property income data from the National Income Product Accounts (NIPA) and was used by Jorgenson and Siebert (1968 a, b), Christensen and Jorgenson (1969), and Fraumeni and Jorgenson (1980). The internal rate of return approach has two important shortcomings. First, it represents an 'ex-post' or realized rate of return, whereas an 'ex-ante' or expected rate of return is preferable when calculating capital services. Second, it can result in negative estimates of rates of return. Indeed, for this reason, the Bureau of Labor Statistics (BLS) uses a constant real rate of return equal to 3.5 percent when constructing measures of capital services and MFP for the agricultural sector, even though it uses the internal rate of return approach when estimating capital use for most sectors of the economy.[18]

Economic theory remains inconclusive regarding the appropriate choice of method for incorporating interest rates into measures of capital services. Diewert (1980, p. 477) wrote: "As usual, neither alternative [endogenous or exogenous] appears to be correct from a theoretical a priori point of view; so, again, reasonable analysts could differ on which [interest rate] to use in order to construct a capital aggregate." It is up to the researcher to determine which measure is best for the given situation, and in the absence of clear guidance from theory regarding the appropriate treatment of interest rates, other practical considerations are relevant. One such consideration is the implications for aggregation procedures (i.e., index number formulae). As raised by Denison (1969) in response to research by Griliches and Jorgenson (1967), the treatment of interest rates can affect estimates of asset rental prices and thus the relative weights used in constructing a chained index of aggregate capital services. Denison showed that changes in asset-specific rental prices will result in changes in the relative cost shares of different assets, and thus in the estimated quantity of capital services.

Stepping back to reflect on the capital use and purchase decisions that typify U.S. agriculture, the relevant real interest rate is likely to be an important determinant of the decision to own or lease machinery or invest in other forms of agricultural capital. As Pardey et al. (2010) make explicit, the price of a capital asset (or its annual rental rate) is typically expressed as the present value of the real rentals (or user costs) that the asset is expected to earn during its lifetime. In forming these forward-looking estimates of expected present values, fixed or variable future interest rates can be used, but in practice capital ownership decisions are likely to be based on some expected average annual rate over the future life of the asset. Ex ante, expected long-term real interest rates may be relatively insensitive to year-to-year fluctuations in observed rates.

Moreover, once an asset has been purchased (or rented) transitory annual changes in real interest rates are likely to have less if any influence on decisions regarding the use of agricultural capital, especially for specialized capital that does not have alternative uses outside agriculture or is physically fixed. Moreover, many agricultural production systems are inherently multi-year because of the nature of the biological production processes combined with durable fixed factors, and with limited flexibility in the short run. Consequently, in many cases decisions about agricultural production and capital utilization are relatively insensitive to short-run movements in prices of inputs and outputs, in some cases even when those price movements are fully anticipated (Andersen, Alston and Pardey 2007).

Then there is the problem of expectations. Even if capital utilization decisions are responsive to anticipated changes in real interest rates in the current year, we do not observe farmers' expectations. Year-to-year changes in observed, ex post, real interest rates—computed as the difference between a prevailing nominal interest rate and the ex post rate of growth of a general price index such as the GDP deflator—will reflect unanticipated changes in the macro-economy.[19] A moving average of past ex post rates may be a suitable proxy for the unobserved expected real interest rate; however, even a smoothed interest rate series, such as a moving average of rates, can impart large interest rate effects into the index of the quantity of capital services, especially given substantial differences in the lives of various asset classes in a typical aggregate measure of U.S. agricultural capital.

Thus, given the multi-year nature of capital investment and utilization decisions and the role of uncertainty and expectations, when estimating annual changes in the quantity and use (or service flow) of capital on U.S. farms, we conclude it is more reasonable to use a fixed rate of interest rather than a rate that varies, perhaps sharply, from year to year in response to the general business cycle or other short-term macroeconomic events. Hence, to estimate asset-specific rental rates the baseline InSTePP series uses a fixed annual real interest rate of 4 percent and a constant (asset-class-specific) annual rate of depreciation.[20] In contrast, the USDA series uses a variable annual real interest rate (i.e., a rate that varies from year to year based on movements in nominal interest rates and inflation), and a rate of depreciation that varies with the age of the asset. The market interest rate used by the USDA researchers was the annual yield on Moody's BAA corporate bonds, minus the rate of inflation as measured by the rate of growth of the implicit price deflator for Gross Domestic Product—the GDP deflator.[21]

Fixed vs Variable Rates in Practice

The USDA estimates of the value of capital services in the 1980s are quite volatile, with a similar general pattern among the states—and we suspect they are so because the USDA used the same annually varying (national) market interest rate to calculate rental rates for each class of capital in each state. We used the USDA approach in conjunction with publicly available data to construct a comparable measure of real variable interest rates to examine the possibility that the use of a variable interest rate is the source of the apparent bubble in the USDA capital input series during the 1970s and 1980s. Specifically, we recalculated the InSTePP indexes of the quantity of capital services using our measure of the variable market interest rate, then compared the resulting variable interest rate version of the InSTePP indexes with the fixed rate version that we refer to as the baseline InSTePP series. Any differences between the two InSTePP series are solely attributable to differences in the treatment of interest rates.

To statistically compare these two capital series we first formed a ratio of the indexes; the variable interest rate version divided by the constant interest rate version. State-specific and national values of these ratios (all normalized to a value of 1.0 in 1949) are provided in Table 2 for the years 1949, 1974, 1984, and 2002. The years 1949 and 2002 are the endpoints of the series, and 1974 and 1984 were chosen because they represent sample years with exceptionally low and high estimates of the real interest rate: specifically 0.85 percent and 10.5 percent respectively. The entries in the columns in the table headed '*p*-values' are the probability values associated with state-specific *t*-tests that the annual average of the ratios is equal to one for the period 1949-2002. Based on these *p*-values, we reject the null hypothesis that the annual average of the ratios is equal to one in 47 out of 48 states at the 1 percent level of significance, as well as the nation as a whole, indicating the pervasive influence of the treatment of interest rates.[22] Given the myriad assumptions that are required to construct measures of capital services related to the depreciation and service lives of assets, as well as the composition of assets to include, the types of data to include, and the appropriate indexing procedure, it is notable that the choice of interest rates is so critical.

[Table 2. Ratios of the Variable to the Fixed Interest Rate Indexes of Quantity of Capital]

The different treatment of interest rates results in a 13 percent difference between the two series in the estimated national quantity of capital services in 1984, and these differences persist such that, compared with the fixed rate method, the variable rate method implies 8 percent more capital was used in 2002. Each state exhibits a similar pattern, whereby the two measures begin to diverge dramatically in the early 1980s, when interest rates took off, and measurable differences persist thereafter. Figure 3 shows the InSTePP indexes of the quantity of capital services under the assumptions of fixed or variable market interest rates for selected states and the nation.

