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May 2015

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Abstract

The USDA Economic Research Service has emerged as an acknowledged intellectual leader in construction and integration of national and state-level productivity accounts in agriculture. The national and state-level ERS productivity measures are widely referred to and used, and international sectoral comparisons rely on the ERS production accounts for foundation methodology in constructing agricultural productivity accounts in other countries. This leadership role has endured for many decades and accelerated in response to the AAEA-USDA Task Force review of the agricultural productivity accounts (Gardner et al. 1980). It is with that backdrop of vigorous intellectual leadership that an external review committee has examined the data sources, methodology, ongoing research, documentation, and reporting of the ERS agricultural productivity accounts.

**JEL Codes:** O30, D24

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September 4, 2014

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The authors were appointed by the U.S. Department of Agriculture (USDA), Economic Research Service (ERS), as an external committee to review the USDA Agricultural Productivity Accounts produced by the ERS. The appointment followed the Office of Management and Budget’s guidelines for the management of Federal information resources. Richard Shumway served as chair. Other authors are listed alphabetically. We wish to express appreciation for the helpful support of the ERS staff, Rachel Soloveichik, Brian Sliker, Erwin Diewert, Dale Jorgenson, Sean Cahill, Julian Alson, Philip Pardey, and to all others who responded to our invitation for stakeholder input.

The views expressed in this paper are solely those of the authors and not necessarily those of the U.S. Bureau of Economic Analysis or the U.S. Department of Commerce.
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INTRODUCTION

Recent research argues that the preponderance of aggregate postwar economic growth in the U.S. was driven by investments in physical and human capital and the expansion of the labor force, while productivity growth accounted for a relatively small share of GDP growth. At the industry level, two notable exceptions to this aggregate trend were the Computer and electronic products and the Farm sectors. Innovation in the Computer and electronic products sector, exemplified by Moore’s law, has led to the proliferation of Information Technology products and the so-called Information Age. Innovation within the Farm sector has increased abundance, availability, and quality of food products, and limited price increases passed on to consumers. Understanding the sources of economic growth is crucial to economic policy (Jorgenson 2011).

The purpose of this report is to review the methods and estimates of the Agricultural Productivity Accounts developed by the Economic Research Service (ERS) of the United States Department of Agriculture (USDA). These accounts generate the official estimates of productivity in the U.S. farm sector. They include estimates of industry outputs and inputs in current and constant prices, and total factor productivity (TFP), the preferred measure of innovation according to the Advisory Committee on Measuring Innovation in the 21st Century (Schramm et al. 2008). These farm-level industry production accounts are an important contribution to the U.S. statistical system, and agricultural policy is both related to and informed by them.¹

Empirical economic analysis and its conclusions are grounded in issues and concerns about data collection, variable definitions and construction, and concordance between economic concepts and statistics. Economic policy makers and scholars working on the frontiers of economic research have relied heavily on the construction of these agricultural production accounts because of their close integration of statistical concepts and economic theory. These accounts are constructed with the primary purpose of measuring the productivity of the U.S. agricultural sector. ERS has emerged as an international leader in construction and integration of these accounts in agriculture, and the national (covering all 50 states) and state-level estimates for the 48 contiguous states are widely cited as the basis for both policy and research work. The task of assembling the accounts is daunting. To match statistics with theory, assembling the accounts often involves creating data series in cases where the primary statistical base is insufficient. In some series, economic theory provides the mechanism to extrapolate from the survey data to what Gardner (1992b) refers to a “representation of facts” that generates “theory-laden data”.

A principal application of these accounts involves the measurement of agricultural productivity to build a clear picture of how the agricultural economy is performing, how it contributes to the expansion of the U.S. economy, and to identify the primary drivers of the agricultural sector’s growth. In doing so, we can determine to what extent attention should be placed on the mobilization and composition of production factors versus the advances in productivity (Jorgenson 1991). From a user’s point of view, Charles Schultze notes that productivity accounts help to keep policy makers and their economic advisors informed about the current state of the economy. He also asserts that an important avenue through which economic statistics have impact is via researchers who consume the data, conduct economic

¹ The Bureau of Labor Statistics (BLS) produces Private Business Sector multi-factor productivity (MFP) that includes Farms, Private Non-Farm Business MFP, and MFP for Crop and Animal production NAICS 111, and 112 covering 1987-2011 as of July 9, 2014. ERS measures differ in the treatment of intrasectoral purchases and labor composition, they include quality adjustments for tractors, and include data back to 1947. Bureau of Economic Analysis (BEA) and BLS have produced a prototype industry-level production account that covers 1998-2012 and includes a labor composition adjustment.
analyses, and engage with policy advisers on appropriate policy actions and design (Schultze at al., 1991, p 423).

The agricultural accounts at the national and state levels are the subject of a wide range of investigations related to a) how intermediate inputs, labor, land and capital use patterns evolve over time and serve as factor substitutes, b) how these factors are impacted by policy, c) how technical change relates to factor use, and d) how quality adjustments are undertaken to reflect input changes and the evolving productive potential of agricultural production.

The sectoral productivity accounts are often used as a benchmark across sectors within an economy and comparison of the sectors across nations to help explain observed differences in aggregate performance and competitiveness. There is considerable interest in cross-country comparisons that investigate international competitiveness and convergence in agricultural productivity across countries. TFP growth is a standard measure employed for such comparisons. When markets are perfectly competitive and operating in long-run equilibrium, price changes can proxy for cost changes. Under these assumptions and assuming that the quality of output is the same across countries, relative output prices can proxy as a competitiveness measure for purposes of international comparisons. If countries share a common stock of knowledge and access to technologies, and if they face no structural barriers to sharing, then theory suggests that prices should change at the same rate. When we do not see this equivalence in price change, economists tend to look at policy incentives and structural differences to explain why, but the appropriate data is necessary to draw such inferences.

The notion of an aggregate production technology is the starting point for studying productivity and the sources of productivity growth. Its origins date back to Tinbergen (1942) and Solow (1957). With the need for aggregate measures of production factor and outputs, the construction of indices emerges as a necessary starting point. Balk (2008, Chapters 1 and 2) presents a historical overview of the emergence of different indices and their evolution. Jorgenson (1991) presents an extensive overview of the emergence of the approaches to measuring productivity growth with an eye toward decomposing the sources of growth. Considerable efforts are required to bridge the theory with the measurement of production factors from observed data. The challenges of adjusting for quality changes and measuring capital inputs as services are particularly difficult.

There are three key manuals governing construction of internationally comparable productivity accounts. The United Nations System of National Accounts (SNA) is an internationally standard set of recommendations on how to compile measures of economic activity. Its recommendations are expressed in terms of concepts, definitions, classifications, and accounting rules (UN, 2009). The SNA is intended for economic analysis in any country. The Organisation for Co-operation and Economic Development (OECD) Productivity Manual (2001b) serves as a standard reference of the theoretical foundations to productivity measurement, its implementation, and measurement issues. It seeks to harmonize efforts for effective international comparisons at both the aggregate and sectoral levels. The European Union Statistical Office’s (Eurostat) (2000) revised manual for constructing the Economic Accounts for Agriculture and Forestry is consistent with the SNA and addresses several specific needs of the European Union member states for sectoral accounts. Its approach is to break down the agricultural economy into production units and household units whose main source of income is agricultural.

The late 1970s found the commissioning of a joint American Agricultural Economics Association (AAEA)-USDA Task force to undertake a comprehensive review of the methodologies employed in constructing the ERS productivity accounts for U.S. agriculture and the scope these accounts covered. The outcome of this task force was a report by Gardner et al. (1980). The recommendations spanned changes in the areas of conceptual and practical productivity measurement with major recommendations to a) move from partial to total factor productivity measurement, b) address hired, operator and family labor
separately in the labor accounts, c) use the product approach (or specify production activities) regardless of the type of establishment in the agricultural production sector, d) account for input quality changes, and use the Divisia index to aggregate inputs and outputs (Gardner 1980, p. iii). The report also included specific suggestions related to the construction of particular input and output accounts, such as a) using the direct sampling approach to construct labor inputs, b) suggesting procedures to convert the land stock to a service flow, and c) several recommendations regarding machinery and equipment to improve the statistical data, revise the depreciation procedures, and apply the Bureau of Labor Statistics (BLS) machinery price indexes to farm machinery.

The ERS addressed the Task Force’s findings and recommendations head on and made focused efforts to bring the ERS construction of productivity accounts into harmony with state-of-the-art protocols, thus becoming an international leader in the statistical community with respect to productivity measurement. The National Agricultural Statistical Service (NASS) supports the ERS product accounts through the surveys they implement as well as by implementing the Agricultural and Resource Management Survey (ARMS) which is jointly administered with ERS.

Why Undertake Another Review?

With the USDA being a principal Federal Statistical Agency, the Office of Management and Budget (OMB) mandates standards for data quality and procedural and analytic guidelines for implementing policies for the management of Federal Statistical information resources (OMB Memorandum, May 31, 2011). This also entails a regular program of data quality reviews. There is a history of external review of agricultural statistics construction and the surveys that serve as a foundation for these statistical products. In addition to the Agricultural and Applied Economics Association (AAEA)-USDA Task Force report in Gardner et al. (1980), several related reviews have been undertaken in the last three decades:

a) AAEA Statistics Committee review of USDA Farm Sector Financial Indicators, 1989-1991 (Boxley 1989);

b) General Accounting Office review of Farm Costs and Returns Survey 2, 1992 (USGAO 1992);

c) AAEA Task Force on Commodity Costs and Returns, 1998-2000 (Eidman et al. 2000);

d) National Academy of Sciences Panel to review USDA's Agricultural Resource Management Survey, National Research Council, 2006-2007 (National Research Council 2007); and

e) ERS independent panel review of financial accounting methods used to summarize the Agricultural Resource Management Survey (Moss 2012).

In 2013, ERS charged our committee to address issues of methodology in the development of estimates, provide feedback on ongoing research programs to improve methodology and operations, review documentation and reporting of methods and uses of the data, and consider the frequency, timeliness, and extent of reporting. The overarching goals of the current USDA ERS Productivity Accounts review are to assess current practices used in assembling the agricultural productivity account and review how the USDA: a) documents its efforts and facilitates the ability to replicate and ensure comparability, b) describes how the community of analysts and scholars use the accounts, c) cooperates with other agencies to reduce duplication, achieve consistency across statistical series, get information at lowest cost, and capitalize on research and expertise, and d) establishes priorities subject to resource constraints.

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2 The Farm Costs and Returns Survey is the predecessor to the Agricultural Resource Management Survey.
Scope of This Review and Organization of the Report

We undertook a focused review of the ERS agricultural productivity accounts and the data products used in their construction. With the full cooperation of the USDA ERS staff that construct, maintain, and communicate analysis of these productivity accounts and related data products, this report organizes the commentary and review of the production accounts into four main parts. Each part, except for the last, includes a number of subsections.

The first part addresses the core parts of the production accounts, specifically labor, non-land capital, land, intermediate inputs, and outputs. The second addresses issues related to the construction and interpretation of the accounts. These include quality adjustments made for production factors and outputs, how residual claimants are addressed, how R&D is reflected and incorporated, the sensitivity of productivity trends to alternative assumptions, and accessibility of these data products on the website. The third addresses the state-level production accounts, cross-country comparisons, ERS measures of productivity compared to other sources, and stakeholder assessment. The final part concludes and categorizes the recommendations by priority level.

A summary of acronyms used in the report, bibliography cited, and appendices follow these four sections. This review engaged stakeholders on issues of methodology in the development of estimates, ongoing research programs to improve methodology and operations, documentation and reporting of methods and uses of the data, and the frequency and timeliness of reporting. In addition, reputed experts from academia and U.S. government and international statistical agencies external to USDA were engaged on several issues related to the ERS agricultural production accounts. Verbatim input from stakeholders and cited personal communications from experts in the field are included in the appendices.

Recommendations

We include 21 recommendations in the top priority category. Of these, eight are designated by the committee as most important. They include two overarching recommendations, two addressing the website, and three focusing on the state-level production accounts:

**Overarching**

1. Fully document and keep current all procedures followed, from data sources through measurement of productivity change, to enable a non-expert to reproduce the accounts.

2. Cooperate with other agencies to reduce duplication, achieve consistency across statistical series, get information at lowest cost, and capitalize on research and expertise.

**Website**

1. Provide detailed documentation online and note ad hoc adjustments to data or deviations from the general procedure (e.g., if fixes were required due to negative implied capital rental rates).

2. Expand the website to provide timely access to more detailed data and procedural detail underlying the quantity and price aggregate and sub-aggregate national and state-level statistics.

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3 Because the U.S. statistical system is decentralized, the ERS relies on data from other statistical agencies in assembling the agricultural productivity accounts.
State-level

1. Continue to develop and publish the state-level total productivity measures as well as price and quantity series (strongly recommended).
2. Cooperate with other government agencies to achieve the lowest cost method of collecting data of sufficient quality to enable the state-level accounts to be extended and maintained.
3. Investigate the possibility of using information in the American Community Survey to update matrix elements in the state labor accounts.
4. Ensure consistency between the national and state accounts where possible, and explain circumstances that prevent total consistency where that is not possible.
PART 1

The first section of this report reviews the components of the agricultural productivity accounts. The fundamental economic entity in the account is the industry. The farm industry as a whole produces outputs by employing labor and capital services, purchasing intermediate inputs, and transforming input to output with available technology. The ratio of output to input yields a measure of productivity, and the theory of productivity measurement provides the conditions such that the growth in output per unit of input corresponds to the change in the level of technology, or innovation. Because the productivity growth measure is a residual, all measurement problems will affect estimated TFP. In economic terms, the objective is to distinguish and measure shifts in the production function from movements along the production function.

I. Labor

The OECD Productivity Manual (2001b, p. 20) states that “labor is the single most important factor of production,” thus highlighting the importance of measurement issues related to the labor input in the productivity accounts. As a partial productivity measure, changes in labor productivity (output per hour worked) help to understand the development of standards of living and income per person in an economy, but these changes embed shifts in the use of capital, the quality of the workforce, and technology. According to the ERS productivity accounts, the nominal value share of hired and family labor in U.S. agriculture output has averaged about 20 percent over the last 60 years. For accurate measurement of productivity, the labor quantity index should capture not only the hours worked but also reflect the marginal product of different types of labor working in the sector. While total hours worked is the preferred measure of the service flow for a given worker, it does not capture the heterogeneity of the labor force. Differences in skills, education, health, and professional experience lead to large differences in the contribution of different types of labor. It is necessary then to distinguish the labor input by type of skill to adequately capture the effects of changing labor quality on productivity.

Procedure Before 1980 AAEA Task Force Recommendations

Labor input data was not derived from surveys of actual hours of labor or workers in agricultural production but was calculated on a "requirements" basis using estimated quantities of labor required for various production activities. The requirement coefficients were obtained on an individual commodity basis by means of consultation with state agricultural experiment station and extension service experts. Requirement coefficients were developed for 1964 and re-done in 1974 based on cost of production surveys. The published estimates of total hours used for farm work for each of 12 enterprise groups and 10 regions (Durost and Black 1978) were obtained by multiplying labor coefficients by estimates of planted acreage (for pre-harvest labor), production (for harvest labor), or animal numbers for livestock, and adding 15% for overhead labor. The national labor input index was obtained by aggregating over the regions and enterprise groups. The U.S. average hired farm wage rate per hour as estimated by USDA's Statistical Reporting Service for 1967-69 was used in the aggregation.

1980 AAEA Task Force Recommendations

The labor input index should be based on direct sampling instead of the requirements approach. The labor input data should be handled separately for hired, operator, and family labor, each weighted to construct an aggregate by their relative wage rates.

The Divisia index should be used for aggregation with expenditure shares as weights.
ERS Implementation of 1980 AAEA Task Force Recommendations

ERS has implemented the recommendations of the AAEA task force and has used theoretically consistent methods to develop Tornqvist (discrete approximation to the Divisia index) and Fisher labor input indexes for use in multifactor productivity analysis. Implementation has followed closely Jorgenson, Gollop, and Fraumeni (1987) as well as the OECD Productivity Manual (2001b).

The first set of labor indexes implementing the AAEA Task Force recommendations were reported in Ball (1985). Tornqvist indexes for the period 1948-1979 were developed that included hired labor and self-employed workers (contract labor was included in intermediate inputs). Data on wage rates as well as hours worked by characteristics of individual workers were developed by Jorgenson and Gollop and provided to ERS by Jorgenson (Ball 1985, p. 476 footnote 3). Matrices of hours worked and compensation per hour cross-classified by gender (2), age (8), education (5), employment class (2), and occupational group (10) were used.

Ball et al. (1997) developed Fisher quantity and implicit price indexes for labor for the period 1948-1994. This index included hired labor, self-employed, and unpaid family workers. Revised to include unpaid family labor in addition to operator labor, data on hours worked and average compensation were from the same sources (Ball et al. 1997, p. 1048 footnote 2). Annual data on hours worked and average compensation per hour were required for 160 matrix entries based on two genders, eight age groups, five educational groups, and two employment classes. Jorgenson and Gollop (1992) used information on employment, hours worked and average compensation from the Census of Population and the Current Population Survey along with bi-proportional matrix balancing (RAS) techniques to allocate across the matrix entries for non-census years. Additional data from the Farm Labor Survey conducted by NASS were used for unpaid family workers.

ERS has undertaken a continuous process of methodological examination and improvement as documented by the use of Tornqvist indexes for 1948-1979 in Ball (1985), Fisher indexes for 1948-1980 in Ball et al. (1997), and a new series of Tornqvist indexes4 for 1948-2011 available on the ERS Agricultural Productivity website.

ERS Current Practice

The description of current practice in this section follows Wang (2013a), the methodological description section on the Productivity Accounts on the ERS website, and information provided by direct communication with ERS.

Table 1 on the ERS website presents Tornqvist price and implicit quantity indexes for labor and its sub-components, hired and self-employed (which includes unpaid operator and family labor), for the period 1948-2011. Following Jorgenson, Gollop, and Fraumeni (1987), matrices of employment, hours worked, and compensation per hour (for hired labor) cross-classified by gender (2), age (8), education (6), and employment class (2) are used as indicated in Wang (2013a). These represent 192 entries and are slightly different than the cross-classifications used in Ball (1985) and Ball et al. (1997).

The two gender categories are: male and female.

The eight age categories are: 14-15 years, 16-17 years, 18-24 years, 25-34 years, 35-44 years, 45-54 years, 55-64 years, and 65 years and over.

The six education categories are matched to information in the Current Population Survey: 1-8 years grade school (elementary and middle school), 1-3 years high school (less than high school

4 Among other changes, the new series uses new data for labor and for land.
diploma), 4 years high school (high school diploma), 1-3 years college (three years of college, vocational/associates), 4 years college (bachelor’s degree), and more than four years college (graduate school, master’s degree, doctorate degree).

The two employment classes are: wage/salary worker, and self-employed/unpaid family worker.

ERS uses a cross-entropy approach in the Generalized Algebraic Modeling System (GAMS), rather than the RAS procedure in Jorgenson, Gollop and Fraumeni (1987), to update matrix elements when new information is available.

Data for hired farm workers (employment, hours worked and compensation) are from the National Income and Product Accounts (NIPA), BEA. Total hours worked for self-employed and unpaid farm workers are from the Census of Population and the Current Population Survey. Wages for self-employed and unpaid family workers are imputed using the mean wage of hired workers in the same cross-classification.

Control totals for hours worked and compensation for hired workers are from NIPA and from a special tabulation by BLS for self-employed and unpaid family workers.

The ERS implementation of the labor index, while broadly consistent with previous vintages, deviates in some ways from previously published approaches. For example, the cross tabulations used by ERS no longer contain the occupation dimension. Further, to be consistent with a change in survey questions in the Current Population Survey, updates after 1992 treat degree attained as the defining characteristic of educational attainment, compared to years of schooling in the previous estimates. Jorgenson, Ho, Stiroh (2005) discuss methods for bridging the two treatments.