[Figure 3. Indexes of the quantity of capital services assuming a variable and constant interest rate]

The difference in the trends of these two capital series, most evident after the early 1980s, is entirely attributable to differences in the treatment of interest rates in calculating capital use. Moreover, the pattern of divergence is intuitively plausible given that on average, interest rates were trending up over time and service structures constituted the fastest growing class of capital inputs in U.S. agriculture over this period.[23] The practical consequence of using a variable interest rate approach is that greater relative weight would be given to the growth in service structures vis-à-vis using a fixed weight approach, causing the variable-rate-based index to increase relative to the fixed-rate-based index after the shock to interest rates in the early 1980s.

Figure 4 plots annual linearized distributions of the state-specific ratios of the variable to the fixed interest rate indexes of the quantity of capital services, with the black dots indicating ratios for individual states. The state-specific ratios were narrowly dispersed prior to the interest rate shock of the early 1980s, but thereafter the state-specific ratios were far less concentrated.

[Figure 4. Ratios of the variable to the fixed interest rate indexes of quantity of capital services (linear distributions of 48 states 1949-2002)]

Implications for Measures of Capital Service Flows and Productivity

To further illustrate the empirical implications of using the InSTePP versus USDA estimates of capital use in U.S. agriculture, we quantified the implied differences in the imputed value of capital service use and the pattern of capital productivity growth in U.S. agriculture during the later decades of the 20th century.

Value of Capital Services

Figure 5 juxtaposes a measure of the real rate of interest for the period 1960-1999 against three alternative measures of the value of capital use in U.S. agriculture: the USDA real value of capital services; the InSTePP real value of capital services calculated assuming a variable market interest rate; and the InSTePP real value of capital services calculated assuming a fixed market rate of 4 percent per year. The measures based on the variable market interest rate closely track the main movements in the market interest rate, demonstrating graphically how the use of a variable market interest rate in the calculation of the capital series has a large, pervasive impact on the estimated aggregate value of capital services.

[Figure 5. The real value of capital services and the real interest rate, 1960-1999]

The USDA and fixed-rate InSTePP estimates of the aggregate national value of capital services are most different during the volatile economic period of the 1980s when market interest rates were abnormally high. In contrast, compared with the fixed-rate version, the variable-rate version of the InSTePP series tracks the USDA series much better during the period from 1980 to 1990 when real interest rates spiked, but less well at the beginning and end of the sample.[24] These comparisons indicate that, while the different treatment of interest rates in the USDA and InSTePP capital series is an important source of the large discrepancies between the final estimates of capital service flows in the databases, other differences in data construction and sources are important as well.

Productivity of Capital

Estimates of the productivity of capital in U.S. agriculture also are sensitive to assumptions about interest rates used in calculating capital service flows. Using both the fixed-rate version and the variable-rate version of the InSTePP series as measures of the quantity of capital used in agriculture, we computed annual state-specific measures of the average productivity of capital for the years 1949–2002. Then we divided the variable-rate measure by the fixed-rate measure. In Figure 6, we plot the resulting annual linearized distributions of the state-specific ratios of productivity of capital formed using a variable versus a fixed rate of interest. Again, the pattern of differences between the productivity indexes is systematic among the states and highly correlated with changes in interest rates over time. Compared with a fixed interest rate measure, a variable interest rate measure of capital use causes a systematic downward bias in measured capital productivity in U.S. agriculture for the period beginning in the late 1970s.

[Figure 6. Ratios of the variable to the fixed interest rate indexes of the productivity of capital (linear distributions of 48 states 1949–2002)]

Table 3 shows the InSTePP and USDA estimates of the productivity of capital in terms of the indexes, as well as the growth rates of the indexes for selected periods (annual averages of 48 states). All of the indexes were set equal to 100 in the base year 1960. The InSTePP and USDA series present markedly different pictures about the level and rate of growth of capital productivity in U.S. agriculture during the last four decades of the 20th century. The capital productivity values in Columns 2 and 3 reinforce the graphical evidence in Figure 6 in terms of changes over time in the relative productivity of capital when variable versus fixed interest rates are used to estimate capital service flows. The USDA series (Column 2) indicates stagnant capital productivity during the 1960s and 1970s, followed by substantial growth in capital productivity during the 1980s and 1990s. In contrast, the fixed rate form of the InSTePP series (Column 3) portrays capital productivity growing at reasonably rapid rates throughout the 1960s, 1970s, and 1980s, with a positive but slower average rate of growth during the 1990s. Columns 5 and 6 in Table 3 highlight the sensitivity of capital productivity trends to assumptions about fixed versus variable interest rates, ceteris paribus.

[Table 3. Productivity of Capital in U.S. Agriculture for Selected Periods (index and percentage change)]

The USDA series (Column 4) suggests that the growth in capital productivity was especially high during the 1980s, growing on average by 4.87 percent per year. This largely reflects a measured and marked decline in the use of capital in U.S. agriculture during this period according to the USDA estimates. The baseline InSTePP series (Column 5) also indicates higher than average rates of growth in capital productivity during the 1980s, but the increases in measured rates of growth are not especially pronounced (compare the 2.14 percent per year estimated growth during the 1960s with the 2.72 percent per year growth of the 1980s). Over the period 1990–2002, both the fixed- and variable-rate InSTePP series show comparatively slow growth in the productivity of capital (0.43 percent per year and 0.29 percent per year, respectively) compared with the USDA measure (2.36 percent per year). All three series show a significant slowdown in the growth of capital productivity (by between 2.0 and 2.5 percentage points per year compared with the 1980s) for the period 1990–2002. As these comparisons indicate, discrepancies associated with the use of variable versus fixed interest rates might have contributed to differences in findings over the extent of the slowdown in multifactor productivity growth since 1990 in studies using the InSTePP series versus the USDA series, (e.g., see Alston, Babcock, and Pardey 2010 and Ball, Wang, and Nehring 2010).

Conclusion

Measuring the annual flow of capital services is a complicated task. It requires decisions about the general approach along with a host of specific assumptions, many of which may significantly influence the resulting measures of capital input. Some of these decisions are driven by the availability of data, and others by the intended purpose for the estimates. In this article we have reviewed common methods used to obtain measures of the annual flow of services from the stock of agricultural capital, and compared estimates from two data sets that measure capital services in U.S agriculture for the 48 contiguous states. Both sets of estimates use modern index number procedures and appropriate economic theory. Even so, the comparison revealed a host of differences between the measures, indicating that the choice of methods used to construct measures of capital input, in conjunction with differences in the underlying data, can have a big influence on the resulting estimates.

We explored various potential sources of differences arising from the numerous and sometimes arbitrary choices made by analysts, and found that the measures are particularly sensitive to the treatment of interest rates, which was shown to be a major source of the very substantial differences in the USDA and InSTePP measures. Furthermore, we presented evidence that the use of a real market interest rate in the calculation of capital services introduces volatility that is not likely to be consistent with the actual services that flow from the stock of capital on farms. These empirical realities, combined with conceptual arguments in favor of using a fixed rate of interest, lead us to conclude in favor of a fixed rate of interest when calculating capital use in U.S. agriculture.