Jorgenson, Ho and Samuels (2014) develop U.S. industry-level production accounts for 65 industries, including agriculture, for the period 1947-2010. As shown in Table XIII.1: Agricultural Output Growth and its Sources in this report, the evolution of the agricultural sector labor index differs from that of ERS.5 Given the overlap in source data and methods between ERS and Jorgenson, Ho and Samuels (2014), it will be important to investigate reasons for the differences across these labor indexes.

**Contract Labor (in Intermediate Inputs)**

Many farms, especially in fruit and vegetable production, hire labor services from contract providers. The workers are not employees of the farm, and hence are not counted as hired labor. They are reported as purchased contract labor services in intermediate inputs, and farm survey respondents are able to report expenses but not employment or hours for such workers. Because there is no available data on hours worked, ERS estimates implicit quantities of purchased contract labor services by dividing expenditures by a wage index. The data consist of nominal expenditures on contract labor. Up to 2000, ERS used ‘piece rate information’ from NASS to deflate these expenditures, but this information is no longer available. ERS has replaced this information with a wage deflator based on hedonic methods. The hedonic framework is used to estimate wage as a function of characteristics, using data from the BLS National Agricultural Workers Survey. Included are gender, years of experience, education, language skills, legal status, employer type, task type, geographic and time controls. Heckman’s procedure is used to correct for sample selection bias.

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5 ERS maintains that the differences in the labor series stem in part from differences in coverage of unpaid family workers and in part from differences in the imputation of wages for farm operators.
Recommendations

1. Investigate the reasons for differences in the labor input computed by Jorgenson, Ho, and Samuels (2014) (Priority A).
2. Investigate the American Community Survey as an alternative, possibly complementary, data source, potentially in collaboration with BEA/BLS (Priority A).
3. Use the latest revision of information on totals from NIPA and the special BLS tabulation (Priority B).
4. Consider further refinements of the cross classification of workers to improve identification of quality differences (Priority B).
5. Adjust for temporal changes in the quality of workers in each demographic group not captured in relative wages (Priority B).
6. Clarify if the imputation of wages for self-employed workers exhausts available income and report procedures used if this occurs (Priority C).
7. Clarify how sample selection estimation is executed when the Heckman procedure is used for the contract labor hedonic wage index (Priority C).

II. Non-Land Capital

Within the growth accounting framework for decomposing the sources of growth, measuring the contribution of capital input requires price and quantity estimates of the capital services that flow into production. Like labor, a key feature of the capital input measure is that it must treat a shift in the composition of capital towards an asset type with a higher marginal product as an increase in capital input used in production. Ignoring this type of composition shift amounts to a systematic bias in estimated TFP. Fortunately, research on productivity measurement has established methods to adjust for composition changes in capital services, and ERS has, for the most part, adopted these procedures.

ERS has carefully incorporated the recommendations of the AAEA Task Force (Gardner et al. 1980) that relate to non-land capital inputs. They include measuring multifactor productivity, improving the quality of data on the stocks of machinery and equipment, and modifying structures and capital equipment depreciation procedures to better reflect “economic value of services at each point of an item’s lifetime” (p. 46).

Since the 1980 review of measurement of U.S. agricultural productivity, there have been substantial developments in the measurement of productivity, particularly in the measurement of capital inputs. Two developments which occurred in the early eighties are of particular note: the publication of the book on U.S. productivity and economic growth by Jorgenson, Gollop, and Fraumeni (1987) and the first release by BLS (U.S. Department of Labor (USDOL) 1983) of multifactor productivity estimates for a number of aggregate sectors. Both included capital inputs in the production function. Similar to ERS, the BLS’s Office of Productivity and Technology (OPT) developed multifactor productivity measures as recommended by a panel review (see Rees 1979).

Later, OECD issued two capital manuals on measuring capital and one on measuring productivity (OECD 2001a, 2001b, 2009). Beginning in 2003 the European Union Capital, Labor, Energy, Materials, Services (KLEMS) project (Van Ark, O’Mahony and Ypma 2007) began to develop industry-level production accounts for European countries; subsequently this effort was extended to other countries through the

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7 For detailed discussions of capital stocks and capital inputs, see Fraumeni and Jorgenson (1980), Jorgenson (1980), and Kendrick (1976).
World KLEMS project. Since most of the activity related to measurement of multifactor productivity and in particular capital inputs occurred subsequent to the 1980 review of measurement of U.S. agricultural productivity, we will not refer further to the 1980 review recommendations.

ERS’s methodology is broadly consistent with the approaches used in the literature. The majority of the implementation choices made are reasonable and defensible. The review committee, supported by productivity expert feedback (Sliker, 2014b), has identified an internal inconsistency and a deviation from a typically used approach that are addressed in more detail below.

### Capital Measurement: General Issues

Measurement of capital differs from measurement of hired labor in that wages paid to hired labor are recorded, whereas rent paid to capital frequently is unrecorded because capital is more often owned than leased. Furthermore, the flow of services from the productive capital stock is unobserved, and the productive capital stock is based on the accumulation of past investments. These fundamental differences give rise to a number of difficulties and assumptions in capital measurement.

The construction of capital input begins with construction of the capital stock. The perpetual inventory method is typically used to develop real capital stock estimates:

\[
K_t = I_t + (1-\delta_t)K_{t-1},
\]

where \(K_t\) is real productive capital stock in period \(t\), \(I_t\) is real gross investment in period \(t\), and \(\delta_t\) is the rate of efficiency decline in period \(t\). The importance of implementing capital stock construction by industry and by asset type has been demonstrated in many empirical applications.

The next step is to construct the user cost of capital for each asset, which is also called the rental price of capital services. It represents the transformation of the acquisition price of capital to the per-period usage price:

\[
p_{K,t} = p_{I,t} (r_t + p_0) - (p_{I,t} - p_{I,t-1})
\]

where \(p_{K,t}\), the user cost of capital, is the cost of using the capital asset in period \(t\), \(p_{I,t}\) is the period \(t\) market price of a new asset, \(r_t\) is the period \(t\) interest cost or opportunity cost of employing capital elsewhere and is often called the rate of return, \(p_0\) is the period \(t\) rate of depreciation or the rate of loss in the value of the asset as it ages, and \((p_{I,t} - p_{I,t-1})\) measures capital gains, losses, or revaluation of the asset between period \(t\) and \(t-1\). Some statistical agencies, such as the Australian Bureau of Statistics, BLS, and researchers associated with Jorgenson, include tax in the user cost formula.

User costs are then multiplied by the real productive stocks to create nominal capital inputs (or capital flows) by asset, which are used as productive capital stock weights in an index number formula to create an aggregate real capital input. The theory of production equates these weights to be consistent with the marginal product of each capital asset.

In our review of non-land capital inputs, we focus on these two themes of capital stocks and capital inputs, the latter beginning with the construction of the user cost of capital.

### Equipment and Structures Capital Stock

ERS uses three major sources for the nominal investment data: BEA fixed assets data for years prior to 1975, NASS Farm Production Expenditures Survey data for 1975-1992, and ARMS data for 1993 to the

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8 See [http://www.worldklems.net/index.htm](http://www.worldklems.net/index.htm) for information on World KLEMS.
9 This brief user cost description closely follows OECD (2009, pp. 64-65).
present. There are four categories of ERS farm nominal investment data: Autos from 1926, farm tractors from 1929, buildings from 1871, and other machinery (an aggregate) from 1914.

Beginning in the year for which BEA fixed asset data are available on the internet (1901 at the earliest), the committee compared the ERS data for all years forward to the BEA fixed asset data. This comparison is preliminary and suggestive; it should not be construed as a precise or totally accurate analysis. However it revealed substantial differences between the current BEA data through 1974 and the ERS data, and there is no perceptible pattern of differences, except that ERS data prior to 1975 tend to be lower for equipment and higher for buildings than the BEA fixed assets data. Beginning in 1975, the ERS data are almost always lower for both equipment and structures.

A comparison was also made between the BEA fixed assets category for all equipment except for autos and farm tractors (other equipment) and the ERS category other equipment from 1947 to the present. With one exception, the percentage that ERS other equipment is of ERS total equipment is consistently lower than the percentage that BEA other equipment is of BEA total equipment, with differences as high as 13 percentage points before 1993. After 1987 BEA farm investment categories include computers and software and after 1992 wind and solar power.

**Benchmarks and lifetimes**

Since the ERS investment data go far back in time relative to the asset lifetimes, it is appropriate to assume a zero benchmark as ERS has done.

The ERS average service lives are 10 for autos, 9 for farm tractors, 17 for other machinery, and 38 for buildings. The ERS average lifetimes for farm tractors and buildings match BEA average lifetimes. BEA does not use an explicit average service life for autos; rather it develops deterioration rates from information on new and used auto prices (see U.S. Department of Commerce (USDOC) 2013). In addition, the BEA category “autos” refers to all autos listed under private nonresidential equipment. This category excludes autos which are classified as durables owned by consumers. BLS average service lives are also the same as ERS except for tractors, which is 8 years (USDOL 1983).

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10 Most of the BEA fixed asset data are available at [http://www.bea.gov/national/FA2004/Details/Index.html](http://www.bea.gov/national/FA2004/Details/Index.html). However, some of the early BEA data are not.

11 There are several possible reasons for these differences: The BEA fixed asset data base used by ERS has not been re-collected since it was first obtained in 1985 although BEA has revised the earlier data since then. The BEA title in the farm category under “total structures” is simply “farms”, so it is not clear if this category only refers to nonresidential farm structures. There is a separate category under the farm industry labeled “lodging” with zeroes in all entries. Patterns also differ for the equipment subcategories of tractors and autos.

12 In this review, the word deterioration is consistently used to refer to the decline in efficiency of an asset as it ages and the word depreciation to the decline in the price of an asset as it ages. This distinction is discussed in a later section.

13 Service life references in addition to USDOC (2003) include USDOC (2013), Hulten and Wykoff (1981a, 1981b), Wykoff and Hulten (1979), and Fraumeni (1997). A footnote in BEA (1983) specifies that the average service life was 8 years for producer durable equipment autos and 14 years for agricultural machinery except tractors; it is possible that the latter category includes autos used in agriculture.

14 Since the BLS category tractors does not specify farm tractors, this average life may reflect average service lives for farm and construction tractors. The source for ERS average service lives of buildings and agricultural machinery except tractors has not been updated since BEA revised its service lives in the latter nineties. See USDOC (2013) for the current BEA lifetimes which are mainly taken from Fraumeni (1997) and in most cases do not depend on Bulletin F lifetimes.
Investment deflators

Investment deflators for all capital assets except buildings were obtained from BLS. The investment deflator for buildings is from BEA. More information is needed about the specific sources, e.g., whether the BLS deflators are those used in the BLS multifactor productivity estimates, whether the BEA structures deflators are those for farm buildings, and whether revisions made in BLS and BEA deflators since 1985 have been incorporated.

Deterioration and retirements

ERS estimates deterioration and retirements using methodology almost identical to that used by BLS. The deterioration function is a hyperbolic function with $\beta$ equal to .75 for buildings and .5 for equipment. The ERS retirement function is a truncated normal distribution with the spread equal to double the average service life, i.e., from 1 to 20 for autos, 1 to 18 for farm tractors, 1 to 34 for other machinery, and 1 to 76 for buildings. The spread adopted by BLS is only slightly different: .02 to 1.98 times the average service life (USDOL 1983, pp. 44-45). This is the only difference between ERS and BLS methodology with respect to deterioration and retirements.15

Capital stock construction

ERS uses a perpetual inventory method to construct stocks. This methodology is also widely used by others. However, Sliker (2014b), as discussed below in the depreciation section, questions whether the aggregation procedure over individual assets is internally consistent.

Capital Input

Rate of return

The real rate of return $r$ is calculated as the nominal yield on investment grade corporate bonds less the expected (forecasted) rate of inflation as measured by the implicit deflator for gross domestic product. An ex-ante real rate of return is obtained by expressing inflation as an ARIMA process.16 In the review panel’s opinion, it is defensible to use an expected rate of return estimated with an ARIMA process instead of an actual rate of return. It is only the choice by ERS of the GDP deflator as the expected rate of inflation measure that is unusual. In widely used approaches, the rate of asset capital gain or loss is measured by an asset-specific deflator in the real rate of return. The choice of the GDP deflator may have been dictated by common problems that researchers have when asset capital gain produces an asset-specific real rate of return which varies widely or may even be negative. However, that can be resolved by following BLS in the use of a smoothing function that takes the average rate of asset inflation over several years. Incorporating asset-specific capital gains is particularly important for assets with rapidly changing prices such as computers.

The formula for $r$ is $\frac{(1+bond)}{(1+\text{expected inflation})}-1$ where the bond rate is that over all maturities for AAA rated bonds.17 The choice of the AAA bond rate as the nominal opportunity cost of invested funds stems from the fact that Farm Credit bonds are almost always rated AAA. This choice is defensible as the Farm Credit system is a major player in the agricultural credit market. In the construction of user cost of capital, $r$ is held constant for a particular vintage of capital goods. No attempt is made to separate corporate and noncorporate capital input, which have different implicit rental prices due to

\[15\] Prior to revising its deterioration methodology sometime after 1997, but before 2003, BEA used skewed Winfrey (1967) retirement distributions for some assets.

\[16\] Some researchers argue for ex-post rates of return; others argue for ex-ante rates of return. There is no consensus among productivity researchers. See OECD (2001b) for a discussion.

\[17\] See Figure XIII.2 for ERS developed real rate of return.
differences in tax structures by legal form. As BEA provides BLS with a corporate/noncorporate split, such a split could be implemented. Additional discussion on the choice of interest rate is included in the section on the Residual Claimant.

**Taxation**

ERS does not incorporate any tax terms into its user cost formula. This differs from the BLS (Harper 1999), Australian Bureau of Statistics (2013), and Jorgenson, Gollop, and Fraumeni (1987) practice. As noted previously, the decision to exclude tax terms may have been made either because it very significantly complicates the user cost of capital equation or because of data availability issues. Whatever the reason, an explanation is warranted.

**Depreciation**

To construct a measure of capital input, first a measure of capital stock is constructed followed by a measure of the user cost of capital; the latter requires a measure of depreciation, i.e. equation (II.2). With the perpetual inventory method of constructing capital stocks, real gross investment is accumulated and reduced by deterioration of capital stock, which differs conceptually from depreciation.

ERS has made assumptions typically employed (for example, by BLS) to measure deterioration and create measures of capital stock. However, ERS takes a different approach to implementing the measurement of user cost, with components representing the opportunity cost of invested funds and the discounted stream of the sum of capacity deterioration, instead of explicitly including a depreciation term. The ERS approach is at variance with the work of several other capital measurement experts who defend the age-price approach (e.g., staff from the Bureau of Labor Statistics’s OPT, Professor Dale Jorgenson of Harvard University, Paul Schreyer of OECD – see Harper 1982 and 1999; Jorgenson 1973; Ho, Jorgenson, and Stiroh 1999; OECD 2009). However, Sliker (2014a, 2014b) appears to reconcile the two approaches.

The difference between deterioration and depreciation comes down to the difference between marginal productivity and marginal revenue product and a time factor. Net capital stocks depend only on the current and past marginal productivity of the stock. The user cost of capital is a function of the price that a buyer is willing to pay for an asset. This price depends upon the current and future revenue stream expected from an asset over its lifetime or its current and future marginal revenue product. Marginal product is an element of marginal revenue product, but only the latter includes the price for the output produced by the input. In addition, the net capital stock construction looks backward, while the user cost of capital construction looks forward in time as already noted. Accordingly, there are two

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18 Some researchers such as BLS use an internal rate of return instead of an r dependent upon a bond rate and expected inflation rate. See OECD (2001b) for a discussion. However, as in the case of the ex-post versus ex-ante choice, ERS’s methodology is defensible.

19 The reference might be to capital service flows or to the rental cost of capital rather than to the user cost of capital, but this choice has no bearing on the methodological question. Sometimes the term capital input is used as well.

20 In this discussion, the term deterioration is used to refer to the capital stock concept and the term depreciation is used to refer to the user cost of capital or capital input concept.

21 Ball et al. (1997) cite Coen (,) for their procedure.
differences between the deterioration and depreciation concepts: the price of the output produced by the asset and the time frame.22

An exposition of how these two differences impact on the shape of the deterioration vs. the depreciation function is in a 1982 paper by Michael Harper, written when he was an economist with the BLS OPT. Harper developed productive capital stocks and the user cost of capital under a variety of assumptions about the shape of the deterioration (age/efficiency) function.23 He considered the case of a concave deterioration function implemented with a hyperbolic function; this case is the one directly relevant to this discussion. He represented the hyperbolic function as:24

\[(II.3) \quad S_t = \frac{(L - t)}{(L - \beta t)}\]

where \(S_t\) is the relative efficiency of a \(t\)-year old asset, \(L\) is the lifetime of the asset, and \(\beta\) is the hyperbolic shape parameter. The depreciation function \(P_t\) for the hyperbolic function, which underlies \(p_{D,t}\) in the user cost formula, is:25 26

\[(II.4) \quad P_t = \frac{\sum_{\tau=t}^{\tau=\infty} S_{\tau} (1-r)^{\tau}}{\sum_{\tau=0}^{\tau=\infty} S_{\tau} (1-r)^{\tau}}\]

where both summations are to infinity, but truncated at 200 years for purposes of illustration with negligible effects, and \(r\) is an assumed real discount rate. The denominator of the function ratio is the sum of the discounted efficiencies of the asset over its entire useful life \(\tau\). The numerator is the sum of the discounted efficiencies of the asset from the present time \(t\) through the end of its useful life \(\tau\).27 This function is directly derived from equation (II.3) by using the neoclassical theory of investment without assuming that deterioration occurs at a geometric rate.28 Harper considered three possible \(\beta\) shape parameters: .5, .75 and .9 and presents the results.29 In all three cases, the deterioration function was concave, but the depreciation (age/price) function was convex.30 31 The depreciation function is forward looking, but the age-efficiency function is backward looking. As ERS uses the same function for deterioration and depreciation, both of their functions are concave.

The 1973 paper by Jorgenson is also particularly relevant to this debate. Although this paper does not address the shape of the deterioration versus the depreciation function, it does make the same distinction as Harper makes. What Jorgenson calls replacement requirements depends upon a weighted

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22 A special case of deterioration and depreciation is when deterioration is assumed to occur at a constant rate. In this special case, depreciation is equal to deterioration. ERS did not make a geometric assumption; accordingly this equivalence does not hold.
23 Productive capital stocks are stocks which are used in productivity measures such as that constructed for agriculture by ERS.
25 Depreciation functions are commonly called age/price functions and deterioration functions age/efficiency functions.
27 With a new asset, this ratio is equal to one. As the asset ages this ratio declines even in the case of a one-hoss shay asset as the asset has fewer years of useful service.
28 For the neoclassical theory of investment with a geometric rate of replacement and a discussion of the cost of capital, see Jorgenson (1963).
29 The Bureau of Labor Statistics (BLS) continues to use \(\beta = .5\) for equipment and .75 for structures as described in Harper (1999). This was verified in a discussion with Steven Rosenthal of BLS. ERS uses the same values for \(\beta\).
30 The ‘price’ in an age/price function is the price that someone is willing to pay for new investment which depends upon the expected future revenue from that asset as described earlier.
31 This is shown graphically for \(\beta = .5\) in Figure 1 on p. 12 and in tabular form for all three assumed \(\beta\)s in Table 2, page 14.
summation of past investments. His depreciation depends upon a weighted summation of future rental prices. The weights in both cases are efficiency and are given by the mortality distribution or the sequence of efficiency declines.  

As both other experts and ERS agree, the productive stock should be multiplied by user cost to obtain capital input. Efficiency decline functions are used by the above experts in deriving capital stocks, and through the user cost expression, which is a revenue concept, as part of the expected future revenue or marginal revenue product arising from a capital asset when a decision is made to invest in new capital by paying a certain price for that asset. Age/price functions critically underlie the revenue (depreciation) concept. Equation (4) of the cited 1999 Harper paper does indeed use an age/price formulation for depreciation rather than an age/efficiency formulation. ERS clearly contends that there should be no difference.

The user cost methodology was outlined by Ball (2014b) and shared with individuals at BEA and BLS. A BEA response (Sliker 2014a) expressed little concern about the appearance of deterioration in the user cost of capital expression and provided what appears to be an internally consistent justification for the ERS method of measuring productive stock and the capital rental rate.

Of greater concern in Sliker (2014a) was the ERS methodology reported in Ball et al. (2008) concerning “construction of a cohort-average replacement function as a weighted average of individual replacement functions, where the weights are the frequencies of each lifespan in the cohort’s original installation.” See Sliker (2014b, 2014c) for the concern and an outline of a methodology to resolve the issue.

Since neither Sliker’s recommended cohort aggregation procedure nor the ERS user cost of capital formulation have been widely vetted, both warrant review by additional experts and practitioners in the field before changes are made or final conclusions reached. Vetting is important to determine if changes should be made to ERS methodology and to inform other productivity researchers.

**Aggregation**

Measures of real capital input are constructed with Tornqvist indexes. This is a procedure employed by many researchers.

**Inventories**

Inventories impact the output, intermediate input, and capital input accounts. Additions to inventories are output, withdrawals from inventories are intermediate inputs, and the stock of inventories is capital input. Inventories include durable assets which produce output, such as milk cows and fruit trees, as well as nondurable items. NASS surveys from the early 1980s (since discontinued) were used to benchmark farmer-owned inventory stocks. Price deflators for inventory investment come from NASS. It is assumed that inventories, including durable assets such as milk cows, breeding livestock, and fruit and nut trees, do not deteriorate or depreciate. ERS considered treating milk cows and breeding livestock as a durable asset which declines in efficiency over time (Ball and Harper 1990), but decided against doing so because of questions about the reliability of the source data (Ball 2014a). Construction of inventory capital stock and capital input otherwise parallels the methodology for equipment and structures.

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Research at BEA

Researchers at BEA are attempting to develop more comprehensive measures of farm output, investment and capital stock for the NIPA (Soloveichik 2014). Some of the findings from the research project might impact on BEA methodology and be beneficial to ERS productivity accounts. Agricultural productivity over the 1948 to 2011 period as currently measured by ERS has increased 1.42% annually (USDA 2014). Treating working farm animals, long-lived farm plants, and land improvements as capital assets, introducing quality adjustments for some of these assets, and valuing farmland based on agricultural rental rates rather than market value would decrease measured TFP, but the total impact of such refinements in methods and the data requirements to support them is research in progress (Soloveichik 2014).

Recommendations

It is the judgment of the committee that the ERS effort to measure agricultural productivity with non-land capital as an input is highly commendable and invokes many of the most important developments in productivity theory. While ERS has been a leader in researching the best ways to measure capital inputs devoted to agricultural production and their prices, we recommend that ERS:

1. Examine non-land capital nominal investment data in consultation with BEA researchers (Priority A).
2. Consider using one or more individual asset deflators in its expected inflation calculation (Priority A).
3. Review investment deflators to determine if sources have been updated or revised since the data were last collected (Priority A).
4. Review average service lives of assets with BEA and BLS to determine if any revisions should be made (Priority A).
5. Investigate whether the indexes of capital service flows during the period 1975-1984 reflect changes in capital service use rather than changes in the behavior of the bonds rate used in calculating the user cost of capital (Priority A).
6. Begin a conversation with BEA researchers to determine if any changes should be made to ERS measures based on recent BEA research (Priority B).
7. Review and vet the capital stock aggregation methodology developed by Sliker and consider whether to revise ERS methodology in response (Priority B).
8. Include investment in computers in the ERS investment data (Priority B).
9. After vetting the current ERS methodology, consider whether to revise its estimate of depreciation in the user cost of capital to bring its construction in line with the methodologies used by other experts in the field (Priority C).
10. As a future research project, revisit the treatment of breeding livestock, building on Ball and Harper (1990) (Priority C).

III. Land

In the agricultural production process, land is a key input. According to the ERS production accounts, payments for the services of land average about 15% of total input cost. Land, along with structures, equipment, and inventories, is a component of the capital index in the ERS accounts. Many of the procedures described in the previous section on non-land capital apply to land. Land, owned or rented, provides services that are an input into the production process. Stocks of land from the Census of Agriculture are used as a basis for the calculation of flow of services. For owned land, the price of the service is the user cost of capital as developed for other capital equipment and structures except that
depreciation is assumed to be zero. ERS treats the total payments to land as a residual (this is discussed in more detail in Section VII. Residual Claimants).

1980 AAEA Task Force Recommendations

The AAEA Task Force (Gardner et al. 1980, pp. 33, 46) recommended several changes in the procedures used to convert land stock to a service flow. They recommended that the stock/flow conversion be based either on the estimated ratio of base-period cash rental value to stock value or a single interest rate of 3 to 4% throughout the whole data series. Whichever is used, it should be used as the conversion rate for all land. The ratio of cash rental value to stock value was previously used only for the equity portion of land owned. They recommended that property taxes as a fraction of land value be added to the conversion factor. They further recommended that service flows from public lands be based on a shadow-rent estimate of rental value of comparable private lands rather than on federal grazing fees.

ERS Past Implementations of 1980 AAEA Task Force Recommendations

Since the AAEA task force recommendations, procedures used by ERS to develop indexes of farmland for the purpose of multifactor productivity measurement have been theoretically consistent and follow best practices as described in Jorgenson, Gollop and Fraumeni (1987) and in the OECD capital and productivity manuals (2009, 2001b). Alternative procedures and sources have been used to develop these indexes per descriptions in Ball (1985), Ball et al. (1997), and Ball et al. (1999), with additional changes in current calculations. They reflect a continuous process of revision and improvement to capture changes in the composition of land, as evidenced by recalculations at lower levels of disaggregation.

Ball (1985) reported the first set of indexes implementing the AAEA Task Force recommendations. National Tornqvist price and implicit quantity indexes of state-level farmland prices and stocks for the period 1947-1978 were constructed (Ball, 1985, page 478). State-level prices were the value of land per acre at the state level implying homogeneity of land within the state. The value of service flows was obtained as a residual from the accounting identity imposed on the system.

Ball et al. (1997) presented Fisher quantity and implicit price indexes for stocks of farmland for the period 1948-1994. These indexes incorporated adjustments for land type by using land area and average value per acre at the Agricultural Statistics District level within each state. For 11 Western states they further disaggregated land into the following land types: irrigated cropland, dry cropland, grazing land, and other land (Ball et al. 1997, p. 1050). Using information from the U.S. Agricultural Census for acres and from NASS for annual updates, percentages in each district and use category were interpolated between census years. To aggregate the different land categories, land values per acre from the annual Agricultural Land Values Survey (USDA) were used. Public lands service flows were estimated from grazing fees paid (Bureau of Land Management and the Forest Service), which was not consistent with the 1980 Task Force recommendation. The value of service flows was obtained as a residual from the accounting identity imposed on the system.

ERS Current Practice

The description of current practice in this section is based on the methodological description section of Productivity Accounts on the ERS website (USDA 2014), Ball (2013), Wang (2013b), and other direct communication with ERS.

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Ball et al. (1997) state that land diverted from production due to federal commodity programs and the Conservation Reserve Program was not included. ERS notes that it is now included.
Verified by our examination of detailed spreadsheets, aggregation to construct an index of land stock now begins at the county level rather than at the state (Ball 1985) or Agricultural Statistical District (Ball et al. 1997) levels. The quantity (acres) of land by county includes all land types from the Census of Agriculture except “Land in house lots, ponds, roads, wasteland, etc.” For inter-census years, the quantity in each county is adjusted by the percentage change in area in each state from the NASS June Area Survey until new Census data become available. When new census data become available, a spline technique is used to estimate usable land area by county and revise previous data between census years.

Price of land at the county level is the average value of land per acre. The Census of Agriculture provides information about the value of land and buildings but not the value of land only nor the value of land by use (cropland, pasture, etc.). The value of land per acre at the county level is obtained from the value of land and buildings in the Census of Agriculture, multiplied by the ratio of the value of land to the value of land and buildings at the state level. The ratio of the value of land to the value of farm real estate was taken from the NASS Agricultural Economics and Land Ownership Survey (AELOS) prior to 1999. The survey, an irregular census follow-on, will not be conducted again until winter 2015 (for 2014 land holdings). To date, the 1999 ratios have been used for subsequent years.

ERS has implemented an alternative approach for estimating the ratio of the value of land to that of land and buildings using data from ARMS. Specifically, ERS uses the ratio of the value of farmland (including trees and vines) to the value of farmland and buildings. Because ARMS has small samples for some states, ERS uses two-year moving averages for the ratio. The resulting estimates were consistent with those based on AELOS for comparisons of nearby ARMS years and the 1999 AELOS.

A Tornqvist state-level price index of county-level land prices is computed before computing a Tornqvist national price index. Acreage shares in each county (state) are used as the index weights. Land stocks at each level are implicit quantity indexes obtained as the value of land divided by the price index of land.

Only the implicit quantity indexes of land stocks are used from this aggregation in the productivity accounts. The value of service flows from land is obtained as a residual when imposing the accounting identity at the national level. Thus, land is the residual claimant of revenues after all other inputs have been paid.

Soloveichik (2014) questions why the ERS land index seems to follow more closely the evolution of Woodland, Pastures and other non-Cropland than that of Cropland. ERS notes that total cropland has remained quite stable over time. The ERS land series includes land in farms. The non-cropland part of that series has declined substantially over time, in large part because of the shift to confined livestock feeding operations. As a result, trends in the ERS series reflect the component that’s changing – non-cropland.

ERS uses the Census of Agriculture definition of “Land in Farms” that includes all grazing land (includes reservation grazing land, land in grazing associations, and any land leased for grazing), except land used on government permits on a per-head basis. Pardey, Andersen, and Acquaye (2006) discuss the relevance of using the concept of ‘Land in Agriculture’ rather than ‘Land in Farms’ as well as the relevance of valuing irrigated land and pasture land separately from cropland, as the basis for this index. They argue that acres in farms should be supplemented by acres out of farms which can be obtained, for example, from the Bureau of Land Management and the Forest Service. They point out that ERS’s use of an average value of land at the county level does not allow the index to capture quality changes within the county.

34 http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1_Chapter_1_US/usappxb.pdf (p. 13)
Recommendations

1. Explore ways to include within-county land type adjustments as well as quality changes given by, for example, irrigation or other improvements in farmland (Priority A).
2. Consistent with the recommendation for non-land capital, replace the GDP deflator used to capture general effects of inflation with a price index for land (Priority A).
4. Investigate the potential departure of the ‘Land in Farms’ definition in the Census of Agriculture used by ERS from ‘Land in Agriculture’. This would impact quantity and composition adjustments (Priority C).

IV. Intermediate Inputs

Much of what is regarded as variable inputs in agricultural production are aggregated into the intermediate inputs category within the production accounts. This aggregate is composed of agricultural chemicals, fertilizer, fuel and lubricants, feed, seed, custom services, machinery leasing, purchased contract labor services, and miscellaneous expenses associated with agricultural production activities.

The major issues of concern in this review with regard to accurate measurement of intermediate inputs for the purpose of the productivity accounts are:

- Addressing the quality adjustments of many these variable factors of production.
- Reconciling the ERS and BLS producer price index series for several factors.
- Considering quality of primary data sources in combination with supplemental data and protocols used where gaps occur.
- Addressing how on-farm consumption of inputs is valued in this production account.

1980 AAEA Task Force Recommendations

With respect to intermediate inputs, the AAEA Task Force (Gardner et al. 1980) made several recommendations:

- Feed, seed, and livestock service flows that are farm outputs used as inputs on the same farm should not be counted as either input or output for productivity measurement purposes. But those components of feed, seed and livestock purchases resulting from resources committed in the nonfarm sector are properly counted as inputs to agricultural production.
- Agricultural chemicals need additional attention to the extent that some chemicals should be counted as part of veterinary expenses, feed additives, and growth hormones.
- Index number procedures should move away from the Laspeyres to the Divisia. This was mentioned specifically for pesticides, fertilizers and aggregate inputs.
- Input quality adjustments are needed.
- ERS was commended for using the gross output approach to productivity measurement rather than the net (value-added) approach used in most non-farm productivity measures.

All of these recommendations have been adopted.

Subsequent Guidance

An important source of additional guidance on intermediate inputs is the OECD Productivity Manual (OECD 2001b) regarding Intermediate Input and Valuation (Chapter 6). It identifies input-output tables as the principal tool for creating a full set of intermediate input price and quantity indexes. OECD considers this to be a preferred mechanism that ensures the consistent treatment of intermediate and primary inputs and produces measures that are consistent with the accounts for the economy as a
whole. When the quantity indexes of intermediate products are weighted by their value share in total inputs, input substitution towards intermediate inputs with higher marginal products is accounted for as a change in the composition of intermediate inputs.

From the perspective of productivity measurement, the choice of valuation should reflect the price that is most relevant for producer decision marking. The basic price is intended to measure the portion of the price actually retained by the producer. It therefore excludes taxes paid and includes subsidies received. Purchasers’ prices are prices relevant for producer decisions on input choices. For goods intended for intermediate consumption, the OECD and the SNA recommend valuing them for the consumer at the purchaser’s prices (which includes taxes, transport and other charges paid by the purchaser). The ERS practice is consistent with this approach.

ERS Current Practice

The core intermediate input data are input expenditures collected from ARMS surveys conducted by NASS in collaboration with ERS. These are expenditure data. For only a few inputs are prices collected. The most commonly used source of prices for intermediate inputs is the Prices Paid Survey which collects price data using telephone enumerated surveys. Prices paid for farm inputs are collected annually through a survey of establishments selling production input items to agricultural producers. The prices paid index does not adjust for changes in item quality or product enhancements (USDA NASS 2011, pp. 1-7). NASS estimates monthly price series for major crops and livestock commodities, which reflects quality premiums and discounts. These prices are generally related to producer prices at first point of sale.

NASS uses the price estimates to calculate the Index of Production Items, which is one of five components in the overall prices paid index for commodities and services, interest, taxes, and farm wage rates (PPITW). The other PPITW component indexes are a) interest paid and interest rate on farm indebtedness, b) taxes paid on farm real estate, c) wage rates paid to hired farm labor, and d) prices paid for family living items.

Livestock, poultry and related expenses are collected by NASS, and implicit quantities are constructed using a NASS prices paid index. Fertilizer, lime and pesticides comprise the broader agricultural chemical input. Fertilizer quality changes are addressed by using a hedonic price index that is documented in Fernandez-Cornejo and Jans (1995) and in Ball, Hallahan and Nehring (2004). BLS also develops a price index for fertilizer. For comparison purposes, the correlation between the BLS index and ERS generated hedonic index is 0.93 over the period 1948-2011. However, the growth rates between these series correlate at only 0.51, and the average growth rates for the BLS and ERS fertilizer series are 3.6% and 2.1%, respectively.

NASS reports the price per ton of “lime spread on the field” as well as lime expenditures. ERS constructs implicit quantities. This is a fairly homogenous input that is not likely to require quality adjustments.

Nominal expenditures are reported by NASS for pesticides, and hedonic prices accounting for quality changes are constructed by ERS (Fernandez-Cornejo and Jans 1995; Fernandez-Cornejo et al. 2014) as are implicit quantities. BLS also develops a pesticide price index which has a correlation of 0.90 over the entire period, but not as high for major subperiods. In particular, in the post-1973 period, the BLS price index changes at a slower rate than the ERS hedonic price. The correlation between the growth rates of these two series is only 0.40. It is not clear if these differences are due entirely to ERS accounting for changes in quality.

NASS provides expenditures for fuels and lubricants, including minor fuels (e.g., coal and wood), as well as expenditures for the major components: gasoline, diesel, liquefied petroleum gas, natural gas, oil and
lubricants, and electricity. NASS is also the source of price data for gasoline, diesel, and liquefied petroleum gas. Natural gas and electricity price data are sourced from the Energy Information Administration which is an agency of the U.S. Federal Statistical System. Oil and lubricants price data are sourced from BLS. ERS constructs a price index and an implicit quantity for fuels and lubricants by deflating total expenditures net of taxes. BLS also develops price indexes for several of these fuel types. For comparison purposes, four of the five series track closely over the period — the correlation between the growth rates in the BLS and ERS series over the entire period is 0.80 for gas, 0.91 for diesel, 0.68 for LP gas, 0.84 for natural gas, and 0.95 for electricity.

The NASS expenditures on feed series use the BLS price index for animal feed other than pet food and the NASS prices paid index for seed as deflators. The BLS deflator does not include on-farm consumption. ERS includes on-farm consumption of feed, as is the practice for the EUROSTAT (2000) and the SNA. ERS treats all on-farm feeding as drawn from opening stocks. The price of corn fed on the farm is the opportunity cost, i.e., the price received by the farmer for corn sold off the farm, net of price supports since the payments are not dependent on end use. The total feed and seed input is an index of purchased and on-farm use. This results in a different input price than that proposed by the OECD Productivity Manual to the extent that the marketing margins and transportation costs of animal feed are not included in the valuation of the BLS price index for animal feeds (OECD 2009, pp. 79-80)

Accumulation of crop and livestock inventories is included in output and the drawdown of inventories is included in the intermediate input category. Presumably these intermediate inventories also refer to seed, feed, etc. Net inventory changes are also added or subtracted from the inventory component of capital. The questionable practice is the treatment of livestock as inventory instead of capital.

Communication with ERS suggests that embodied technical change is not being addressed by the NASS price indexes. Since NASS is not adjusting for input quality change, this leads to overstating the price. ERS acknowledges that changes in seed consumption are understated because they do not adjust for quality changes in this input. ERS indicates they have plans to develop a hedonic price index for seed. Hedonic price indexes for machinery are addressed in the quality section of this report.

Purchased services are another major component of the intermediate input series. Expenditures for repairs and maintenance of machinery and buildings use the BLS deflators to construct implicit quantities.

Purchased machine services use the index of machine rental prices (source not clear), implying purchased machine services are a perfect substitute for services from own-capital. No data on actual prices of purchased machine services are collected. Other purchased services include a) transportation, marketing, and warehousing which use the BLS price index series for farm product warehousing and storage, and b) veterinary and pharmaceuticals. Custom livestock feeding uses a feed price index obtained from an “informal” survey as a deflator. Other management expenses use the BLS employment cost index for wages and salaries, professional, and related services.

Miscellaneous expenses include two general categories. The first is irrigation expenditures from public sellers of water and the cost maintenance index for water projects compiled by the Bureau of Reclamation. The second is general production expenses (tools, shop equipment, and other unallocated expenses) which use the BLS price index for hardware as a deflator.

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35 Farmers are eligible to claim a refund of excise taxes on fuel.
36 This survey is a set of several phone calls to livestock feeding operations. It is not conducted annually and the survey is not stratified by size of operation, geographic location, or time of year.
The last component is purchased contract labor services. A hedonic price index is used. This is covered in the labor section of the report.

The price and quantity series for energy, fertilizer and lime, pesticides, purchased services, and other intermediate inputs are available on the ERS website.

**Recommendations**

1. Examine the robustness of the intermediate input accounts constructed by ERS to the use of alternative sources of price deflators (Priority B).

2. Investigate the logic and practical effect of how ERS intermediate inputs compare to those based on input-output tables (Priority B).