The interest-rate choice influences findings from applications that use the measures as well as the measures of capital service flows themselves. To illustrate this point we evaluated the implications of alternative interest rate treatments for measures of the quantity and value of capital use and the productivity of capital in U.S. agriculture. The choices matter. It is incumbent on researchers to be aware of the choices that underlie the measures that they use as data in studies concerning the structure of agricultural production, and the likely consequences of those choices.

Some types of applications may be more sensitive than others to the types of differences we have illustrated as resulting from the use of the annually variable versus fixed interest rates. For example, we identified 10 recently published studies that utilized the USDA capital data in applications including estimations of capital use (e.g., Ball

2000; Ball et al. 2008), productivity growth (e.g., Ball et al. 1999; Ball et al. 2001b), convergence of productivity growth (e.g., Rezitis 2005; McCunn and Huffman 2000), factor demands (e.g., O'Donnell et al. 1999), environmental effects of production (Morrison-Paul et al. 2002; Ball et al. 2004), and the benefits from public investments in agricultural R&D (e.g., Huffman and Evenson 2006).[25] The results from those studies that focused on input (especially capital) uses may be especially vulnerable to the measures of capital service flows, but the results from all studies are sensitive to data measurement details to some degree. As suggested by Gardner "The bottom line is, for data producers, that full disclosure of procedures and labeling of data series are essential; and, for data users, be careful and investigate the data before using them . . . (1992, p. 1076)." This dictum seems to apply especially well to the data series on agricultural capital use, and to the interpretation of findings based on these data.

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Notes

[1] For example, several recent studies have discussed a potential slowdown in agricultural productivity (e.g., Alston and Pardey 2009: and Alston, Babcock, and Pardey 2010) but our ability to accurately measure productivity and detect a potential slowdown is directly related to our ability to measure inputs like capital services.

[2] OECD (2001) and Diewert (2003) examined the measurement of capital in detail.

[3] These data and their documentation will be posted at www.instepp.umn.edu in Fall 2010. Pardey et al. (2010) provide more complete details for the InSTePP capital series. Additional details about the InSTePP and USDA capital series can be found in Alston et al. (2010).

[4] Huffman and Evenson (1993) also developed a set of state-level input, output and productivity accounts wherein they ". . . estimated the nominal service flow from these [automobiles, trucks, tractors and other equipment] capital items as depreciation plus a fixed percentage (.04) of their current value at replacement cost" (p. 361). In later published work, Huffman and Evenson abandoned this earlier series in favor of the USDA data (e.g., Huffman and Evenson 2006).

[5] The procedure the USDA researchers used to partition the national data among states is not reported in Ball, Butault, and Nehring (2001); nor in the more-recent on-line documentation: http://www.ers.usda.gov/data/agproductivity/methods.htm.

[6] The authors are grateful for assistance provided by John Smylie and the Association of Equipment Manufacturers in making data available. Details of all data sources used to construct the InSTePP series are in Pardey et al. (2010).

[7] See Craig and Pardey (1996b) for a discussion and quantification of agricultural input quality or compositional attributes.

[8] BLS (2009) PPI data are available on line at http://www.bls.gov/data/#prices.

[9] Any statements concerning the construction of the USDA data are the authors' interpretation of the methods based on the published data documentation.

[10] There is little consensus in the literature on the appropriate pattern of deterioration to employ when measuring capital, although a couple of points warrant mention. Part of the disagreement relates to the distinction between the decline in efficiency of an individual asset and the decline in efficiency of the stock of a heterogeneous group of assets. Berndt (1990, p. 155), wrote: "…because of varying vintage composition over time, the average efficiency (deterioration)

function of an entire cohort can be quite different from the individual efficiency functions; while each asset in a stock might, for example, follow the one-hoss-shay form, the cohort as a whole can follow a rather different age-efficiency (deterioration) pattern." Furthermore, Jorgenson (1995, p. 218) argued that the ". . . available empirical evidence supports the use of a geometric decline in efficiency as a useful approximation to replacement requirements and depreciation."

[11] An income tax rate is sometimes included in the rental rate expression as well.

[12] This is true when the interest rate enters the rental rate calculation additively thus affecting the different rental rate estimates disproportionately. If the variable interest rate affects all rental rates proportionally then changes in interest rates do not affect the estimated quantity of capital services. We observe that the USDA estimates of the rental rates for capital services change disproportionately over time because of changes in real interest rates. Thus, an interest rate effect is present in their measures of capital services.

[13] Annual capital use could vary systematically in response to annual changes in interest rates if farmers respond by changing the intensity with which they use their capital assets. However, little if any evidence is available that would suggest that farmers do adjust their utilization of existing capital assets at all based on annual fluctuations in interest rates, let alone as though they were permanent changes. Notably, any changes in real interest rates that affect farmers' decisions to purchase new assets will affect the measures of capital stocks, and thus the estimated flow of capital services via stock effects, not rental rate effects.

[14] The indexes of the quantity of capital service flows overlap for the period 1960–2002; however, we also have national data on the value of capital services for different categories of assets that overlap for the years 1949–1999. Therefore, comparisons of national value data are for the years 1949–1999 where indicated.

[15] We performed two-tailed *t*-tests for equality of the means (annual average 1960–2002) of the two series under the assumption of unequal variances. In 38 of the 48 states we calculated *p*-values of less than 0.05, indicating rejection of the null hypothesis of equal means in these states.

[16] In this example, the 'other machinery' category for the InSTePP series represents the sum of the service flows from combines, pickers/balers, mowers, machine hire, and automobiles. In the USDA series it represents their category of 'other machinery' plus automobiles. Nominal values were deflated using the GDP-IPD (base year 1996).

[17] Conceptually, a fixed rate can be a nominal before-tax rate, as utilized in studies by Hall and Jorgenson (1967), Hall and Jorgenson (1969), and Coen (1975), but the other aspects of the analysis would have to be done in a manner consistent with the use of a nominal interest rate rather than a real rate. A fixed rate could also be a real rate, computed as nominal rate of return minus a nominal capital gains term, commonly assumed to be in the 3–4 percent range.

[18] As noted, the internal rate of return approach relies on property income data. In the case of agriculture, in particular, using such data can result in negative estimates of rates of return. Dean and Harper (1998) provide more details about the BLS capital and productivity measurement procedures.

[19] Moreover, the business cycle factors that influence ex post real interest rates, and consequently eventually capital investments and utilization, might have more-immediate direct impacts on agriculture through associated impacts on prices of other, non-capital inputs and outputs. Hence, we might observe agricultural production responses that are correlated with real interest rates that were in fact capital utilization responses to prices of other inputs and outputs.

[20] The fixed 4 percent rate of interest is slightly higher on average than the inflation-adjusted market rate before 1980 and lower than the market rate thereafter.