**V. Outputs**

Accurate measurement of the prices and quantities of agricultural output is critical for accurate measurement of productivity growth as well as understanding output supply and other important commodity and sectoral relationships. Because a large body of research uses output and input price and quantity measures as basic data, it is important that the aggregates as well as the individual commodities and inputs be measured accurately and communicated clearly. Timeliness, transparency, and public access to the series at each stage of development of the aggregate output series will facilitate its broader value for analysis and policy, as well as invite research and exploration on ways to more accurately develop the productivity accounts to extend their value.

Major issues of concern with regard to accurate measurement of outputs for purposes of the productivity accounts are:

- Measurement of sectoral output and input
- Definition of the sector, i.e., the scope of the establishments to include
- Accounting for quality changes
- Measurement of prices relevant to the sector, including the effects of different tax and subsidy forms
- Aggregation
- Type of productivity measures to compute
- Consistency between aggregates and state and international cross-sectional comparisons
- Data quality

**1980 AAEA Task Force Recommendations**

AAEA Task Force (Gardner et al. 1980) recommendations addressed each of the above issues. They recommended that ERS a) account for quality changes to provide a close-to-total productivity measure, b) switch from a Laspeyres index procedure in which base weights are held constant for an extended period and then spliced with the next period to a Tornqvist discrete approximation to the Divisia index procedure that adjusts weights every year, c) focus on TFP for all agricultural output and not develop TFP measures for individual outputs, d) use comparable definitions for cross-sectional comparisons across states or nations, e) utilize most reliable data sources, and f) report more analysis and fewer numbers.

They also included commendation for focusing on multifactor productivity using gross output measures and using an index number approach rather than switching to a production function approach (since TFP changes account for technical and allocative efficiency changes as well as technical change).
However, only two of the recommendations were uniquely output-oriented: a) concentrate on productivity measures for a more stable definition of the product, and b) include net indemnity payments from publicly-provided disaster insurance in the measure of output. With regard to the first, they recommended that the definition be raw agricultural output measured at the first point of assembly rather than measured as the output of farms. Their concern was that the output of farms depends on what is done and not done on the farm and thus varies with commodity, location, time, and business establishment.

For the most part, their recommendations are consistent with the later OECD Productivity Manual (OECD 2009, pp. 23-24). This manual notes that data quality is enhanced when output and input measures are based on the same statistical sources. It finds that gross, sectoral, and value-added measures all have value as valid complements at the industry level. Sectoral and value-added measures converge at the aggregate level, but require additional restrictions on the specification of production technology related to the separability of primary and intermediate inputs.

ERS Current Practice

Output is measured as the sum of marketings, net inventory accumulation, and consumption by farm households. The gross measure has become the standard now used by many government agencies when developing productivity accounts, but the BLS continues to use the sectoral concept.

It appears that the most appropriate data available are generally used to construct the productivity accounts. Production and marketing data are collected by NASS through surveys of farms. Prices received data are collected by NASS from surveys of purchasers at the first point of assembly (e.g., packers, dealers, auction houses). Use of these data result in a stable product definition of output, i.e. raw agricultural product measured at the sector border between agriculture and processing.

Discontinuation of the NASS Farm Labor Survey has resulted in the discontinuation of the state-level accounts because other labor data of sufficient quality and breadth do not exist.

Net distorting payments (deficiency, diversion, loan deficiency, market gains, certificate gains, milk income loss payments) are added to market prices of individual commodity output prices and distorting taxes (dairy assessment) are subtracted. Non-distorting flex payments are treated as transfer payments and not included in output price. Although potentially distorting, counter-cyclical payments are also ignored because the data are aggregated with flex payments.

They have continued to use an index number approach and have switched from Laspeyres indexes for aggregation to Tornqvist indexes that adjust weights every year. They appropriately use revenue or cost shares as weights. ERS has discontinued reporting partial productivity measures, and they don’t develop productivity measures for individual outputs. They use comparable definitions for cross-sectional comparisons.

More attention has been given to explaining construction of the statistics. In addition to reporting statistics, considerable analysis has been conducted and reported. Exploration of alternatives for improving the productivity accounts has become a standard part of the ongoing effort. However, while considerable attention has been given to measuring quality changes in inputs, quality changes in outputs has not been addressed in the productivity accounts.

Our Assessment

We concur with the AAEA Task Force in commending ERS for computing gross measures of outputs and inputs. While both gross and value-added measures are valid complements at the industry level, the gross measures are more appropriate because they do not impose the arbitrary and generally unsupported assumption of weak separability of the underlying production function between labor and
capital provided by the sector and inputs provided by other sectors. Many other government agencies have now followed ERS in adopting the gross measurement concept for outputs and inputs, or something closely related, in their productivity accounts. For example, the Bureau of Labor Statistics uses sectoral output defined as gross output less intrasectoral purchases.

We also concur with the AAEA Task Force in commending ERS for focusing on multifactor productivity rather than partial productivity measures. We concur with the Task Force that:

“The most important uses of productivity statistics are: (1) identifying the sources of economic growth, (2) justifying the appropriation of agricultural research funds, (3) estimating production relationships, (4) serving as an indicator of technical changes, [and] (5) comparing intersectoral economic performance ....” (Gardner et al. 2000, p. iii)

Partial productivity statistics compare intertemporal ratios of output quantity to the quantity of a single input. As such, they have important limitations and are often misleading for the decision-making purposes for which they are used. ERS appears to have discontinued reports of partial productivity statistics. Our internet search failed to identify any partial productivity measures produced by ERS in the last decade.

Several of the issues warrant further comment and/or revisitation, some of which are also addressed in other sections.

**Measurement of sectoral outputs which are also inputs**

Own-account capital formation, whether building a house for a farm employee, accumulating inventories, investing in land improvements such as tiling, or spending on farmer safety, should conceptually be treated consistently on both sides of the account. For example, if the labor and intermediate materials used in tiling is on the input side of the account, the land improvement should be on the output side of the account. Alternatively, the input should be netted out of the input side of the account. Similarly, if farm resources are used to build a barn, the barn should be on the output side of the account, or the resources used to build the barn should be removed from the input side of the account. Feed produced on one farm and used on another is both an output and an input. ERS includes the imputed rental value of employer-provided housing and inventory accumulation and the value of feed sold and purchased as both input and output. Land improvements, however, are currently included only in the input quantity measure but not in output quantity. Recent exploration by ERS has discovered that data are available on investment in land improvements to permit their incorporation into the output measure, and they plan to incorporate this into future revisions.

**Measurement of prices relevant to the sector**

Although ERS accounts for most distorting government programs in commodity output prices, the distorting effects of crop insurance are not included. Because of the subsidy, the effect of crop insurance is to increase the effective output price for the insured crop. By increasing effective price while simultaneously reducing risk, crop insurance can be expected to induce increases in both outputs and inputs. Under decreasing returns to scale this would result in a decrease in productivity, but under constant returns to scale, as assumed in the national agricultural productivity accounts, it would have no effect. What is clear is that subsidized crop insurance increases the effective price of the insured crop in addition to reducing risk and is thus distorting. Thus, the subsidy augments market price and should be included in the calculation of the effective price faced by farmers.

We concur with the way that ERS uses market and distortion policy-adjusted commodity prices. Prices inclusive of distorting subsidies and exclusive of distorting taxes are used to aggregate across outputs. Market price (alternatively, opportunity cost) is used to value on-farm consumption because the policy
distortions are not dependent on use of the output. The only issue is that the distorting effects of crop insurance are not considered in aggregating across outputs.

**Aggregation**

The Divisia index is an exact aggregator for a linear homogeneous translog production function, so it has considerable appeal when production is well represented by the translog production function. The Tornqvist discrete approximation is used in implementation of the Divisia index. The Tornqvist index uses two-year rolling average revenue shares (expenditure shares for inputs) as the weights in computing geometric means of the individual commodity (input) data. This index, recommended by the AAEA Task Force and implemented by ERS, is an important improvement over the Laspeyres index previously used which uses base weights over extended time periods. However, it is not clear that the geometric mean is an improvement over the arithmetic mean calculation of the Laspeyres. That depends on the nature of the underlying functional form of U.S. agricultural production.

Unfortunately, there has been little comparative research in the last few decades on the form of the agricultural production function.37 There has been more attention to choice of functional form of dual models of U.S. and state-level agricultural production. While the evidence is inconclusive, the translog has not fared better in empirical tests than alternatives such as the quadratic or generalized Leontief (e.g., Perroni and Rutherford 1998; Anderson et al. 1996; Ornelas, Shumway and Ozuna 1994; Shumway and Lim 1993; Ornelas and Shumway 1993), both of which are better represented by an arithmetic mean than a geometric mean aggregator function. What is clear is that empirical evidence of theoretical consistency and policy-relevant implications of the dual production models are both sensitive to choice of functional form (e.g., Baffes and Vasavada 1989). The same is true for sectoral productivity measures using different aggregator functions when prices change substantially.

Most researchers and government agencies who compute TFP rely on the translog as the underlying production function. While it may fail to secure unambiguous empirical support, there is an alternative way to arrive at the translog as an appropriate basis for indexing. That is to differentiate the nominal accounting identity and the group quantities. Multifactor productivity can then be defined as the difference in quantity indexes. The relationship between true technology and measured multifactor productivity is broken, but this is still a valid index of productivity in the sense that it takes into account all measured inputs weighted appropriately.

Despite the current dominance of the Divisia index as the aggregator function used for productivity measurement and its validity as an index of productivity, alternatives warrant consideration. For example, the chained Fisher index is consistent for both extremes of substitutability, i.e., linear and Leontief aggregator functions (Diewert 1976).38

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37 Fulginiti (2010) used the square rooted quadratic output distance function to represent the U.S. aggregate technology because of its relative ease for imposing regularity conditions. Giannakas, Tran, and Tzouvelekas (2003) conducted tests of several functional forms for estimating stochastic production frontiers of Greek olive orchards. They concluded that the Box-Cox dominated all nested functional forms including the translog, generalized Leontief, and normalized quadratic but that none of three non-nested functional forms (Box-Cox, minflex Laurent translog, and minflex Laurent generalized Leontief) dominated another form.

38 Recent work seeking to explain TFP growth in U.S. agriculture has been based on a variety of functional forms, including translog cost functions (Plastina and Fulginiti 2012), normalized quadratic value functions (Onofri and Fulginiti 2008), and quadratic cost function (Wang et. al. 2012).
Data quality
The issue of data quality is an ongoing concern of all involved with data collection, processing, and use. Substantial effort has been expended to ensure that the best available data are used in the construction of the productivity series. There is considerable coordination between agencies. For example, to develop cash output prices, the ERS Farm Income Group develops cash receipts (including net loans) and quantities marketed data series from primary data collected by NASS in the ARMS surveys. The ERS Productivity Group searches for outliers and works with the Farm Income Group when evidence of errors are found before dividing cash receipts by quantities marketed to develop the cash price series for each commodity.

Recommendations

1. To account for the distorting effect of crop insurance when outputs are aggregated, add the insurance indemnity to the insured crop’s price and deduct the farmer’s premium (Priority A).
2. Revisit measurement issues related to own account investment, specifically consistency between the output and input sides of the account (Priority A).
3. Continue to explore the effect of alternative aggregator functions, including the chained Fisher index, on productivity measures and include sufficient detail in the data available on the website to enable users to explore them (Priority C).
PART 2

The first section of this report addressed specifics of methodology and measurement issues related to the particular outputs and inputs. This section addresses issues that are broader in scope, including quality adjustment, residual claimants, research and development spending, alternative assumptions, and the ERS website.

VI. Quality Adjustments

The theory of productivity measurement prescribes that the outputs coming from and inputs used in production should be measured in constant-quality units (Jorgenson, Ho, and Stiroh 2005; OECD 2001b). The intuition for this is that productivity measurement attempts to differentiate between shifts in the production function (change in technology) and movements along the production function (input substitution or change in input use). Outputs and inputs need to be measured in constant-quality units because a change in the quality of one for a fixed level of the other is a shift in production possibilities. ERS recognizes the importance of capturing quality in their productivity accounts and uses state-of-the-art techniques to adjust a subset of their input series for quality improvements. However, a few open questions remain. This section provides a brief overview of quality adjustment and addresses how each of the components of the ERS productivity accounts addresses the issue of quality change.

A Simple Model of Production with Quality Change

As an illustrative example of the importance of considering quality change when measuring productivity, consider a Cobb-Douglas production function:

\[ Q = AK^\alpha L^{1-\alpha} \]

where \( Q \) is the raw number of units of output produced. Allowing for quality change of output and the capital input, the production function for quality-adjusted output can be rewritten as:

\[ Y = q_Y Q = q_Y A(q_K K)^\alpha L^{1-\alpha} \]

where \( q_Y \) and \( q_K \) represent the quality of output and capital input, respectively, and \( Q \) and \( K \) represent the raw quantity of output and capital input. This specification makes it obvious that a shift in \( A \) cannot be distinguished from a change in \( q_Y \) and amounts to a shift in the production function for \( Y \). An increase in \( q_K \) is movement along the production possibilities curve, i.e., the production of output using additional constant-quality capital input.

Figure VI.1 demonstrates graphically the difference between a shift in production possibilities (TFP growth) and a movement along the production possibilities curve by employing higher quality capital.
Quality and Composition in Productivity Measurement

In discussions of productivity measurement, it is easy to confuse the notions of quality and composition. This confusion may occur when discussing both the output and input side of the production account. Typically, quality refers to a particular characteristic, or set of characteristics, that determines the functionality of the output or input. For example, the processing speed and memory of a computer or the effectiveness of a particular fertilizer are intuitive examples of characteristics that are important on the output and input sides of industry-level economic accounting. For reasons discussed above, it is important in productivity analysis and measurement that individual outputs and inputs be measured in constant-quality units.

Composition effects in productivity measurement are related to measures of quality, but composition effects are a byproduct of the aggregation of heterogeneous outputs and inputs when constructing measures of productivity. For example, in the aggregation of multiple individual outputs to a single industry-level output, the Tornqvist index weights each output by the average of its revenue share in the current and previous period. Thus, outputs with higher revenues receive higher weights when aggregating over individual outputs. In comparison, an alternative model of output that is more restrictive may impose the condition that all outputs are homogenous and thus have the same price.

Note: In the case of a single output or input, aggregation is a non-issue, but in the farm productivity accounts there are multiple outputs and inputs.
This restrictive assumption provides an alternative measure of industry output growth. The difference between the two measures is due to composition, or reallocation.\footnote{Jorgenson et al. (2007) refers to the difference between value added growth from an aggregate production function (homogenous good) and the Tornqvist index on industry value added as reallocation.}

**Quality of labor input (non-contract)**

The ERS labor measure categorizes workers by gender, age, education, and employment class (and state for the state-based estimates).\footnote{The ERS website notes that they follow the Jorgenson, Gollop, and Fraumeni (1987) classification but do not state explicitly the age and education groupings. The groupings should be included in the website notes.} The key feature of the ERS methodology on labor input measurement is that it identifies industry-wide substitution towards workers of differing marginal products as changes in the measure of labor input, consistent with the theory of productivity measurement. In the terminology of Jorgenson, Ho, and Stiroh (2005), substitution towards workers with higher marginal products is termed a change in “labor quality” (or labor “composition” in the terminology of OECD (2001b)). The methodology of constructing labor input as an index number over these different types of workers appears to implicitly assume that the quality of worker by each demographic group is constant over time. That is, the quality of an hour worked by the self-employed farmer of a given age (experience), gender, and educational attainment is the same in 1948 as in 2011. Further, the classification presupposes that there are no other dimensions on which workers differ in their marginal productivities. For example, to purchase an additional unit of labor services, a farm owner pays workers with and without specialized training the same wage rate if the worker is in the same demographic group. It is important to note that the assumption of constant quality by worker type is not the same as assuming that the marginal product of the workers by type is fixed over time.

Overall, the ERS labor input measure for non-contract workers follows standard practice with respect to controlling for worker quality (Jorgenson, Gollop, and Fraumeni 1987; OECD 2001b). An open question remains as to whether there are categories other than gender, age, education, and employment class that are important (and feasible) to include in the estimates of labor composition. For example, specialized workers within the current demographic groups are not identified, nor are supervisory and non-supervisory workers. In a previous version of the data, ERS recognized occupational categories (Ball 1985). Including occupation has the potential to account for shifts to skilled supervisory workers. A finer breakdown of labor attributes might allow for different patterns of quality change. However, it is not clear that the data required for a finer breakdown are available.

One potential concern is the implicit argument that age of worker identifies experience. Due to changes in preferences, job conditions, or external events (e.g., war), the experience of a given age may be very different across cohorts. It is an open question how important this effect is for the measure of labor input.

**Capital input**

The underlying assumption of the capital input measure is that the prices used to deflate investment are measured in constant-quality units. Thus, in the estimation of productive capital stock, investment flows are added to the stock in constant-quality units. That is, a capital good with double the quality of the previous period adds twice as much to the productive capital stock. With measurements of nominal investment, controlling for quality occurs by applying the appropriate quality-controlled price index.

The ERS productivity account takes investment deflators from the BEA and BLS. ERS has conducted research suggesting the investment price for tractors requires additional quality adjustment, but they
Currently use the BLS deflator for tractors. They do not make additional adjustments for investment good quality.

For land prices, ERS assumes homogeneity at the county level, and average price per acre is used. There have been important changes, mainly with the introduction of irrigation, and these are not captured by the procedure used. The data on irrigated acres is available at the county level and there are some statistics for rental rates. The assumption of homogenous land at the county level should be reevaluated. Furthermore, ERS assumes that additions to and subtractions from acreage within a county are for homogenous land, abstracting from the likely alternative that land discards occur in unproductive land (see Soloveichik (2014) for a more detailed discussion).

**Intermediate inputs**

The ERS productivity account recognizes the importance of quality change in intermediate products that are used by farms. For a subset of the intermediate goods used in the agricultural industry (pesticides, fertilizer, and purchased contract labor services), ERS makes adjustments for quality gains using hedonics. For other categories, the ERS relies on published price deflators.\(^{42}\) The website mentions that “Input measures are adjusted for changes in their quality, such as improvements in the efficacy of chemicals and seeds,” but we find no evidence that seed price is adjusted for quality change. Potentially, quality adjusted seed prices could be constructed with either hedonics or matched model methods depending on data availability.

For the majority of the intermediate inputs ERS relies on input prices from the Survey of Agricultural Prices. For purchased services, ERS uses the BLS implicit capital rental price index for machines. The rationale for this is the assumption that agricultural services that are outsourced are perfect substitutes for own account services. This assumption is debatable because it implies zero productivity gains relative to owned machines in the provision of these services, when productivity gains would be a major reason to switch to the service. The intuition for why productivity gains in outsourced services could induce switching is that productivity can be equivalently identified as a decrease in the output price per price of input. Therefore, a productivity gain in Agricultural Services is manifested as a lower price which could potentially induce the farmer to switch to outsourcing if not matched by the same productivity increase in owned machines. ERS should investigate deflating Agricultural Services with an alternative price index from BEA or BLS that captures market transaction prices.

**Output**

Quality improvements in output are not addressed in the ERS accounts. Potential quality improvements are the development of organic foods, reduced food-borne illnesses (safer foods), increased availability of milk and eggs in the winter due to improved farming methods (not improved transportation), more flavorful products, high oleic soybeans, high-total-fermentable-ethanol hybrid corn, specialized corn, high protein wheat, chicken with a higher proportion of white meat, lower fat meats, free range meat, vegetables that are easier to transport, and increased variety.

It is unclear whether such commodity-specific quality changes are of sufficient magnitude to alter the measurement of sectoral productivity. For example, if prices for groups such as organic fruit and non-organic fruit are tracked and then aggregated, is the aggregate measure different than if all fruit is aggregated first? If it is, then following the pattern of developing hedonic indexes for pesticide and

\(^{42}\) Hedonics is not the only alternative for quality adjustment, and statistical agencies often use matched-model approaches to construct constant quality price indexes. Both hedonics and matched-model approaches are potentially effective with the proper source data and econometric techniques, although oftentimes estimates will differ across methods (Triplett 2004).
fertilizer inputs, similar methods could be explored for measuring quality changes in outputs. Matched model price indexes are another possibility. The work of Chun and Nadiri (2008) could inform this process.