[21] Ball, Butault and Nehring (2001) provide a detailed description of the methods used to construct this measure. The USDA researchers used an “ex ante” real interest rate in their calculations. The real interest rate was expressed as a first-order autoregressive process and the predicted values were taken to represent an ex ante real interest rate. To investigate the implications of applying an ARIMA process to smooth the interest rate series, we performed the same smoothing procedure on a real interest rate series that we compiled using the USDA approach, and we determined that this procedure essentially lagged the series by one period, preserving almost all of the annual volatility of the original series.

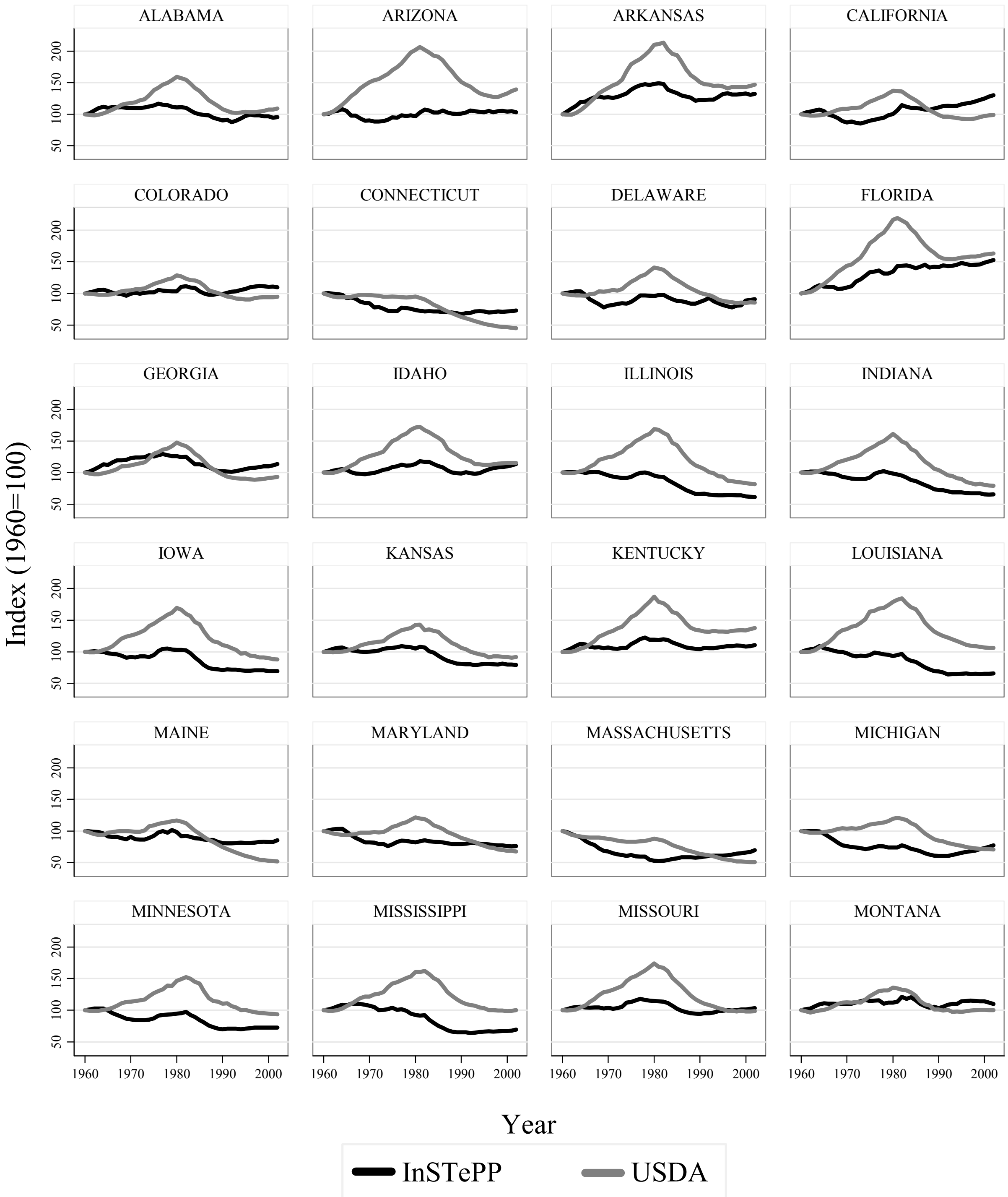
[22] We also performed *t*-tests of the hypothesis that the average of the ratios across states is equal to one in each year. The results indicated rejecting the null hypothesis in all years but 1962 and 1977–1979. In these four years the averages of the ratios across states were not significantly different from one.

[23] In terms of 48-state averages for the period 1949–2002, service structures grew at an average rate of 1.09 percent per year, while machinery grew at 0.31 percent per year, and biological capital declined by 1.15 percent per year. In 2002, service structures constituted 29 percent of the

estimated total quantity of capital used in U.S. agriculture according to the baseline InSTePP series.