**Recommendations**

1. Research methods for incorporating quality adjustments to seed and consider whether seed quality change should be treated solely as an input, or both an output and an input (Priority A).
2. Determine whether the degree of quality change in outputs has been sufficient to warrant quality adjustment, and, if so, explore alternative methods to adjust productivity measures for output quality change (Priority B).
3. Check alternative data sources for price of purchased machine services (Priority B).
4. Research the possibility and ramifications of subdividing labor into supervisory and nonsupervisory workers in the cross-classification of labor (Priority C).

**VII. Residual Claimants**

In the U.S. and international TFP calculations, it is typical that modelers impose the assumptions that producers operate in a perfectly competitive market, face constant returns to scale, and pay each factor of production the value of its marginal product. Under this set of assumptions with the additional stipulations that outputs and inputs are measured properly and in constant quality units, changes in TFP correspond to changes in economic technology, i.e., innovation. For these assumptions to hold, it is necessary to “clear the account” to ensure that gross receipts equal gross expenditures. After deducting the cost of purchased inputs that are fully utilized in the production period (typically a year), the operating surplus is distributed across capital inputs and unpaid operator and family labor. This distribution requires that one or more of these inputs becomes a “residual claimant” input in deriving its rental rate. Whether all or just a portion of the various capital and unpaid labor inputs is designated the residual claimant is a decision of judgment influenced but not dictated unambiguously by theory. The same can be said about how to allocate the residual if multiple inputs are included as residual claimants.

One important theoretical consideration in choosing the residual claimant(s) is the length of run considered in the TFP calculations. For example, if TFP calculations are based on a relatively long run, then the residual claimant(s) should be the input(s) that remain fixed (or quasi-fixed) for the longest adjustment period. If TFP calculations are based on the short run (e.g., a single production period), then the residual claimants should be all inputs that remain fixed over the selected short-run period. In that case the residual should be allocated among claimants in a way that equalizes the rate of return to the fixed inputs. Diewert (2012) argues that, when all fixed assets carry the same risk, the real rate of return should be the same across the fixed assets, which is consistent with the implementation in Jorgenson, Gollop, and Fraumeni (1987). Gu (2012) defends Statistics Canada’s use of the nominal rate of return as the equilibrating price, which is consistent with Jorgenson’s recent modeling in which all inputs are flexible, i.e., long run, no adjustment costs, and perfect foresight (e.g., Jorgenson, Ho, and Stiroh, 2005). In the latter case, there are no fixed inputs so all inputs share alike as residual claimants. Approaches to rates of return are also considered in the OECD capital manual (OECD 2009, pp. 66-75).

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43 Having unpaid operator and family labor is the most serious issue in mixed-income industries. Such industries have a subset of enterprises owned by members of the household who also work without receiving a wage or salary. It is not a major issue in industries dominated by publicly-held corporations. The latter may use self-employed workers, the cost of which is typically included in the productivity accounts as part of labor expense, generally as contract labor. It is a severe issue in agriculture.
A single fixed input, land, has been chosen for the U.S. agricultural productivity accounts as the residual claimant. This is consistent with the view that land is the most nearly fixed of all inputs used in agricultural production and consequently is the residual claimant for rents from production. An alternative single fixed input, entrepreneurship, could also be considered for the agricultural productivity accounts (Diebolt 2014). Since data are available on the actual payments for rented land, land rents and the imputed wages for unpaid family labor could be subtracted from the net operating surplus to obtain the entrepreneurial residual to land and labor supplied by the farm proprietor.

BLS splits the residual between self-employed and non-corporate capital assets. Their logic and procedure for implementing the split is documented in a BLS bulletin (USDOL 1983, p. 52).

Agriculture and Agri-Food Canada has chosen self-employed labor as the residual claimant to “clear the account”. They argue that this is “consistent with the usual definition of net farm income, where all but operator/unpaid family labour is accounted for” (Strain 2013). It is also consistent with Canada’s federal tax code for non-corporate farms that allows all expenses except the operator’s labor to be deducted from revenue and with Statistics Canada’s definition of net farm income (Cahill 2014). Cahill argues that there is little theory to guide the selection of residual claimant(s). They cite Hotell and Gardner (1983) and Gardner (1992a) in support of their choice of self-employed labor as the residual claimant. There is also a practical reason for their choice – they lack a satisfactory data base for imputing the wage for self-employed labor (Commission of the European Communities, et al. 1993). Diebolt (2014) notes that an argument against this choice could be made by considering the possible sale of the farm with a professional manager subsequently hired to manage it. In this case, both farm labor and manager salary would be paid and the residual would accrue to the land owners. The same would occur without a land sale by the existing owner-operator choosing to hire a professional manager and no longer working on the farm.

In their analysis of Canadian multifactor productivity, Diebolt and Yu (2012) use 17 separate capital stocks as the residual claimants and assume that all receive the same real rate of return, which was computed endogenously. The Statistics Canada’s Canadian Productivity Program spreads the residual across all capital inputs by assuming that all capital inputs within a sector receive the same nominal rate of return (Gu 2012). This difference in the use of real or nominal rates of return is largely responsible for the substantial differences in Diebolt-Yu’s and Statistics Canada’s estimated TFP growth over the half century, 1961-2011, 1.03% vs. 0.28% average multifactor productivity growth rate (Diebolt 2012). Diebolt defends use of the real rate of return as the balancing price on the basis of better following market rents and leasing rates as well as greater stability in the real rate of return over time. Jorgenson, Ho, and Stiroh (2005) further argue for incorporating asset-specific capital gains into the calculation of the real rate of return since assets, such as computers, with large expected capital losses would only be purchased if they have relatively high marginal products. Regardless of how one regards the persuasiveness of these arguments, it is clear that how rents to the residual claimants are handled matters in empirical estimation of TFP.

**Recommendation**

The committee does not have an unambiguous recommendation for altering the residual claimant used in the national agricultural productivity accounts. Continuing to use land as the residual claimant is supported by the logic of selecting the input that is most nearly fixed in long-run supply. It is also an

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44 While Cahill (2014) cites Gardner (1992a) as referring “to the earnings of farm operator households as a residual”, Gardner actually refers to these earnings as “part” of the residual which also includes the returns to “capital assets” (page 83).
intermediate choice between the extremes of a) all capital assets plus self-employed labor and b) entrepreneurship.

The committee does recommend that this be a subject of research and thoughtful consideration in the future (Priority B). As a minimum, the sensitivity of the productivity accounts to the alternative residual claimant extremes and different choices of expected asset inflation should be explored.

VIII. Research and Development

It is widely recognized that spending on research and development (R&D) potentially yields future improvements in production. This is because current spending on R&D yields a capital service flow over time. The 2013 Comprehensive Revision of the U.S. NIPA officially recognized spending on R&D as the production of an investment good, and measures of fixed assets, capital stock, capital consumption, and GDP were revised to reflect this treatment (McCulla, Holdren, and Smith 2013). This redefinition has implications for productivity measurement because recognizing R&D requires potential adjustments to the output side (when own-account R&D is produced) and to the input side of the production accounts (when R&D capital is used in production). The February 2014 release of the BEA industry accounts (including the farm industry) reflects the production of R&D output, and (Rosenthal, et al. 2014) incorporates R&D in both the output and input side of the BEA/BLS industry-level production account.

In practice, on the output side of the account, if R&D is conducted in the same establishment as the primary output, this spending on R&D (total expenses) should be added to the value of gross output of the industry, and industry value added should increase by the same amount. If there is any own-account R&D, the growth rate of the price index for industry output is now an aggregate of the pre-R&D output price and the R&D price. That is, industries that undertake R&D are modeled as producing two distinct outputs. On the input side of the account, flows from R&D capital should be priced by the implicit rental rate. It’s noteworthy that while the official GDP by Industry accounts conceptually allows for R&D spending by any industry, the current version does not attribute any R&D spending to the Farm sector.

R&D in the ERS Agricultural Productivity Account

Currently, the ERS does not consider R&D on either side of their agricultural production account. This section provides some background on R&D measurement and discusses the rationale for and feasibility of incorporating measures of R&D into the measure of agricultural productivity. R&D activity has played a clear role in the advancement of agricultural production, but the case for adjusting the ERS productivity accounts to reflect R&D is not clear cut.

Between 1948 and 2011, the period covered by the current ERS productivity account, it is not obvious what, if any, own-account R&D was taking place on farms. Potential investments in R&D include spending on improved breeding methods (for animals and plants), worker safety, and seed improvement. Anecdotal evidence from on-farm visits suggests that farmers engage in creating their own equipment and other innovations. For example, farmers invest resources in recombining machinery parts to create new artifacts, modifying feed ratios and health recommendations, changing application of chemicals, and creating GPS maps to inform fertilizer recommendations. These are difficult to conceptualize, let alone measure.

Taking a concrete cast, Monsanto is a company that conducts a significant amount of agriculture-related R&D. Compustat reports Monsanto as an agricultural company, implying that R&D spending by

45 Typically, the R&D output price is based on R&D input price growth, plus a productivity adjustment. See Robbins, et al. (2012) for details on the price index and Strassner and Wasshausen (2013) for a discussion of defining industry output.
Monsanto would be treated by Compustat as an output of the agricultural sector within the framework of industry-level productivity. But if the primary output of a Monsanto establishment is R&D, not agricultural output, then the appropriate place to include this R&D is the R&D sector because outputs are grouped by the primary good of the establishment. According to Monsanto’s website, the company produces agricultural and vegetable seeds, plant biotechnology traits, and crop protection chemicals. An open question is whether any R&D takes place as secondary production in establishments where the primary output is farm products, for example seed production. If not, then no adjustments to the ERS-measured farm output are required in this particular case.46

It’s also noteworthy that the NAICS classification for Farm includes breeding related establishments. To the extent that there has been R&D in breeding by these establishments over the time series, an adjustment to farm output may be warranted.

In summary, own-account R&D spending by farms should be added to farm output if it exists, but additional research is required to determine what type of farm R&D was conducted, when it was conducted, and by whom it was conducted. Further, according to the SNA, “the salaries of employees engaged in own account capital formation are directly classified as acquisitions of capital formation,” so any paid work done on the farm to build future productive capacity is potentially spending on capital formation and should be treated as such (European Commission et al. 2009).47

The input side of the productivity account should, ideally, account for all inputs used in production of R&D including the flow of services from R&D assets, regardless of the original investor in the R&D. Due to limited source data, the investment data by industry and asset that is produced by the BEA (and which underlies the ERS capital estimates) includes R&D investment, but the R&D assets are allocated to industries by the original funder. Thus, for example, farm-related R&D conducted by the government is allocated to the government sector, even though this investment yields a direct service flow to the agricultural sector.

Reconsidering the Monsanto example, presuming that Monsanto were not classified in the Farm industry, then allocating R&D investment to the capital stock and services of Monsanto is consistent with productivity measurement theory, even though the output of Monsanto’s R&D is used by farms. The reason why this is a reasonable treatment is that R&D investments and capital used by Monsanto presumably leads to quality improvements in farm inputs which are purchased and measured on the input side of the agricultural productivity account.

The recognition of R&D as an investment good reinforces the need for constant-quality prices of outputs and inputs in productivity accounting. The provision of government R&D to the agricultural sector is not captured in the ERS-productivity estimates, but the unmeasured contribution of government investment and services is broader than the single contribution of R&D, and not unique to the agricultural sector.48

In general, national accounting standards and practices do not address the contributions of government to industry production, thus government R&D services provided to the agricultural sector need not be moved to the input side of the agricultural productivity account, even though a theoretically correct measure of TFP should include this input.49

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46 The NAICS classification is establishment based so that establishments within a company may be classified to different industries.
47 This may be more appropriately thought of as organizational capital, which is an active area of research.
48 E.g., military, weather forecasting, highways, GDP statistics.
49 The government produces both investment and consumption goods. If one allows government production of consumption goods to be used as intermediate input by the private sector, official nominal GDP decreases by the value of the intermediate purchases, and industry intermediate input would now include these purchases. If one
Recommendation

ERS should follow developments in the literature on accounting for R&D in the productivity measure, and, if minimal R&D is conducted on farms, include a note of explanation in the methodology description indicating why sectoral R&D is not incorporated in the accounts (Priority B).

IX. Alternative Assumptions

The current ERS policy toward growth accounting maintains the standard basic assumptions that a) factors are paid the value of their marginal products, b) there are no adjustment costs, c) input use is correctly measured, d) outputs and inputs are measured in constant-quality units, e) production exhibits constant returns to scale, f) firms maximize profit, and g) all input and output markets are perfectly competitive. Further, capital utilization is governed by the capital valuation rule (discussed in the non-land capital draft). Capacity utilization is implicitly reflected in the internal, shadow value of capital. This value is computed assuming continuous steady-state, long-run equilibrium. Changes in input quality are accounted for generally through hedonic pricing models or matched-model methods. While output quality is assumed fixed over time, output quality changes potentially could be dealt with by constructing constant-quality adjustments for output or as deviations of prices from marginal revenue.

The logic for these assumptions is the perspective that, over the longer term, most of these assumptions are easier to justify and it is more appropriate to analyze productivity and its growth in terms of the sources of long-term growth. However, there are important examples when long-run equilibrium in the agricultural production sector has been a heroic assumption – the 1970s when there was a rapid expansion of land and capital (including animals) and the middle-to-late 1980s when there was a period of significant financial stress. The significance of the assumption that this sector is always operating at the steady state impacts how the marginal productivity of capital relates to the rate of return on capital (OECD 2009, p.17-18) and the consequent deviations from productivity growth measurement.

While it is rare that an input is fully constrained to the point that its level cannot be changed, an input can present a limited degree of flexibility in adjustment which leads to its alternative characterization as a quasi-fixed factor (i.e., a factor that requires adjustment costs). Oftentimes, a firm cannot readily accommodate large changes in factor use within a single production period. This inability to easily absorb large changes can be related to forces that are internally driven (e.g., the firm’s processes and organization) or externally driven (e.g., transaction costs associated with expansion or contraction, or land markets that are not fluid within a decision maker’s sphere of operation). The implication for non-freely adjustable inputs is that some additional costs must be absorbed by the firm beyond the acquisition cost. The consequence of this inflexibility is an economic environment which places a high cost on adjusting the factor level. Consequently, the marginal product of the quasi-fixed factors bear an extra cost (Eisner and Strotz 1963; Rothschild 1971; Basu, Fernald and Shapiro 2001). Conversely, the characterization of freely adjusted factors implies that altering the levels of these factors does not impose a penalty on the firm beyond their acquisition cost.

A more appropriate view may be the trichotomy of a) the current period decision (or short-run), b) the steady-state equilibrium, and c) the adjustment phase between the current decision and the steady-state equilibrium. The deviations from value of marginal product pricing are the impact of an additional unit of the factor that shifts the internal shadow value of quasi-fixed factors. This adjustment phase has been characterized as the temporary equilibrium (Berndt and Fuss 1989) which occurs when the shadow allows government capital to be used as a productive input by other sectors, aggregate investment is unchanged, but the industry capital accounts would have to be reorganized. We are not aware of any proposals to make these adjustments.
value of any input and/or output differs from its market price. In long-run equilibrium or in static situations, the shadow values equal market prices for all inputs and outputs. That is, the firm is presumed to be making all the right decisions in moving toward the steady-state equilibrium although it may not be there yet.

In an intertemporal production decision environment, there is no longer a short-run period and a long-run period, but rather a continuum of runs. Alchian (1959) and Smith (1961) are two early efforts offering a more complete description of dynamic producer behavior by focusing on the minimization of the discounted stream of costs. Such a characterization focuses on intertemporal costs as a stock concept, while the nested current-period decision problem involves a flow.

The consequence is that the capital factor disequilibrium impact is a component of input growth (Luh and Stefanou 1991). That is, we have variable input growth, capital growth (which depends on the firm’s shadow value of capital), and growth in the shadow value of capital (which is an internal, endogenous ‘price’). The calculation of the disequilibrium involves two components:

1. Valuing the infusions/elimination of the capital stock using the (internal) shadow value of capital, and
2. Accounting for changes in the shadow value of capital as the capital stock is adjusting.

When firms are undercapitalized, the first component has a dampening effect on aggregate input growth and the second component has an expansionary effect on input growth. When the rate of investment is increasing, the overall impact is to dampen input growth. The period of the 1970s was a capital expansionary period in U.S. agriculture, so we can expect that productivity growth was underestimated. During the 1980s firms were overcapitalized and looking to relieve financial stress, so we can expect productivity growth to have been biased upwards. The analytical consequence of such disequilibria is the need to find the relevant shadow values of the capital input series. This would involve an annual calculation either through re-estimation of econometric models [Epstein and Denny 1983] or calculation of a nonparametric-based intertemporal cost minimization [Silva, Lansink and Stefanou 2014].

Similar to capital, the assumption that labor input is paid its marginal product in each period is easy to challenge. For example, under the hypothesis that some forms of education are merely a signal from workers to employers, additional education may have no actual value in the production process. Furthermore, worker intensity may vary over the business cycle, breaking the link between hours as a measure of labor input. See Basu, Fernald and Shapiro (2001) for an example of a macro model that incorporates labor effort.

**Recommendation**

Although a disequilibrium approach to capital factors is not widely applied in the productivity literature, we recommend that ERS engage the scholarly community in an examination of effective ways to account for disequilibrium (Priority C). While there are always legitimate concerns about mixing approaches in the construction of data series, ERS has already been a leader in this regard in its econometric estimation of hedonic prices and series used in the construction of indexes.

**X. Website**

The AAEA Task Force on Measuring Agricultural Productivity (Gardner, et al. 1980) recommended that the productivity statistics be made readily available in electronic form. That has been more than fully accomplished. All data are maintained electronically. Aggregates and sub-aggregates are publicly
available and accessible from their website. Details of individual commodities and inputs are generally available on request.

The ERS Agricultural Productivity in the U.S. website (http://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us.aspx) is the primary means to disseminate ERS productivity-related products, including the data, results, methodology, and related research. It is also accessible through the Agricultural Productivity homepage: http://www.ers.usda.gov/topics/farm-economy/agricultural-productivity.aspx through the “Agricultural Productivity in the U.S.” link in the right sidebar under Related Data. The website includes downloadable Excel files with productivity measures and quantity and price indexes for the U.S. and for each of the contiguous 48 states.

For the U.S. it includes a) productivity measures for several time periods, sources of growth (output and input with input decomposed into labor, capital, and materials and further decomposed into quantity and “quality” growth) and b) annual price and quantity indexes for the output and input aggregates as well as several output and input sub-aggregates. It’s worth noting that the ERS definition of “quality” in their tables may be nonintuitive for novice data users. 50

The sub-aggregates are tiered. In the first output tier there are three sub-aggregates: livestock (including miscellaneous livestock products not separately identified), crops, and farm-related output (which includes output of goods and services from certain non-agricultural or secondary activities; these are activities closely related to agricultural production for which information on output and input use cannot be separately observed). In the second tier, livestock is disaggregated into meat animals, dairy, and poultry and eggs; crops are disaggregated into food grains, feed crops, oil crops, vegetables and melons, fruits and nuts, and other crops (which include sugar crops, maple, seed crops, miscellaneous field crops, hops, mint, greenhouse and nursery, and mushrooms).

The first input tier consists of three sub-aggregates: capital, labor, and intermediate inputs. In the second tier, capital is disaggregated into durable equipment, service buildings, land, and inventories; labor is disaggregated into hired and self-employed labor; intermediate inputs are disaggregated into farm-origin, energy, fertilizer and lime, pesticides, purchased services, and other intermediate inputs.

In September 2013, the U.S. indexes were provided on the website for the years 1948-2011. Recognizing the huge effort required to gather and process the various sources of essential data utilized in developing these indexes, we commend ERS for providing them in such a timely fashion and urge that the current timeline of the statistics be continued and, if possible without sacrificing quality, even shortened.

State-level productivity, price, and quantity estimates that cover 1960-2004 have been available for about a decade, but were first published on the website in September 2013. Although they do not satisfy all desirable properties of spatial indexes, 51 these indexes are spatially as well as temporally comparable and transitive. As with the U.S. aggregate information, they include productivity measures for several time periods and annual price and quantity indexes for the output and input aggregates as well as several output and input sub-aggregates. The output price and quantity sub-aggregates are the same as the first tier of U.S. sub-aggregates – livestock, crops, and farm-related output. The input price and quantity sub-aggregates have two full tiers and a third partial tier. The first input tier is the same as for the U.S. – capital, labor, and intermediate inputs. In the second tier, capital is disaggregated into land and capital services excluding land; labor is disaggregated into hired and self-employed labor.

50 The ERS definition of quality in Table 2 is the difference between weighting schemes in input aggregation. Some others developing productivity estimates refer to this as “composition”.

51 E.g. circularity and identity.
intermediate inputs are disaggregated into energy, chemical inputs, and other intermediate inputs. In the third partial tier, chemical inputs are disaggregated into fertilizer and lime, and pesticides.

The availability of productivity data on the website is a substantial improvement in making the agricultural productivity accounts and major quantity and price indexes used in their development publicly available. Since a primary function of ERS productivity accounts is the data product, it is imperative that the website that hosts the data not only provides the data but also includes pertinent information that helps stakeholders use the data. To be most effective, the website should be a) accessible and findable, b) accurate, c) complete (in the sense that the contents cover the ERS deliverables) and up-to-date, d) searchable, e) legible, and f) explain the role of the productivity program within the context of ERS’s mission and related work. We evaluate each of these criteria in turn. Overall, the ERS productivity program’s website is effective, but some changes should be considered.

**Accessibility and Findability**

The Agricultural Productivity homepage is accessible via the ERS homepage (http://www.ers.usda.gov/) under “Topics->Agricultural Productivity”. It includes a brief overview of the program with appropriate program contacts clearly posted on the bottom of the page. The webpage sidebar splits program deliverables into easy-to-access sections: Related Data, Related Reports, and Related Amber Waves Articles.

Information from the productivity program is findable. Searching for “agricultural productivity” in both Google and Bing ranks the ERS Agricultural Productivity homepage among the first sites. From the ERS homepage, searching for productivity yields the Agricultural Productivity homepage as the third result. There does not appear to be a direct link from the ERS homepage to the agricultural productivity statistics, only to the Agricultural Productivity homepage. Clicking on “Data” on the ERS homepage provides a long list of products, the 6th of which links to the Agricultural Productivity in the U.S. website with links to the downloadable national and state-level Excel tables. Although there are several ways to get to the agricultural productivity pages, links to the productivity statistics might be featured more prominently on the ERS homepage.

**Accuracy**

The descriptions on the Agricultural Productivity in the U.S. website appear to be accurate, and without broken links. One small note is that the “Findings, Documentation, and Methods” section in the left sidebar mentions that productivity provides a summary statistic for welfare (paraphrasing). While appealing, the economic correspondence between productivity and welfare is often avoided except in more academic ponderings.

Accuracy of the website data relative to their internal calculations was not examined by the committee due to limited access to the ERS internal calculations. Verifying that the data posted to the website matches internal calculations should be standard part of the ERS web review, if it is not already.

**Completeness**

As previously noted, the core U.S. and state-level accounts data and methodology are accessible from the Agricultural Productivity homepage under the “Related Data” links. In addition to the link for “Agricultural Productivity in the U.S., there is a link for “International Agricultural Productivity”.

The Agricultural Productivity in the U.S. website contains the national data, the state-level data, and a findings, documentation, and methods section. The national data include price and quantity of the components of farm output and farm input. From these data series, users should be able to replicate the
published ERS-productivity series (this was not verified). The state-level files contain a similar level of
detail and also state-level sub-aggregates, but only for the period 1960-2004.

The website International Agricultural Productivity contains international data and productivity
estimates for 174 countries for the period 1961-2010 and a documentation and methods section.
Productivity estimates, gross agricultural production, and factor shares and quantities of inputs for each
country are included in the downloadable data spreadsheets. Downloadable productivity estimates are
also available for regions.

For both websites, remaining questions are: a) what underlying details of the accounts and their
components (sub-aggregates) are available, and b) how much of the underlying data detail should be
posted to the website, since the final estimates are built up from underlying source data. The desired
goal would be sufficient completeness to enable outside users to replicate the results from the ground
up and to use the source data for additional purposes. Obviously, that goal must be balanced against
releasing underlying source data and estimates that may not be as high quality as the top-line estimates
and also against the burden of building and maintaining an online database of all the source data.
Nonetheless, it should be pursued to the extent feasible, with priority given to the national accounts and
followed by the state accounts. Several stakeholders also recommend that more detailed data be made
available on the website.

Basic documentation is available on the website and is accessible, although the committee found that
many important details are missing. In particular, details on the source data and current methodology is
thin. The committee struggled with the available documentation to understand how the current
estimates were built up from the available source data.

The “Related Reports” section on the Agricultural Productivity homepage is not linked to the “Related
Data” pages, so one must go back to the homepage to get to the related reports or vice versa. It is
noteworthy that the publications related to the construction of the statistics are not included in the
“Related Reports” section. It’s also noteworthy that the “Related Reports” webpages do not link to the
“Related Data” webpages nor vice versa. An alternative would be to create a linked “Related Reports”
page that contains the pertinent reports and is cross-linked with the “Related Data” pages.

**Searchability**

Data is posted to the website in Excel format, and related reports are posted in a combination of html
and PDF format. Because the data is posted in Excel, it is not interactive; that is, users cannot make
queries to request particular components of the data. This is not a major point of concern given the
nature and primary users of the data.

The research and related reports are posted in the appropriately named sections of the website, are
easy to locate, and appear to be searchable through the ERS homepage.

**Legibility**

The website is viewable and legible on various screens and browsers. There does not appear to be a
mobile version of the webpage, but a mobile version is probably extraneous.

**Website and Productivity Program in Context**

The productivity program website gives a brief overview of farm productivity but does not put the
program in context of the USDA mission, nor does it put the agricultural productivity statistics in the
larger context of industry-level productivity analysis. The program should consider including this
information in some form on its website.
Recommendations

1. Provide detailed documentation online and note ad hoc adjustments to data or deviations from the general procedure (e.g., if fixes were required due to negative implied capital rental rates) (Priority A).

2. Expand the website to provide timely access to more detailed data and procedural detail underlying the quantity and price aggregate and sub-aggregate national and state-level statistics (Priority A). The detailed data should include primary data used in the development of each statistic, processed only sufficiently to be non-confidential. The procedural detail should be sufficient to enable outside users to replicate the results reported on the website from the ground up and to use the source data for additional purposes. The data should be maintained in a user-friendly environment on the website for convenient downloading and use.

3. Include a paragraph on typical release dates in addition to the current practice which is to post date of “next update”, which as it turns out is blank (Priority B).

4. At each release, post a note describing revisions and reasons for revisions (Priority B).

5. Change exposition on website about welfare (Priority B).

6. Include links to other productivity related data and research including the BEA/BLS industry-level production accounts, BLS Non-Farm Productivity, European Union (EU) KLEMS, and World KLEMS (Priority B).

7. Add a link to a “Related Reports” page that contains links to the pertinent related reports (Priority C).
PART 3

Part 3 of this report reviews the State-level productivity accounts, the cross-country comparisons, and compares ERS measures to alternatives produced in the research community. Additionally, this section includes information on stakeholder feedback on the productivity accounts.

XI. State-level productivity

During the 1990s and 2000s, ERS prepared state-level productivity measures. They began with the year 1960 and ultimately included estimates through 2004. They also provided underlying price and quantity data series for outputs, inputs, and several disaggregated categories of each component. Since September 2013, the historical estimates have been publicly available on the ERS Agricultural Productivity in the U.S. website. The productivity measures and the accompanying price and quantity series have been widely used by the research community.

1980 AAEA Task Force Recommendations

The AAEA Task Force (Gardner et al., 2000) recommended that ERS continue to develop regional total productivity measures.

ERS Response

ERS responded to the AAEA Task Force recommendation by developing state-level productivity measures for the contiguous 48 states. These accounts have been used extensively in a wide variety of research studies and have been influential in policy analysis as well. They constitute a high quality panel data set that facilitates econometric model estimation at the national level with greater precision than could be achieved with only the national-level accounts. They also permit examination of state and regional issues of importance to local legislators and producer groups.

Unfortunately, the productivity measures have not been updated since 2004 largely because the NASS Farm Labor Survey was discontinued which limited ERS ability to develop spatially reliable measures of the labor input. State-level price and quantity data for some outputs and inputs have been updated to at least 2008, but have not been publicly released.

The most recent state accounts were developed using procedures generally similar to the national agricultural accounts. Data on outputs, land input, capital stocks, and capital input are first compiled for each state before being aggregated to the national level.

Outputs

Data from the NASS surveys on output cash receipts, quantities marketed, gross production, and inventory change are compiled by commodity in each state before being aggregated to the national level. Data on government payments from the USDA Farm Services Agency’s Kansas City office are also compiled by commodity in each state before being aggregated to the national level.

Inputs

Although state-level land price and implicit quantity indexes are constructed as an intermediate step in aggregation to the national level for the national accounts, a different procedure is followed in the state accounts. Spatial price indexes and implicit quantity indexes of land are calculated using a hedonic approach to account for differences in land characteristics across states. This permits estimation of a quality-adjusted price index. This procedure estimates the price of land as a function of soil acidity, salinity, moisture stress, irrigation, population accessibility (population density and distance) and other
characteristics as well as state dummy variables. These are used to construct a quality-adjusted price index at the county level to use in obtaining the implicit quantities.

Tornqvist indexes of land prices and implicit quantities at the state level are obtained based on the county level information. The value of service flows at the state level are the state-level stocks multiplied by the rental rate for land. The rental rate is the expected real rate of return multiplied by the state’s land price index. The expected real rate of return for land is an ex-ante rate of return calculated in the same way as for non-land capital. It is the nominal average yield on investment grade corporate bonds (AAA rated bonds) less the inflation rate captured by the implicit GDP deflator, where inflation is modeled as an ARIMA process.

At the national level, the value of service flows from land is obtained as a residual from the imposition of the accounting identity. In the state accounts, the value of service flows from land is obtained by multiplying the state-level stocks by the expected real rental rate for land. The accounting identity is not imposed in the state productivity accounts.

Measures of capital stocks and capital input are developed for each state. Capital stock for each asset type is constructed using the perpetual inventory method. User costs for each asset type are obtained following the same procedure as for the U.S. aggregate. Investment data is obtained from the ERS Resource and Rural Economics Division. BLS asset price deflators from the Producer Price Index for automobiles, motor trucks, wheel-type farm tractors, and agricultural machinery excluding tractors are used as investment deflators. The implicit price deflator for nonresidential structures is from NIPA. Aggregation for each state is accomplished by aggregating over the different capital assets using the asset-specific user cost indexes as weights.

ARMS provides expenditure data for intermediate inputs. For the state accounts, hedonic price functions of fertilizer and pesticides are estimated for individual states and the United States. Although not publicly released, these input groups and energy have been updated for the states through 2008. For the national accounts, the hedonic price functions are conducted at the national level rather than being aggregated across states. This could lead to some of the inconsistency between the state and national accounts.

Data on purchased inputs and investment come from ARMS.

Until 2002, the NASS Farm Labor Survey was used as the primary source of data on hired, self-employed, and family labor. It provided sufficient detail to reliably estimate state-level labor quantities and prices. The same type of matrices for hours worked and hourly compensation were developed for each state as for the U.S., controlling for hours worked and compensation totals based on USDA data for the state. The farm sector matrices used for the U.S. aggregate were combined with state-specific demographic information available from the Census of Population. This was accomplished using the RAS procedure (Jorgenson, Gollop, and Fraumeni 1987). Using the cross-classified data, indexes of labor input were constructed by state.

Since the NASS Farm Labor Survey was discontinued in 2002, an adequate source of information for updating the cells in the matrices has not been available. At the U.S. level, information is now obtained from the Current Population Survey, but sample size is too small to use this source to update matrix elements of the worker classification at the state level. The discontinuation of this survey played a major role in the decision to discontinue updating the state-level productivity accounts after 2004.

With ERS and NASS participation, hired labor data used in the national accounts now come from BEA. Self-employed labor data in those accounts are from the BLS and are based on the Census of Population and the Current Population Surveys. Unfortunately, these sources do not provide sufficient detail to
reliably estimate state-level labor quantities and prices via the cross-classification method. However, some alternatives have been identified by ERS personnel that might provide minimally sufficient reliability to surmount this obstacle. BLS funds a survey of hired labor. If access to the data can be obtained by ERS, it could provide a sufficient information base to compute state-level hired labor quantities and prices. The American Community Survey provides additional data that could be useful in combination with other sources. ARMS data separate hours worked by hired and self-employed labor. While it will not be possible to develop state-level labor quantity and price series with the matrix element accuracy possible from the NASS Farm Labor Survey, sufficient data sources appear to be available to provide estimates of adequate quality to enable the state-level productivity accounts to be reinstated.

**Spatial indexes**

ERS currently uses the multilateral chain-linked Caves-Christensen-Diewert index to construct state-level input and output price indexes in each state and year.\(^{52}\) This index solves the intransitivity problem of binary indexes, but O’Donnell (2013) documents that it does not satisfy the circularity property and is thus biased. He demonstrates that three alternative multilateral indexes (Lowe, geometric Young, and Färe-Primont) satisfy nine desirable properties, including transitivity and circularity. Each is a properly constructed multilateral index and is preferred to the Caves-Christensen-Diewert index.

**Our Assessment**

**Continue the state-level accounts**

The lack of data of sufficient quality is most acute for labor because it hinders development of reliable state-level labor price and quantity series. The loss of reliable farm labor data has been primarily responsible for discontinuing the widely used and important state-level price, quantity, and productivity series. This is a great hindrance to high quality research on the economics of U.S. agriculture important for public and private decision making.

Our independent assessment, which is supported by input from several stakeholders, is that the state-level accounts are too important to be discontinued regardless of data and resource challenges. They provide the foundation for the U.S. aggregate accounts and give more detail, consistency, and robustness to the U.S. aggregate. These panel data are important in econometric analysis by achieving greater statistical efficiency and reliability, and they are widely used. Further, although they may not provide the same quality, other options (e.g., BEA/BLS) exist for developing national agricultural productivity accounts. No other options exist for reliably developing state-level agricultural productivity accounts.

While U.S. aggregate accounts trace performance across time, they do not provide understanding of performance across space. The state-level series are essential to understand differences in regional performance driven by differences in endowments and comparative advantage across the U.S. regions. They allow examination of the supply of geographically-specific commodities and enhance our understanding of the impacts of commodity-specific policies in particular regions and how they alter regional terms of trade and geographic distribution of income, in particular returns to labor. Rural development, as well as food security policy, is informed by knowledge of the impact of innovations on labor and labor mobility across regions and across sectors. The usefulness of the U.S. productivity accounts is greatly enhanced when we understand performance of the regional economies and the differential impacts of federal policy on regional and state performance.

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\(^{52}\) The ERS Agricultural Productivity in the U.S. website indicates the Elteto-Koves-Szulc index is used to construct these indexes.
The importance of this assessment is evident by the large amount of research and policy work that has made use of the state-level data. A considerable number of researchers and analysts have used the state-level data for research. This includes a wide array of government and university researchers. For example, a Google search of Ball’s productivity research yielded 80 publications, the 4th most highly cited of which was Ball et al. (1999) that developed and explained the state-level quantity and price series developed by ERS for TFP analysis. The large number of citations helps document the need to revive this part of the ERS program. The importance for high quality research of continuing and strengthening the state-level series was also registered by stakeholder input.

Continuing the state-level accounts will not only require additional analytical and data processing effort by ERS personnel but will require coordination with the data collection agencies to ensure that farm labor data are collected in a way that is regionally reliable and available for interagency use.

**Spatial aggregator index**

Alternative spatial aggregation indexes that satisfy all nine desirable properties of spatial aggregation indexes, including identity, transitivity and circularity, warrant exploration. They include the Lowe, geometric Young, and Färe-Primont indexes.

**Comparability between national and state accounts**

The state-level price and quantity indexes have been developed using procedures generally consistent with those used to develop U.S. indexes (Ball et al. 1999). We commend ERS for the care used in developing the state-level series to ensure considerable consistency with the U.S. series. However, our examination of the data available on the ERS Agricultural Productivity in the U.S. website reveals some important differences:

- Gross receipts equal gross expenditures in the U.S. series but not in the individual state series nor in the sum of the state receipts and expenditures.
- The sum of gross state receipts is not equal to U.S. gross receipts, nor is the sum of gross state expenditures equal to U.S. gross expenditures.

Ball et al. (1999, p. 165) provide one explanation for the second difference. They note:

“Interstate deliveries of output (livestock and feed) from farms in one state to farms in other states enter state-specific intermediate input and output accounts. From the perspective of the aggregate U.S. farm sector, however, these interstate transactions are wholly internal to the nationwide farm sector and therefore do not enter the aggregate accounts.”

This would imply that the U.S. gross output receipts and gross input expenditures should always be smaller than the sum of the corresponding state series. That is not the case in the online data series. In some years one or both is smaller and in other years larger. On average, U.S. input expenditures are smaller, but output receipts are larger. Consequently, greater consistency between the two series is needed as well as clearer explanation of reasons why they cannot be totally consistent, e.g., theoretical reasons, lack of consistent data between the two levels of geographic aggregation, data revisions at the national level that have not been incorporated into the state-level accounts.

State-level price and quantity series reported on the website (USDA 2014) are not for the same sub-aggregates as the national series. Currently, there is an additional tier of output sub-aggregates for the U.S. than for the states. It would be helpful to report the additional tier in the state-level series. In the second tier of input sub-aggregates, the U.S. series has a larger number of disaggregated capital categories. It also has a larger number of disaggregates within the other intermediate input category but does not have the chemical aggregate of fertilizer-lime and pesticides.
Recommendations

1. Continue to develop and publish state-level total productivity measures as well as price and quantity series – strongly recommended (Priority A).
2. Cooperate with other government agencies to achieve the lowest cost method of collecting data of sufficient quality to enable the state-level accounts to be extended and maintained (Priority A).
3. Investigate the possibility of using information in the American Community Survey to update matrix elements in the state labor accounts (Priority A).
4. Ensure consistency between the national and state accounts where possible, and explain circumstances that prevent total consistency where it is not possible (Priority A).
5. Report state-level price and quantity series on the website for the same sub-aggregates as the national series (Priority B).
6. Update the state-level accounts on the same schedule as the national accounts (Priority B).
7. Place more underlying data detail on the website (Priority B).
8. If feasible, include Alaska and Hawaii in the accounts (Priority C).
9. Replace the Caves-Christensen-Diewert spatial aggregator index with a Lowe, geometric Young, or Färe-Primont index (Priority C).

XII. Cross-country comparisons

There is considerable interest in cross-country comparisons that investigate international competitiveness and convergence in agricultural productivity across countries. When markets are perfectly competitive and operating in long-run equilibrium, then price changes are proxies for cost changes. Under these assumptions, relative output prices can proxy as a competitiveness measure for purposes of international comparisons, assuming that the quality of output is the same across countries. If countries share a common stock of knowledge and access to technologies, and if they face no structural barriers to sharing, then theory suggests that prices should change at the same rate. When we do not see this equivalence in price change, we tend to look at the policy incentives and structural differences to explain why.