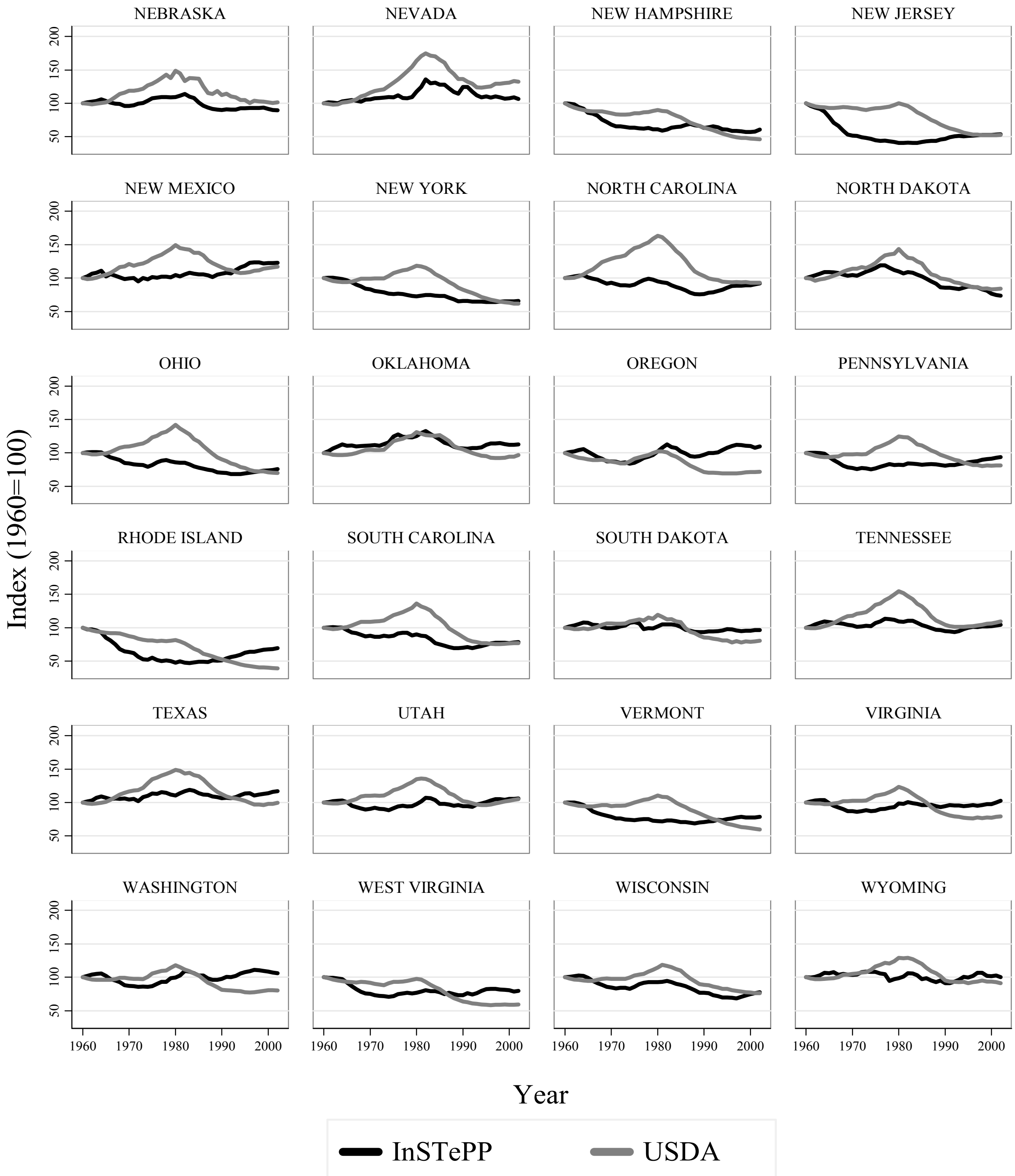
[24] No doubt the divergences among these patterns will be more pronounced in some states than others and compared with the national aggregate, since the national aggregate measures tend to average out some variations.

[25] Other recent studies using the USDA capital data include: Ball, Bureau, Nehring, and Agapi (1997); Ball, Bureau, Butault, and Nehring (2001); Ball, Butault, and Mesonada (2004); Ball, Hallahan, and Nehring (2004); Pope, LaFrance, and Just (2007); and Liu and Shumway (2009).



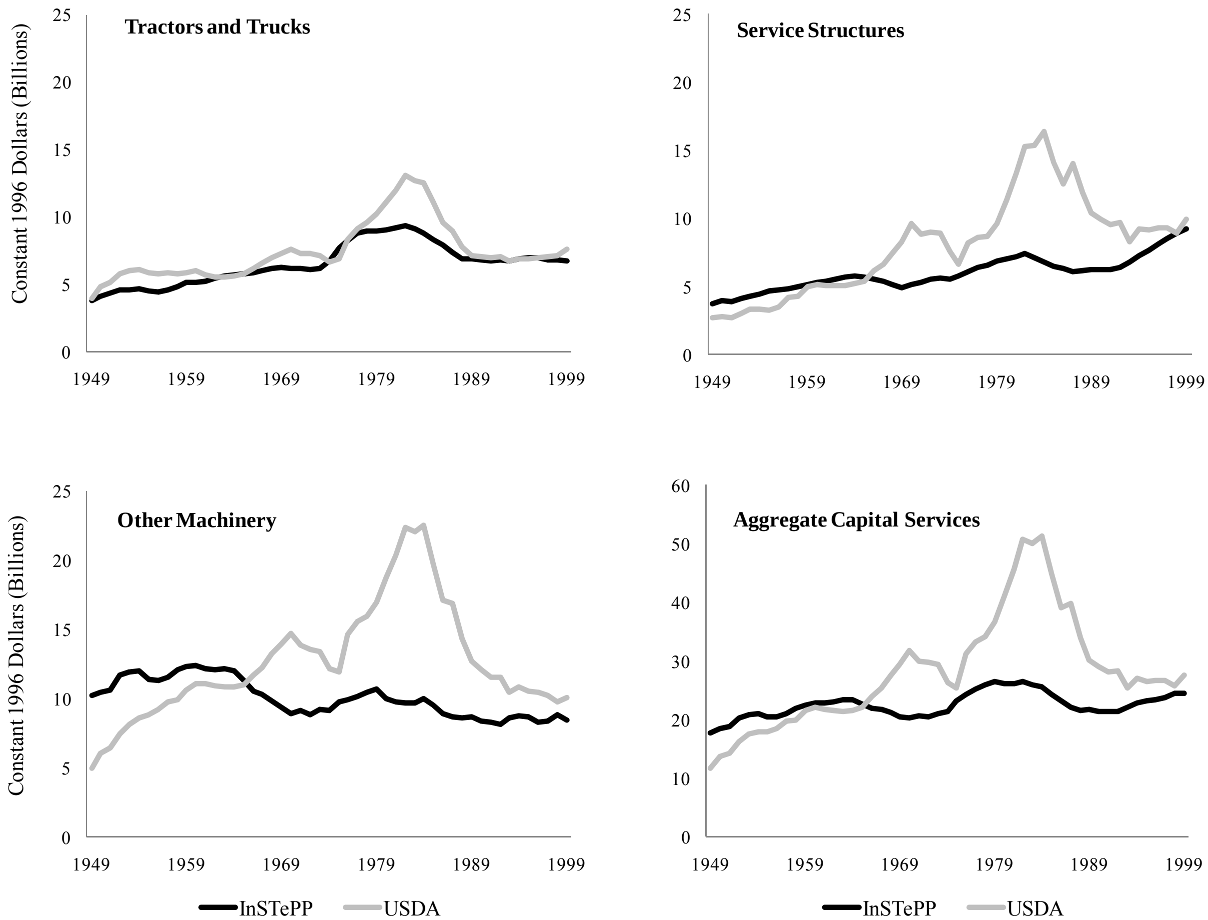
Note: Calculated by authors.

Figure 1. State-specific indexes of the quantity of capital service flows, 1960 = 100



Note: Calculated by authors.

Figure 1. State-specific indexes of the quantity of capital service flows, 1960 = 100 (contd.)



Note: Compiled by authors. All figures deflated using the GDP Implicit Price Deflator (base year 1996). For InSTePP data "Other Machinery" includes autos, combines, mower/conditioners, picker/balers. For USDA "Other Machinery" includes autos and unspecified miscellaneous machinery.

Figure 2. The real value of capital services in U.S. agriculture, 1949-99

Table 1. Growth Rates of the USDA and InSTePP Indexes of Capital Services

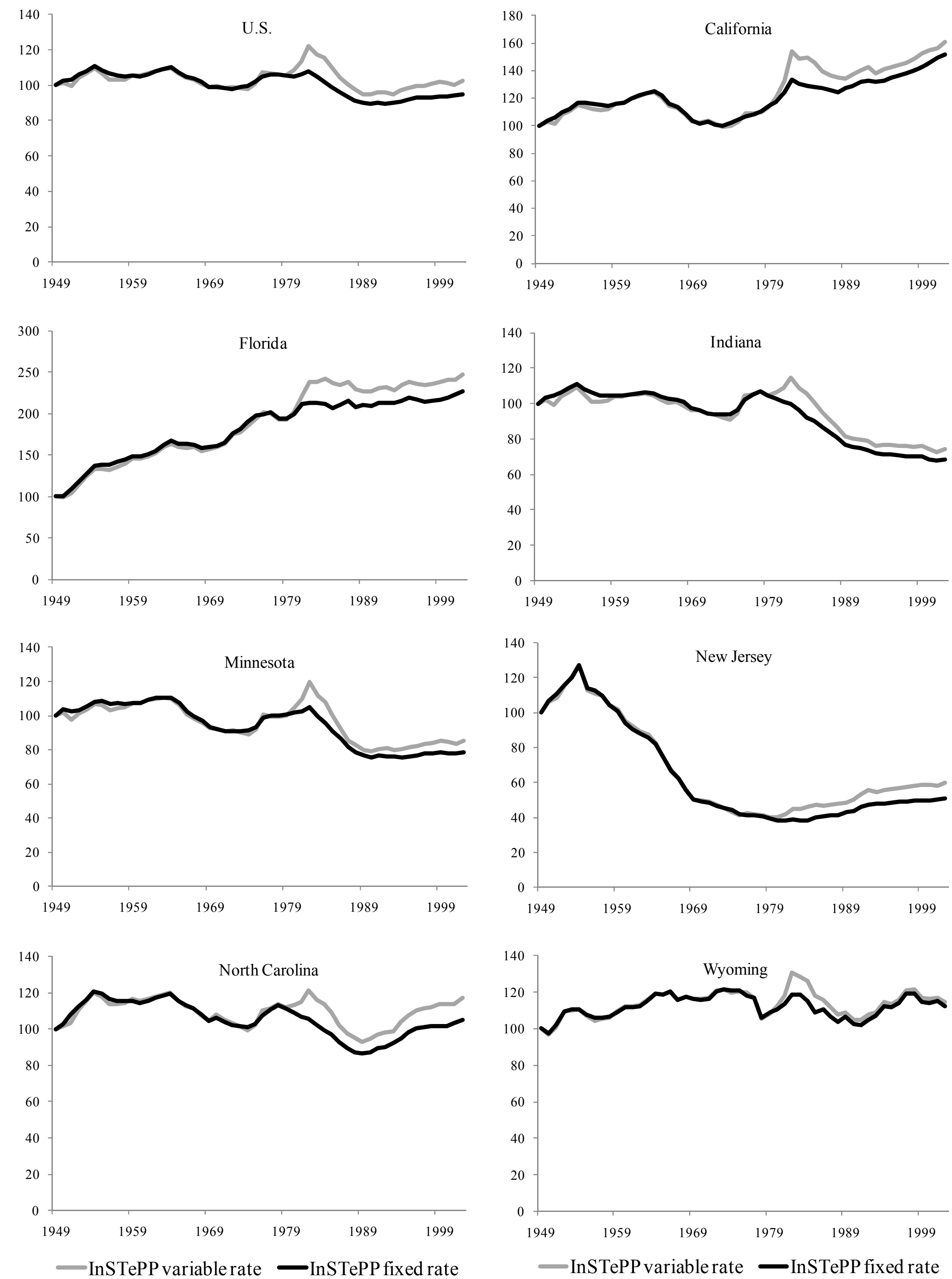
	1960-70	1970-80	1980-90	1990-2002	1960-2002
California			*percent*		
USDA	0.82	2.33	-3.28	0.02	-0.02
InSTePP	-1.38	1.43	0.97	1.36	0.63
Illinois					
USDA	2.20	3.04	-4.38	-2.39	-0.48
InSTePP	-0.40	-0.07	-3.70	-0.59	-1.16
Minnesota					
USDA	1.27	2.54	-2.84	-1.38	-0.16
InSTePP	-1.59	1.02	-3.01	0.33	-0.76
Nebraska					
USDA	1.71	2.27	-2.82	-0.84	0.04
InSTePP	-0.41	1.29	-1.96	-0.03	-0.27
North Dakota					
USDA	1.32	2.29	-3.73	-1.34	-0.41
InSTePP	0.44	0.53	-2.52	-1.24	-0.72
Texas					
USDA	1.52	2.47	-2.83	-1.00	-0.01
InSTePP	0.45	0.55	-0.38	0.80	0.37
Wyoming					
USDA	0.48	2.07	-3.06	-0.35	-0.22
InSTePP	0.35	-0.49	-0.77	0.76	0.01
48-State Average					
USDA	0.96	2.17	-3.48	-1.06	-0.39
InSTePP	-0.91	0.29	-1.18	0.55	-0.27

Note: Author's calculations using the USDA and InSTePP indexes of capital input.

Table 2. Ratios of Variable to Fixed Interest Rate Indexes of Quantity of Capital (variable interest rate divided by constant)