The ERS program is a leader in the construction and analysis of international comparisons of agricultural productivity. The program has focused on US-EU nations and OECD nation comparisons. The ERS International Agricultural Productivity website provides Excel spreadsheets with indexes for most countries as well as a “Documentation and Methods” link. Fuglie and Wang (2013) provide an interpretive overview. In addition, there are several journal articles and chapters that address international comparisons (Ball et al. 2001; Ball et al. 2010; Wang, Schimmelpfennig, and Fuglie 2012).

A major challenge of the program is to ensure that data construction is comparable across nations. The EU has constructed a system of integrated economic accounts that identifies the concepts, definitions, accounting rules and uniform classifications to be used by EU member states that produce economic data. There are three key adjustments needed to ensure that the U.S. series are comparable for comparisons with EU Member States:

- Inseparable outputs: The EU protocol accounts for outputs, intermediate consumption, compensation of employees, labor input, and gross fixed capital formation that cannot be separated from information on main agricultural activity. These are referred to as ‘inseparable output’ and are reported as agricultural activity under that designation. An example is agrotourism activities. ERS products recognize this complication and make adjustments to ensure consistency for the purposes of the international comparison. Whether this adjustment method is reasonable is another issue. To the extent that on-farm assets and activities are
leveraged to create value for the enterprise, it can be considered a portfolio decision taken at
the farm level. The ‘inseparable’ output is just that; it demonstrates a technological jointness in
the original sense of the concept dating back to Carlson (1939).

- Choice of index formula: The EU protocol measures changes in volume using the Laspeyres-type
index and changes in price using Paasche-type indexes. The rationale for using these indexes,
which are generally regarded as inferior to Divisia-type indexes, is that they can be created from
less intensive data sources. Although U.S. data are aggregated using more appropriate Tornqvist
and Fisher indexes, ERS makes the necessary adjustments in the cross-country comparisons to
ensure consistency. Given the European data are available at the farm level in the Farm Data
Accountancy Network, the re-computation of the EU data are executed at a comparable level as
the U.S. series.

- Capital: The EU protocol does not generate a standard procedure for measuring the user cost of
capital. When precise information on the average probable economic life of a particular stock of
capital goods is unavailable, the protocol recommends the perpetual inventory method. The
reference period acquisition price is the replacement value of the assets during the reference
year. The linear depreciation method is recommended in the protocol, although the geometric
depreciation approach may be appropriate in certain cases.
  a. Livestock is excluded as a component of the consumption of fixed capital because a) the
withdrawal of animals that form the productive herd may be a function of the economic
environment (e.g., slaughter prices, price of animal feed), and b) animal productivity and
economic value is linked to age but not by way of a direct continuous function.
  b. In EU-U.S. cross country studies, construction of the capital input and rate of return
measurement follows the ERS protocol. They treat the relative efficiency of new capital
goods as being the same across countries.

- Labor and Intermediate Inputs: In addition to direct basic wages and salaries, gross wages and
salaries in the EU protocol include in-kind compensation (goods and services provided by
employers to their employees (and family members) free or at a reduced price. There is no
apparent modification for quality adjustment in labor. No mention is made in publications
reporting ERS cross-country comparisions how the quality adjustments used in the U.S. series are
juxtaposed with the EU Member State series. When reviewing the relative labor price for the
U.S. and EU Member States in Table 6 of Ball et al. (2010), the U.S. relative labor price exceeds
the other nations from the mid-1980s to 2002 (the last year reported). It is not clear to what
extent quality-adjusted labor is driving this result. The same critique applies to intermediate
inputs (most notably, pesticides) for which the U.S. uses a hedonic price series to estimate
quality-constant prices and quantities.

Across a wider set of countries, challenges include differentiating land quality (e.g., irrigated vs.
non-irrigated, semi-arid vs. arable/pasture), cropland definitions (e.g., distinguishing arable/permanent/
pasture), gaps in series, etc. The ERS and country input series are typically grouped into five categories
(land, labor, machinery capital, livestock capital, and material inputs) and then cost shares are used to
combine them into an aggregate input (Fuglie 2012). In the absence of complete data series at the
country level, the construction of the country series often uses a representative country to serve as a
proxy for the cost shares for other similar nations. For example, Brazilian cost shares in livestock
production are applied to South America, West Asia and North Africa on the basis that this latter group
of nations, like Brazil, are middle-income countries with relatively large livestock sectors (USDA 2013).
These challenges add to the concern about how comparable these series are across nations.
Recommendations

1. ERS should emphasize that cross-country comparisons are really research work and establish whether they are an integral part of the ERS agenda (Priority A).

2. The methods used have presumably passed some peer review (because they have been published), but there is not a consensus on these methods, in contrast to the well-established approaches codified in, for example, the OECD manual on measuring productivity. This work raises the question whether ERS series that are quality adjusted (and U.S. specific) should be compared to series in other nations that are not quality adjusted (Priority B).

XIII. ERS Measures of Productivity Compared to Alternative Sources

There are several alternative estimates of agricultural productivity. In this section, the ERS measures of productivity are compared to those of Jorgenson, Ho, and Samuels and those of InSTePP.

Comparison with Jorgenson, Ho, and Samuels

In ongoing research into the sources of U.S. economic growth, Dale Jorgenson and collaborators have constructed measures of outputs, inputs, and productivity in the farm sector (e.g., Jorgenson, Gollop and Fraumeni 1987; Jorgenson, Ho and Stiroh 2005). The conceptual and methodological framework of the Jorgenson accounts is similar to that of the ERS accounts, and the empirical results for the period as a whole are generally consistent. However, for estimates within output and input components and for subperiods within the sample, there are differences that warrant investigation. This section compares the sources of growth in the agricultural sector based on the ERS productivity accounts relative to growth estimates in the sector for the period 1948-2010 based on Jorgenson, Ho and Samuels (JHS) (2014).

We note five differences between the methodologies used by ERS and JHS. First, JHS bases estimates of output and intermediate input on a time series of input-output tables that underlie the official national accounts; thus, their measures are consistent with official totals, such as aggregate GDP. These underlying input-output tables have approximately 65 intermediate inputs that flow into the farm sector. Second, capital service flow estimates are based on the level of detail in the BEA fixed assets accounts. This is a finer level of detail than that used by ERS although many of the detailed assets are zero in the farm sector. Third, JHS distinguishes between the capital service flow of corporate and noncorporate assets by distinguishing the tax structures facing corporate and noncorporate establishments. Fourth, the ERS productivity measures include quality adjustments for pesticides, fertilizer, labor services, and tractors. Fifth, the ERS accounts provide a state-level dimension that is not available in the JHS industry-level production account.

For the 1948-2010 period as a whole, TFP growth estimates are remarkably similar when comparing the ERS estimates to those from JHS. ERS estimates that TFP grew by 1.46% per year on average over the period while JHS estimates that TFP grew by 1.44% per year on average. Details are provided in Table XIII.1.

Output growth and the contributions of inputs are slightly different when comparing the sources of growth. ERS estimates that output grew slower by about 0.2 percentage points per year (1.53% versus 1.75%) over the 1948-2010 period. The majority of the slower growth estimate occurs after 1973; before 1973 ERS estimated faster output growth than JHS.

ERS estimates the flow of services from capital input fell slightly over the period as a whole, while JHS estimates a small increase. This is largely due to a negative contribution of capital services estimated by the ERS between 1973 and 1995.
Table XIII.1: Agricultural Output Growth and its Sources

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ERS:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Growth</td>
<td>1.53</td>
<td>1.82</td>
<td>1.57</td>
<td>1.52</td>
<td>0.30</td>
</tr>
<tr>
<td>Contribution of Capital</td>
<td>-0.07</td>
<td>0.09</td>
<td>-0.25</td>
<td>-0.08</td>
<td>0.01</td>
</tr>
<tr>
<td>Contribution of Labor</td>
<td>-0.50</td>
<td>-0.76</td>
<td>-0.17</td>
<td>-0.66</td>
<td>-0.36</td>
</tr>
<tr>
<td>Contribution of Intermediate Input</td>
<td>0.64</td>
<td>1.13</td>
<td>0.40</td>
<td>0.29</td>
<td>-0.01</td>
</tr>
<tr>
<td>Contribution of TFP</td>
<td>1.46</td>
<td>1.35</td>
<td>1.59</td>
<td>1.98</td>
<td>0.65</td>
</tr>
<tr>
<td><strong>Jorgenson, Ho, and Samuels (2014):</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output Growth</td>
<td>1.75</td>
<td>1.69</td>
<td>1.86</td>
<td>1.93</td>
<td>1.20</td>
</tr>
<tr>
<td>Contribution of Capital</td>
<td>0.18</td>
<td>0.18</td>
<td>0.23</td>
<td>0.18</td>
<td>-0.07</td>
</tr>
<tr>
<td>Contribution of Labor</td>
<td>-0.56</td>
<td>-1.03</td>
<td>-0.32</td>
<td>-0.13</td>
<td>-0.15</td>
</tr>
<tr>
<td>Contribution of Intermediate Input</td>
<td>0.70</td>
<td>1.31</td>
<td>0.28</td>
<td>-0.08</td>
<td>1.05</td>
</tr>
<tr>
<td>Contribution of TFP</td>
<td>1.44</td>
<td>1.24</td>
<td>1.67</td>
<td>1.97</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Notes: Average annual percentages. A contribution is a share-weighted growth rate. ERS data are computed from Table 1 posted on the ERS website (USDA 2014), JHS data provided by Jon Samuels.

Estimates of the contribution of labor input to output growth are broadly consistent for the period as a whole. Comparing subperiods, ERS estimates a higher contribution of labor through 1995 and a slower contribution after.

The contribution of intermediate inputs to output growth is similar between the two estimates for the 1948-2010 period. Discrepancies between the two estimates increased after 1995.

Estimates of TFP growth basically match for the period as a whole. By subperiod, the results line up closely as well, except for the 2005-2010 period where ERS estimates significantly higher TFP growth rates. The discrepancies in later years appear to be tied to the different estimates of output and intermediate input growth.

**Comparison with InSTePP\textsuperscript{53}**

The International Science and Technology Practice and Policy (InSTePP) Center at the University of Minnesota maintains an alternative database of productivity accounts. Documentation and database archiving is based at InSTePP (see Pardey, et al. 2006). In this report, we refer to this alternative as the InSTePP productivity accounts which date back to the initial efforts of Pardey and Craig (1989) and Craig and Pardey (1990a, 1990b, 1996) and have undergone periodic updates with the collaboration of additional colleagues. The history of these accounts can be found at [http://www.instepp.umn.edu/united-states](http://www.instepp.umn.edu/united-states). Overall their approach is to build the productivity accounts from the state level up to the national level. Their general approach uses state- or regional-level data.

\textsuperscript{53} We appreciate the helpful comments of Julian Alston and Philip Pardey on an earlier draft of this section.
whenever possible. As of this writing, InSTePP has released their series which runs from 1949 to 2002, with an update to 2007 pending.

They identify four broad input categories: capital, labor, land, and materials. We address each separately and compare their series to the ERS series. We conclude with TFP pattern differences.

**Capital**

An exhaustive set of comparisons between the ERS and InSTePP capital services series is presented by state and in aggregate in Andersen, Alston, and Pardey (2011). We summarize primary methodological differences between the two approaches in Table XIII.2.

Table XIII.2. Comparison of Capital Services Series Construction for ERS vs. InSTePP

<table>
<thead>
<tr>
<th>Capital Stock Estimates</th>
<th>ERS</th>
<th>InSTePP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perpetual inventory method</td>
<td>Physical inventory method</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interest rate</th>
<th>ERS</th>
<th>InSTePP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market-based</td>
<td>Real Constant (4%)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level of aggregation</th>
<th>ERS</th>
<th>InSTePP</th>
</tr>
</thead>
<tbody>
<tr>
<td>National capital stock for the national accounts, state-specific stock for the state accounts</td>
<td>State-specific</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Categories of variables</th>
<th>ERS</th>
<th>InSTePP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machinery (4)</td>
<td>Machinery (6)</td>
<td></td>
</tr>
<tr>
<td>Biological (3)</td>
<td>Biological (5)</td>
<td></td>
</tr>
<tr>
<td>Structures (1)</td>
<td>Buildings (1)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depreciation</th>
<th>ERS</th>
<th>InSTePP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperbolic, average service life and distribution of asset retirement around the average following a normal distribution</td>
<td>Geometric pattern for durable assets</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Retirement Age</th>
<th>ERS</th>
<th>InSTePP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service lives estimated from BEA Fixed Assets and Consumer Durable Goods, 1925-94</td>
<td>Service life, ( L ), calculated for constant depreciation rate, ( \delta ), such that the threshold is set at 10%; i.e., ((1-\delta)^{L} = 0.10)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rental rates</th>
<th>ERS</th>
<th>InSTePP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market rate</td>
<td>Fixed real interest rate</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Sources</th>
<th>ERS</th>
<th>InSTePP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic sources: NASS etc.</td>
<td>Basic sources plus unpublished Association of Equipment Manufacturers surveys</td>
<td></td>
</tr>
</tbody>
</table>

When plotting a) tractors and trucks, b) service structures, c) other machinery, and d) aggregate capital, the pattern is similar across all categories, although the InSTePP series is smoother than the ERS series. In all cases, the ERS series exceeds the InSTePP series as measured in constant 1996 dollars starting in the early 1960s. The greatest divergence is between the mid-1970s and 1990.
One point of departure to note between the two series regarding construction of capital services is the treatment of machinery. As noted in the table, the InSTePP series use survey data from the Association of Equipment Manufacturers (AEM). The type, quality and comparison of these data to the ERS series are discussed in Andersen, Alston, and Pardey (2011) and Pardey, et al. (2006).

ERS treats machinery purchased for on-farm use as part of the capital services series. When machinery is hired for on farm use (by either lease or hiring of custom services), it is considered a component of the intermediate input services as part of purchased services. Income generated from the farmer hiring out services to others is recorded as income.

The InSTePP series use data from the AEM, which is the link in the chain selling equipment to dealers. It is the dealers who sell to end users. When machinery is sold to a customer who has a custom hire enterprise, this equipment is accounted under the purchased services ledger which is transacted as intermediate input. Capital owned by farmers but used on a farm is already counted as an expense in the InSTePP series. However, it is not if the AEM survey data are segmented into farm-owned capital and otherwise. The documentation available is not clear on this point. Our concern with the capital series using the AEM data series is that farm-owned capital may be double counted as being farm-owned and also measured in the materials input category.

The capital services series for InSTePP and ERS are presented in Figure XIII.1. Both series in this figure exclude land. The ERS series exceeds the InSTePP series by 31.6%, on average over the entire series, with the ERS series exceeding the InSTePP series by 85% on average during the 1966-1993 period. The trends are countercyclical over significant periods (1965-1972, 1978-1982, 1990-2001). The growth rate in capital services between the two series has a correlation of only 0.40.

Sources include InSTePP Capital series from sheet 4 in InSTePP U.S. Production Accounts (version 4), Pardey et al. (2010a), and http://www.instepp.umn.edu/products/instepp-us-production-accounts-version-4-input-q. ERS Capital series less Land is constructed using the data series found in http://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us.aspx#28247, National Tables, 1948-2011 (posted 27 September 2013). The ERS series for Capital less Land, $K'$, is constructed using Equipment, Buildings and Inventories. The quantities and price indexes for these
three components of capital are found in Table 1a of this spreadsheet. Specifically, aggregate capital is constructed as,

\[ K' = \left( \frac{P_{eq}^t \times Q_{eq}^t + P_{bdg}^t \times Q_{bdg}^t + P_{inv}^t \times Q_{inv}^t}{P''_K} \right) \],

with the normalizing price of capital less land provided by ERS. This series is then normalized to 1949=100.

For comparison, the following figure shows the expected real rate of return used by ERS to convert non-land capital stocks to flows. Although the expected rate of inflation is subtracted from the nominal AAA bonds rate, the real rate still mirrors the evolution of the nominal AAA bonds rate. It shows a sharp increase in 1977-1984 during the period of high inflation and peaks just a little later than the largest difference between the ERS and InSTePP capital service flow estimates plotted in the previous figure, suggesting a potential role of the choice of real interest rate in the difference between the two capital measures.

Figure XIII.2: Ex-Ante Real Rate of Return, \( R_{AAA} \), used by ERS (real rate on vertical axis).

Table XIII.3 summarizes the ERS and InSTePP capital services series growth rates by periods. Over the 1949-2002 period, the ERS series increased an average of 0.6% compared to the InSTePP average of 0%. The ERS series presents capital services growth until 1979, followed by a declining period.

<table>
<thead>
<tr>
<th>Years</th>
<th>InSTePP</th>
<th>ERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950-1959</td>
<td>0.001</td>
<td>0.038</td>
</tr>
<tr>
<td>1960-1969</td>
<td>-0.001</td>
<td>0.014</td>
</tr>
<tr>
<td>1970-1979</td>
<td>0.001</td>
<td>0.023</td>
</tr>
<tr>
<td>1980-1989</td>
<td>-0.004</td>
<td>-0.025</td>
</tr>
<tr>
<td>1990-2002</td>
<td>0.001</td>
<td>-0.014</td>
</tr>
<tr>
<td>1949-2002</td>
<td>0</td>
<td>0.006</td>
</tr>
</tbody>
</table>

NB: Growth rates calculated as log differences.
Focusing on the impact of the different assumptions about interest rate, Andersen, Alston, and Pardey (2011) recalculated the InStePP series using the ERS market interest rate assumption to isolate the impact of this assumption in explaining the divergent series. This is presented in Figure 4 (first panel) in Andersen, Alston, and Pardey (2011) which shows the capital services series are nearly identical up to 1979, and then the ERS series exceeds the InStePP series through 2002, with the differences in the early 1980s being more dramatic than the period from the later 1980s to the end of the series.

Table 3 in Andersen, Alston, and Pardey (2011) provides the capital productivity (output per unit of capital) index values by periods. For the period 1960-2002, the interest rate assumption accounts for approximately one-third of the discrepancy between the ERS and InStePP series. However, the finer period breakdown suggests that the interest rate assumption plays no role in explaining differences for the 1960-1980 period. For the decade 1980-90, the InStePP fixed rate assumption accounts for one-third of the difference between the InStePP and the ERS series. From 1990-2002, the InStePP series calculated with the variable rate runs only 3% lower than the ERS series.

From 1960 onwards, the differences in the capital series is driven significantly (but not entirely) by the constant (InStePP) versus market (ERS) interest rate assumption in generating the rental rates and capital stock calculation. The remaining discrepancies are attributable to the composition of the data in terms of level of aggregation for baseline data, the number of capital categories, depreciation rate approach, retirement age, and data sources.

InStePP justifies its use of the constant interest rate as being more consistent with farmer expectations and capital decision making. Their complaint with the use of the variable market rate is that it implies that all existing assets are subject to variable use in response to annual variations in interest rates. They argue that this is not consistent with the observed structure and nature of capital use in U.S. agriculture, where existing assets represent 90% or more of the capital use on farms in a given year.

InStePP arguments in support of a constant interest rate include:

- The expected long term relative interest rates may be relatively insensitive to year-to-year fluctuations in observed rates.
- Once an asset is purchased or rented, transitory changes in real rates are likely to have less influence on decisions regarding the use of agricultural capital.
- Biological capital combined with durable fixed factors show limited flexibility in the short run. Therefore, decisions about agricultural production and capital utilization are relatively insensitive to short-run changes in input and output prices.

**Our assessment of capital methodologies**

The 1980s were a period of highly volatile market interest rates. If market interest rate volatility is not impacting agricultural capital services, a clear explanation is needed why agriculture is different from other sectors of the manufacturing and service economy. If agriculture is not substantially different from other firms, then it cannot be argued that agriculture is insensitive to the market interest rate in its demand for capital. Crop farmers are borrowing in the market every year. When replacement of capital is needed at the time of volatile rates, purchases can be delayed, thus using less productive capital longer. Sharp increases in interest rate lead them to hold off investment. Smoothing out the interest rate volatility masks the underlying decision environment, which will surely influence investment timing.