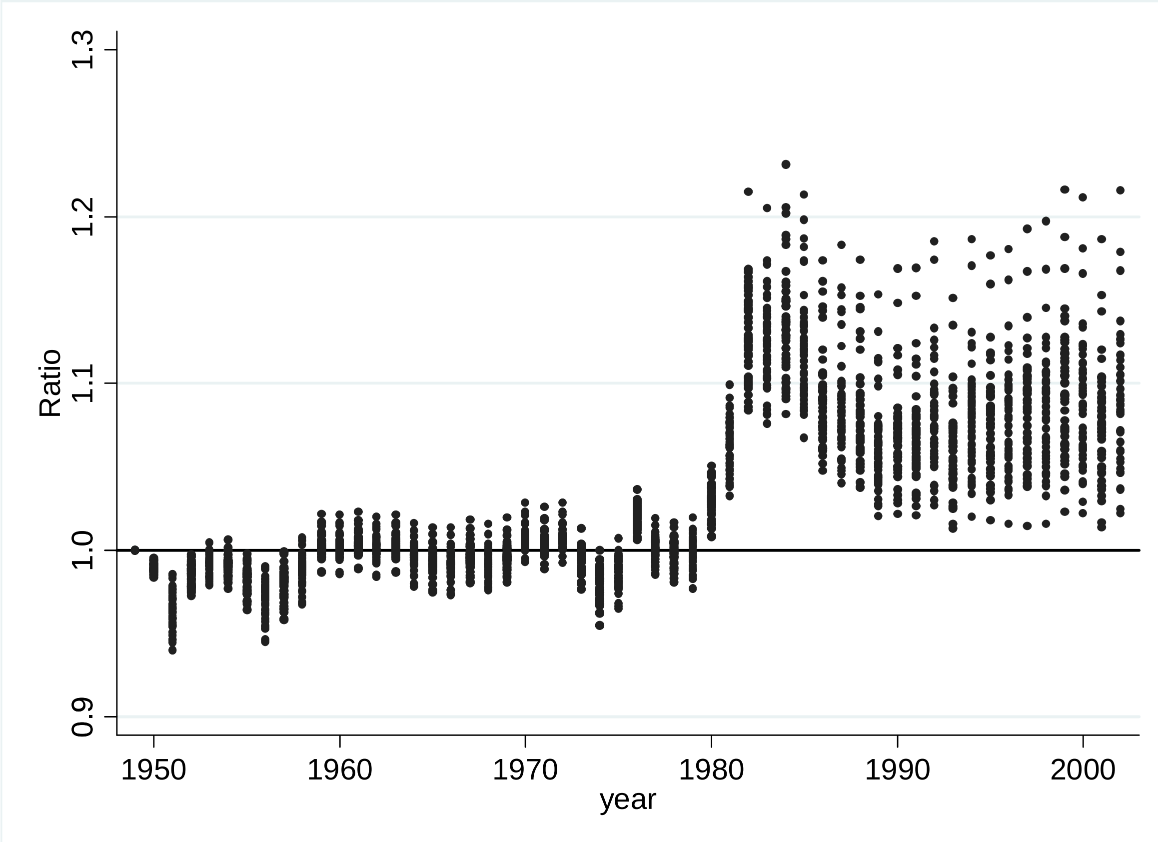
State	1949	1974	1984	2002	*p*-value
		ratios			
Alabama	1.00	0.99	1.12	1.08	*0.000*
Arizona	1.00	0.96	1.14	1.02	*0.055*
Arkansas	1.00	0.99	1.15	1.09	*0.000*
California	1.00	0.98	1.16	1.06	*0.000*
Colorado	1.00	0.99	1.13	1.09	*0.000*
Connecticut	1.00	0.98	1.11	1.13	*0.000*
Delaware	1.00	0.95	1.23	1.13	*0.000*
Florida	1.00	0.97	1.15	1.09	*0.001*
Georgia	1.00	0.98	1.14	1.08	*0.000*
Idaho	1.00	0.98	1.11	1.05	*0.000*
Illinois	1.00	0.98	1.14	1.11	*0.000*
Indiana	1.00	0.97	1.15	1.08	*0.000*
Iowa	1.00	0.98	1.15	1.10	*0.000*
Kansas	1.00	0.99	1.10	1.06	*0.000*
Kentucky	1.00	0.98	1.15	1.10	*0.000*
Louisiana	1.00	0.99	1.11	1.06	*0.000*
Maine	1.00	1.00	1.19	1.14	*0.000*
Maryland	1.00	0.95	1.15	1.11	*0.000*
Massachusetts	1.00	0.97	1.17	1.17	*0.000*
Michigan	1.00	0.97	1.13	1.11	*0.000*
Minnesota	1.00	0.98	1.13	1.09	*0.000*
Mississippi	1.00	0.99	1.09	1.05	*0.000*
Missouri	1.00	0.99	1.11	1.08	*0.000*
Montana	1.00	0.99	1.10	1.07	*0.000*
Nebraska	1.00	0.99	1.12	1.07	*0.000*
Nevada	1.00	0.99	1.15	1.05	*0.000*
New Hampshire	1.00	0.98	1.19	1.13	*0.000*
New Jersey	1.00	0.97	1.20	1.18	*0.000*
New Mexico	1.00	0.99	1.13	1.04	*0.000*
New York	1.00	0.96	1.13	1.11	*0.000*
North Carolina	1.00	0.98	1.15	1.12	*0.000*
North Dakota	1.00	0.98	1.10	1.05	*0.000*
Ohio	1.00	0.97	1.15	1.10	*0.000*
Oklahoma	1.00	0.99	1.08	1.04	*0.000*
Oregon	1.00	0.98	1.16	1.09	*0.000*
Pennsylvania	1.00	0.97	1.14	1.11	*0.000*
Rhode Island	1.00	0.97	1.21	1.22	*0.000*
South Carolina	1.00	0.98	1.14	1.12	*0.000*
South Dakota	1.00	0.99	1.11	1.06	*0.000*
Tennessee	1.00	0.98	1.09	1.07	*0.000*
Texas	1.00	0.99	1.10	1.05	*0.000*
Utah	1.00	0.98	1.10	1.05	*0.000*
Vermont	1.00	0.97	1.12	1.11	*0.000*
Virginia	1.00	0.97	1.18	1.12	*0.000*
Washington	1.00	0.97	1.16	1.09	*0.000*
West Virginia	1.00	0.98	1.13	1.09	*0.000*
Wisconsin	1.00	0.97	1.13	1.07	*0.001*
Wyoming	1.00	0.99	1.09	1.02	*0.000*
US	**1.00**	**0.98**	**1.13**	**1.08**	*0.000*

Note: Author's calculations. Figures represent the ratios of the variable to the fixed interest rate indexes of the quantity of capital services The *p*-values are from *t*-tests of the null hypothesis that the annual average (1949-2002) of each state-specific ratio is equal to one.



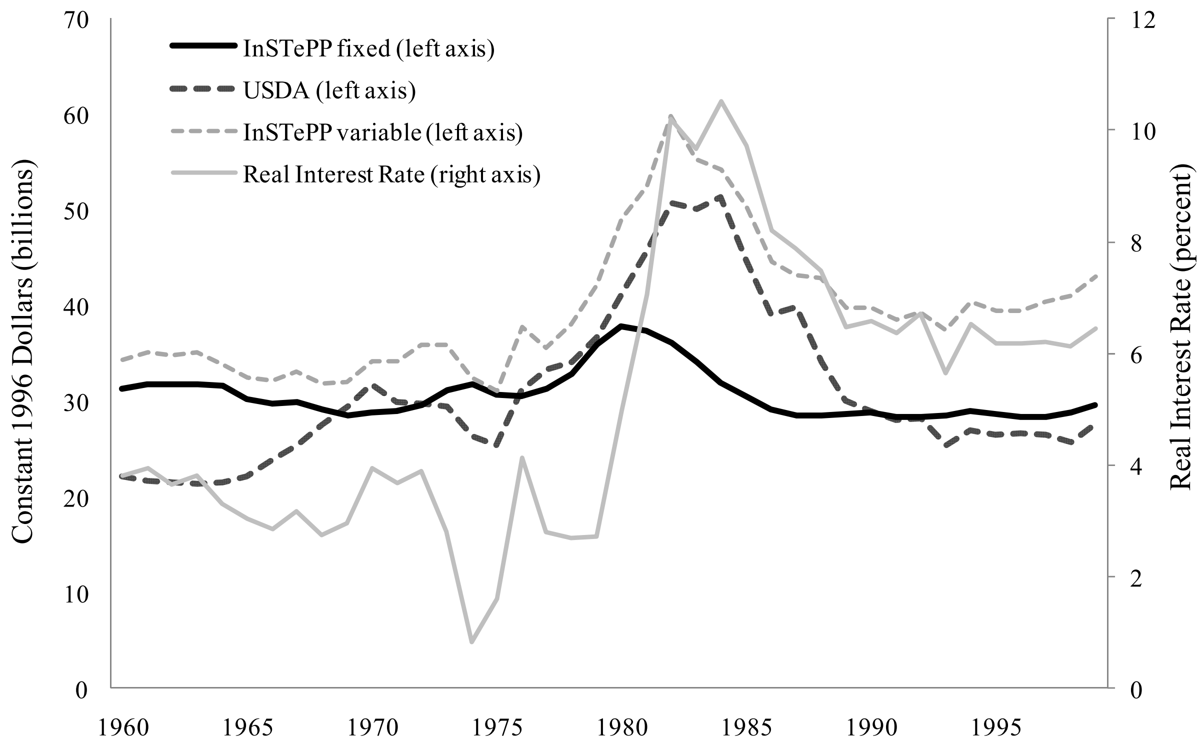
Note: Indexes calculated by the authors using the InSTePP capital data.

Figure 3. Indexes of the quantity of capital services assuming a variable and constant interest rate



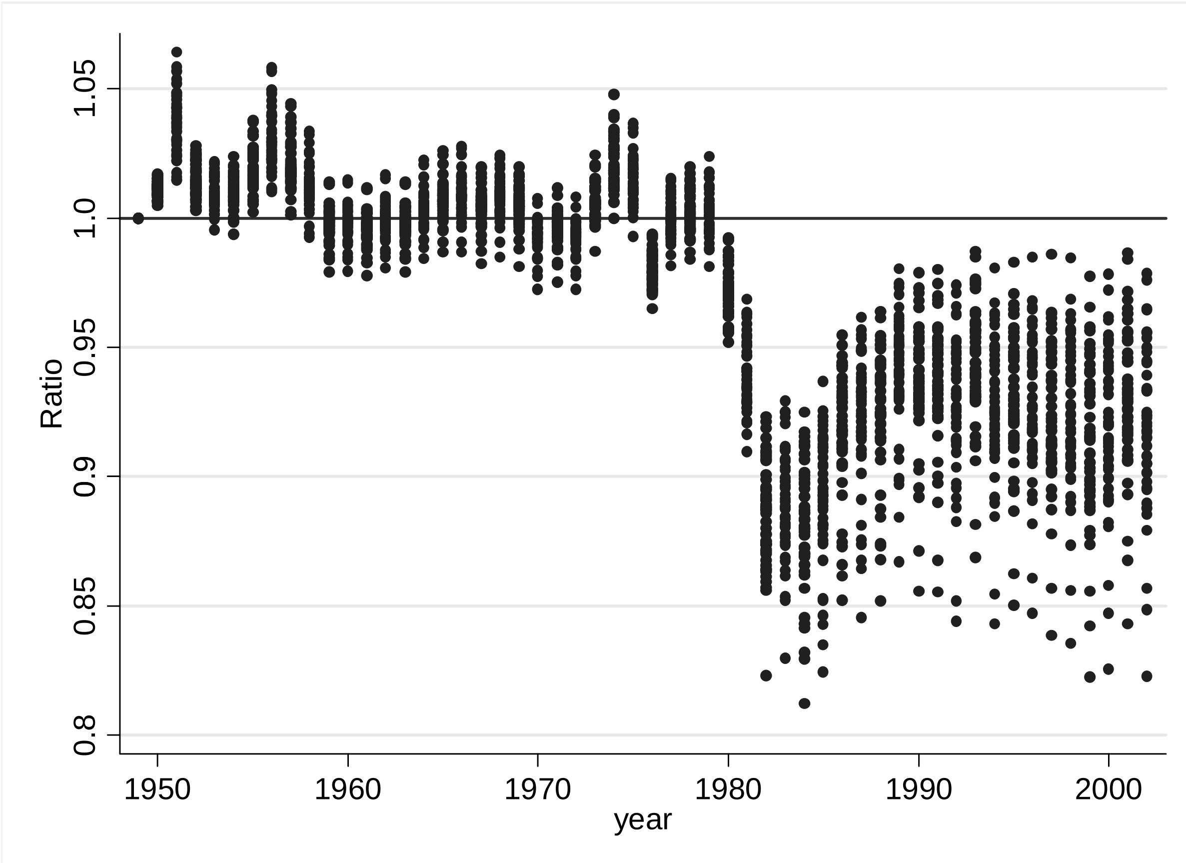
Note: The black dots represent the ratio of variable to fixed interest rate indexes of the quantity of capital services for each of the 48 contiguous states for each year in the sample. The ratios for all states were normalized to equal one in the base year 1949.

Figure 4. Ratios of variable to fixed interest rate indexes of quantity of capital services (linear distributions of 48 states 1949-2002)



Note*:* The real interest rate is the annual yield on Moody's BAA corporate bonds, minus the rate of inflation as measured by the rate of growth of the GDP deflator. The source of annual yields on Moody's BAA corporate bond is the Federal Reserve Bank of St. Louis. The source of the inflation series is the Bureau of Economic Analysis. The USDA value series excludes inventories. The value series are deflated using the GDP-IPD (based equal to 1.0 in 1996).

Figure 5. The real value of capital services and the real interest rate, 1960-1999



Note: The black dots represent the ratio of variable to fixed interest rate indexes of the productivity of capital for each of the 48 contiguous states for each year in the sample. The index of the productivity of capital is the ratio of the index of output to the index of capital input. The ratios for all states were normalized to equal one in the base year 1949.

Figure 6. Ratios of the variable to the fixed interest rate indexes of the productivity of capital (linear distributions of 48 states 1949-2002)

Table 3. Productivity of Capital in U.S. Agriculture for Selected Periods

	Period average index value			Period average growth rates		
		InSTePP			InSTePP	
	(1)	(2)	(3)	(4)	(5)	(6)
Period	USDA	Fixed	Variable	USDA	Fixed	Variable
	1960 = 100			*Percent per year*		
1960-1970	104	109	109	0.05	2.14	2.09
1970-1980	102	134	134	-0.68	1.26	1.05
1980-1990	123	163	150	4.87	2.72	2.33
1990-2002	193	202	187	2.36	0.43	0.29
1960-2002	134	154	147	1.68	1.58	1.39

Note: Author's calculations using the USDA and InSTePP indexes of output and capital services. All figures represent the annual average of 48 states for the given period. The index of the productivity of capital is the ratio of the index of output to the index of capital input. The indexes were set equal to 100 in the base year 1960. The figures represent the annual averages of the indexes and the growth rates of the indexes for the given periods.