Clearly, the choice of interest rate is important. The treatment of capital services relates to the debate between the use of ex-ante (Diewert and others) versus ex-post (Jorgensen and others) approach. The ex-ante real rate used by ERS is more stable than an ex-post rate such as that used by BLS. The BLS uses the ex-post approach (Jorgenson’s) and the perpetual inventory method as well. As apparent from
Table X.1, the JHS capital contribution to growth differed most from the ERS contribution during the 1973-1995 period, which included the greatest volatility in real interest rate. Although our recommendation is to not ignore at least some of the volatility in real interest rate, it is interesting to note that the 1980 AAEA Task Force recommended the use of a constant rate of 3 or 4% (Gardner et al. 1980, p. 33, para. 3) as a proxy for a long-run real interest rate.

An important issue is the choice of deflator to use in obtaining real rates. The perfect deflator would be to use the change in prices of the goods of interest or an index that reflects the specific capital goods. ERS uses the general GDP deflator and this might result in a real rate with residual inflation for capital goods. How much of the ERS capital service flow pattern in the 1980s is induced by the use of a price index to deflate the nominal rate that is broader than the prices of these assets?

**Labor**

In the InSTePP series, farm operators are set into 30 classes with five age classes and six education classes. The Census of Population was used as the source for this series prior to the availability of ARMS data. No specific hedonic modeling is used to quality adjust the data. There is a matching of operator hourly wages that are calculated by age/education cohort using national-level estimates of annual income and state-level estimates of operator hours worked on-farm.

Family labor is one type of labor and its price is generated by a scaled index. The family labor, along with the operator and hired labor are obtained from NASS.

Figure XIII.3 compares the ERS and InSTePP series. The InSTePP series consistently exceeds the ERS series from the late 1950s, and the gap grows over time until the InSTePP series exceeds the ERS series by 35% on average during the 1990-2002 period. The correlation of the growth rates in these two labor series is very low at 0.16.

**Figure XIII.3: Labor index ERS vs InSTePP**

**Land**

InSTePP notes ERS practice of using “land in farms” as a measure of the land input is problematic for the following reasons:

- Does not allow for consistent and economically meaningful treatment of cross-sectional, temporal variation in land quality, and
- Significantly mis-measures the actual number of acres in agriculture.

InSTePP attempts to measure acreage more accurately by building up from the state level using three land categories (cropland, irrigated cropland, and grassland and pasture). The InSTePP distinction is to separate grassland and pasture land from cropland. Further, state-level estimates of total irrigated acres for cropland and pasture land along with interpolations are used to generate the irrigated land series (Pardey, et al. 2006).

Land rental rates paid differ by agricultural land type. InSTePP uses information on rents from a state-level series as well as from two other reports (Daugherty 1989; Doll and Widdows 1982). When the data are insufficient to differentiate land rental rates between cropland and pastureland, and irrigated and non-irrigated land at the state level, one of six alternative methods is used to approximate state rental rates. They are then aggregated up to the national level.

Figure XIII.4 compares the ERS and InSTePP land series. The InSTePP series consistently exceeds the ERS series, and the gap widens over time. For the 1990-2002 period, the InSTePP series exceeds the ERS series by 27% on average. The correlation of the growth rates in these two land series is very low and negative, -0.09.

![Figure XIII.4: Land Index ERS vs InSTePP](image)

**Materials**

The materials input is comprised of fertilizer, pesticides, seed, purchased feed, water use, and other operating expenses which include machine hire. The challenge in creating the state series is that the collection of data for some inputs was discontinued during the time period. With the goal of developing state-level series uppermost in the InSTePP protocol, creative approaches to filling in these series were undertaken.

InSTePP made an effort to extend the separate fertilizer commodities by state after 1985, when the separation was discontinued. For fertilizer prices, national-level prices post 1988 were extrapolated using the trend in average prices of a) urea, b) triple superphosphate and c) muriate of potash/potassium chloride, with the price data coming from Agricultural Prices (NASS publication).

Pesticides prices use ERS series with prices paid indexes from NASS. No quality adjustments are addressed. The seed series uses the total nominal expenditure of seed purchases by state in 1949-86 for seed used on farms. This series does not include seed grown and used on farm or purchased for resale. A national level price index is used. Purchased feed series use the nominal value of expenditures and total feed purchases by state for various types. The value of feed used on farm was not included but hay purchases were included even though consumed on farm. InSTePP generates the quantity index using the price of feed and they do this for 14 feed categories. Water use and other operating expenditures use the same data as ERS.

Figure XIII.5 compares the ERS and InSTePP materials series. The InSTePP begins to differ dramatically by the late 1950s with the gap growing dramatically. For the 1990-2002 period, the InSTePP series exceeds the ERS series by 21% on average. The correlation of the growth rates in these two materials/intermediate input series is 0.76.

![Figure XIII.5 Materials Index USDA vs InSTePP](http://www.instepp.umn.edu/products/instepp-us-production-accounts-version-4-input-q)


**Output**

Output quantity and price data are from NASS. They identify three categories – crops, livestock and miscellaneous. There are 60 crop outputs grouped into four categories – field crops (17), fruits and nuts (21), vegetables (21), and an aggregate nursery/greenhouse products; 9 livestock outputs – broilers, cattle, eggs, hogs, honey, milk, sheep, turkeys and wool; and a miscellaneous category with 5 components that includes machines rented out and Conservation Reserve acreage. Of the 74 outputs, 71 are based on both quantity and price data collected by national or state-level statistical services. Only 3 products (cattle, sheep, and machine hire out) generate a quantity series implicitly using revenue data and a price series.

Figure XIII.6 compares the ERS and InSTePP series. The InSTepp series coincides with the ERS series over the entire period, with a correlation of 0.999.

![Figure XIII.6: Output Index ERS vs InSTePP](image)

Total factor productivity

While the capital services series receives considerable attention in discussions concerning the discrepancies between the InSTePP and ERS series, the discrepancies other input series are not insignificant. Figure XIII.7 compares the ERS and InSTePP TFP series. The InSTePP series exceeds the ERS series from the outset, with the most dramatic differences emerging in the late 1970s to late 1980s, and then generally converging. For the 1990-2002 period, the InSTePP series exceeds the ERS series by 13%. The correlation of the growth rates in the TFP series is high at 0.94.


Concluding comments

When comparing these series, nuanced differences emerge in the composition of the data in terms of levels of disaggregation and the use of state- or regional-level prices when available versus the national prices. By focusing on the state-level data series and matching highly disaggregated quantity series with their prices, the InSTePP series obviates some of the need for hedonic approaches that are used by ERS using national level data. An exception is the ERS land accounts which are not quality adjusted. Starting with the most disaggregated level possible can clearly be an advantage in data quality and consistency, but this necessitates high quality state-level data.

While there is considerable discussion about the difference between the InSTePP and ERS methodological differences in the capital series, controlling for use of the market versus constant interest leads to closer harmony between the ERS and InSTePP series. But not to be overlooked, the ERS and InSTePP series differ dramatically since the 1960s for labor, land, and materials.
In the end, the TFP series for ERS and InSTePP tells a more harmonious story than any of the components separately.

Recommendation
Engage with researchers in the field to analyze the sources of differences with alternative estimates and to determine whether they warrant changes in data or procedures used (Priority B).

XIV. Stakeholder Assessment

As part of the review process, the committee contacted stakeholders from academia, government, and the broader research community for comments on the productivity accounts. Overall, the comments were overwhelmingly supportive of the agricultural productivity accounts and repeatedly indicated the value of the accounts as analytical, research, and teaching tools. A common theme among stakeholder comments was requests for additional documentation, underlying source data, and for re-establishing the state-level accounts. The comments from stakeholders who granted permission to have their comments included verbatim are included in Appendix 2.

The call for stakeholder input was announced in the AAEA Newsletter and extended via direct email contact to representatives from both the agricultural economics community and the broader community of those doing productivity research. The committee received 33 responses. All but two have agreed to have their comments included verbatim in a supplemental appendix to this report. Three are included in Appendix 1 along with other input cited in this report. The remaining 28 are included in Appendix 2.

We divided the stakeholder responses into four categories: a) those expressing a complimentary view of the accounts, but offering no specific suggestions, b) those with feedback or requests related to the ERS productivity program, but no explicit critique or methodological suggestion, c) those with a specific critique or methodological concern, and d) those that offered no specific suggestion or critique or were not familiar enough with the program to offer feedback. It is important to note that those with a critique or methodological concern were often complimentary of the overall program.

Thirteen respondents offered specific suggestions or comments for the ERS productivity program but did not convey major methodological critiques. For example, respondents requested more documentation, more detailed and timely release of data, reinstatement of the state accounts, additional crop detail, coverage of aquaculture, and suggested that the ERS search for ways to make all of the data more visible. Within this group, respondents argued that measuring input quality is of utmost importance, questioned whether change in TFP should be zero if all inputs are accurately measured, and pointed out the potential differences between industry and firm-level TFP estimates. Furthermore, two respondents discussed choice of the residual claimant. As noted above, these respondents were often complimentary of the program overall.

Eight respondents offered a complimentary review of the ERS accounts without offering any specific suggestions for future directions. These respondents enumerated many reasons for their positive assessment of the accounts. In particular, stakeholders noted that ERS has been an international leader in productivity measurement and provides useful source data for international comparisons and policy work.

Four stakeholders responded with measurement or methodological issues related to the accounts. Within this group, respondents mentioned choice of index number formula, the consistency between the international and national agricultural accounts, the consistency in aggregation of productive stocks...
and the formulation of the rental rate of capital, the inclusion of biological capital, and the measurement of agricultural land as important areas that deserve additional attention.

Eight respondents did not offer specific comments or suggestions.
CONCLUSIONS

ERS has emerged as an acknowledged intellectual leader in construction and integration of national and state-level productivity accounts in agriculture. The national ERS productivity measures are widely referred to and used, and international sectoral comparisons rely on the ERS production accounts for foundation methodology in constructing agricultural productivity accounts in other countries.

This leadership role has endured for many decades and accelerated in response to the AAEA Task Force review of the agricultural productivity accounts (Gardner et al. 1980). Under the leadership of Eldon Ball, the procedures used to construct the productivity accounts underwent a major overhaul, and the bulk of the AAEA Task Force recommendations were implemented by the mid-1980s. Despite limited personnel and resources, a vigorous research program was initiated and has continued over more than three decades to examine additional ways to improve the sectoral productivity accounts and to extend their reach and value.

It is with that backdrop of vigorous intellectual leadership that the ERS Agricultural Productivity Account Review Committee consisting of Barbara Fraumeni, Lilyan Fulginiti, Jon Samuels, Spiro Stefanou, and Richard Shumway (Chair) has examined the data sources, methodology, ongoing research, documentation, and reporting of the agricultural productivity accounts. Our recommendations are many and some are substantial. In order to guide implementation of the recommendations, we group them into three orders of priority based on our collective perception of their importance relative to the cost (in intellectual difficulty, time, and resources) of implementation. We judge the most important to be the Priority A Overarching, Website, and State-Level recommendations.

Recommendations

Priority A

Overarching

1. Fully document and keep current all procedures followed, from data sources through measurement of productivity change, to enable a non-expert to reproduce the accounts.
2. Cooperate with other agencies to reduce duplication, achieve consistency across statistical series, get information at lowest cost, and capitalize on research and expertise.

Labor

1. Investigate the reasons for differences in the labor input calculations of Jorgenson, Ho, and Samuels (2014).
2. Investigate the American Community Survey as an alternative, possibly complementary, data source, potentially in collaboration with BEA/BLS.

Non-Land Capital

1. Examine non-land capital nominal investment data in consultation with BEA researchers.
2. Consider using one or more asset deflators in its expected inflation calculation.
3. Review investment deflators to determine if sources have been updated or revised since the data was last collected.
4. Review average service lives of assets with BEA and BLS to determine if revisions should be made.
5. Investigate whether the indexes of capital service flows during the period 1975-1984 reflect changes in capital service use rather than changes in the behavior of the bonds rate used in calculating the user cost of capital.
Land

1. Explore ways to include within-county land type adjustments as well as quality changes given by, for example, irrigation or other improvements in farmland.
2. Consistent with the recommendation for non-land capital, replace the GDP deflator used to capture general effects of inflation with a price index for land.

Outputs

1. To account for the distorting effect of crop insurance when outputs are aggregated, add the insurance indemnity to the insured crop’s price and deduct the farmer’s premium.
2. Revisit measurement issues related to own account investment, specifically consistency between the output and input sides of the account.

Quality Adjustments

1. Research methods for incorporating quality adjustments to seeds and consider whether seed quality change should be treated solely as an input or both an output and an input.

Website

1. Provide detailed documentation online and note ad hoc adjustments to data or deviations from the general procedure (e.g., if fixes were required due to negative implied capital rental rates).
2. Expand the website to provide timely access to more detailed data and procedural detail underlying the quantity and price aggregate and sub-aggregate national and state-level statistics.

State-level

1. Continue to develop and publish the state-level total productivity measures as well as price and quantity series (strongly recommended).
2. Cooperate with other government agencies to achieve the lowest cost method of collecting data of sufficient quality to enable the state-level accounts to be extended and maintained.
3. Investigate the possibility of using information in the American Community Survey to update matrix elements in the state labor accounts.
4. Ensure consistency between the national and state accounts where possible, and explain circumstances that prevent total consistency where it is not possible.

Cross-country comparisons

1. ERS should emphasize that cross-country comparisons are really research work and establish whether they are an integral part of the ERS agenda.

Priority B

Labor

1. Use the latest revision of information on totals from NIPA and the special BLS tabulation.
2. Consider further refinements of the cross classification of workers to improve identification of quality differences.
3. Adjust for temporal changes in the quality of workers in each demographic group not captured in relative wages.

Non-Land Capital

1. Begin a conversation with BEA researchers to determine if any changes should be made to ERS measures based on recent BEA research.
2. Review and vet the capital stock aggregation methodology developed by Sliker and consider whether to revise ERS methodology in response.
3. Include investment in computers in the ERS investment data.

Land
1. Report separate indexes for Cropland, Woodland, Pasture and Other non-Cropland.

Intermediate inputs
1. Examine the robustness of the intermediate input accounts constructed by ERS to the use of alternative sources of price deflators.
2. Investigate the logic and practical effect of how ERS intermediate inputs compare to those based on input-output tables.

Quality Adjustments
1. Determine whether the degree of quality change in outputs has been sufficient to warrant quality adjustment, and, if so, explore alternative methods to adjust productivity measures for output quality change.
2. Check alternative data sources for price of purchased machine services.

Residual Claimant
1. Examine the sensitivity of the productivity accounts to the choice of residual claimants and different choices of expected asset inflation.

Research and Development
1. Follow developments in the literature on accounting for R&D in the productivity measure, and, if minimal R&D is conducted on farms, include a note of explanation in the methodology description indicating why sectoral R&D is not incorporated in the accounts.

Website
1. Include a paragraph on typical release dates in addition to the current practice which is to post date of “next update”, which as it turns out is blank.
2. At each release, post a note describing revisions and reasons for revisions.
3. Change exposition on the website about welfare.
4. Include links to other productivity related data and research including the BEA/BLS industry-level production accounts, BLS Non-Farm Productivity, EU KLEMS, and World KLEMS.

State-level
1. Report state-level price and quantity series on the website for the same sub-aggregates as the national series.
2. Update the state-level accounts on the same schedule as the national accounts.
3. Place more underlying data detail on the website.

Cross-country comparisons
1. Because the methods used to develop agricultural productivity accounts for other countries do not follow the same procedures ERS uses for the U.S. accounts (e.g., inputs are not quality adjusted), determine whether cross-country comparisons should be made.

ERS Measures of Productivity Compared to Alternative Sources
1. Engage with researchers in the field to analyze the sources of differences with alternative estimates and to determine whether they warrant changes in data or procedures used.

**Priority C**

**Labor**

1. Clarify if the imputation of wages for self-employed workers exhausts available income and report procedures used if this occurs.
2. Clarify how sample selection estimation is executed when the Heckman procedure is used for the contract labor hedonic wage index.

**Non-Land Capital**

1. After vetting the current ERS methodology, consider whether to revise its estimate of depreciation in the user cost of capital to bring its construction in line with the methodologies used by other experts in the field.
2. As a future research project, revisit the treatment of breeding livestock, building on Ball and Harper (1990).

**Land**

1. Investigate the potential departure of the ‘Land in Farms’ definition in the Census of Agriculture used by ERS from ‘Land in Agriculture’.

**Outputs**

1. Continue to explore the effect of alternative aggregator functions, including the chained Fisher index, on productivity measures and include sufficient detail in the data available on the website to enable users to explore them.

**Quality Adjustments**

1. Research the possibility and ramifications of subdividing labor into supervisory and nonsupervisory workers in the cross-classification of labor.

**R&D**

1. ERS should follow developments in the literature on accounting for R&D in productivity measures. If it determines that minimal R&D is conducted on farms, ERS may consider a note in its description of the methodology about the reasons it does not and need not include R&D.

**Alternative assumptions**

1. Although a disequilibrium approach to capital factors is not widely applied in the productivity literature, we recommend that ERS engage the scholarly community in an examination of effective ways to account for disequilibrium.

**Website**

1. Add a link to a “Related Reports” page that contains links to the pertinent related reports.

**State-level**

1. If feasible, include Alaska and Hawaii in the accounts.
2. Replace the Caves-Christensen-Diewert spatial aggregator index with a Lowe, geometric Young, or Färe-Primont index.
### ACRONYMS USED IN REPORT

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tr>
<td>AAA</td>
<td>Triple A bonds</td>
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<tr>
<td>AAEA</td>
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APPENDICES

Appendix 1. Personal Communication Documents to Review Committee

Appendix 1.1. Note on user cost of capital by Brian Sliker, BEA

Individual and Cohort Capital from the Point of View of the Primal

Brian K. Sliker
U.S. Bureau of Economic Analysis
April 16, 2014; Revised June 18, 2014

Most students of production economics would recognize the user-cost of capital formula by an expression like:

\[ c = p(i + \delta) - \dot{p} \]  \hspace{1cm} (1)

...where \( p \) is the supply price of a new “machine” and \( \dot{p} \) is the expectation of that price’s impending revaluation, \( i \) is the finance rate, and \( \delta \) is the rate of depreciation: the rate of decline of the new price as the machine ages. When \( \delta \) is a constant, then it also describes the rate of decline of the price at any age with respect to further aging, as well as the rate of decline of rent and of the machine’s “efficiency,” all at any age. The constant-\( \delta \), or geometric, hypothesis permits a simple description of the development of constant-price capital stocks via a memory-less perpetual-inventory recursion:

\[ \dot{K} = I - \delta K \]  \hspace{1cm} (2)

...where \( I \) is the constant-price investment stream and \( K \) is the capital stock — the wealth stock and the productive stock being identical in the geometric case. The model operates at the cohort level (i.e., taking as the unit of analysis all individuals together, even defunct ones, from a certain installation-date bracket or vintage); as such, it cannot make much use of evidence on individuals.

When \( \delta \) is not a constant, things are more complicated. The expression for \( \delta \) takes on different forms across the wealth and productive stocks, varies by age, and depends on the “own” interest rate, \( r = i - \dot{p}/p \). Moreover, the \( \delta \) in user-cost formula (1) is the rate of decline of the new-asset price only, even though it is put toward pricing service flows (i.e., rents). Evidence on individuals becomes pertinent, as do patterns of retirements across individuals. Consistent aggregation from the individual to the cohort level becomes critical: the same sequence of steps that “work” at the individual level — i.e., that transform an individual’s age-efficiency patterns to age-price patterns and back again — must also work at the cohort level, even as the cohort-level forms are themselves derived as proper aggregates of individual forms. A tall order then, and subtle.

1 All opinions expressed are my own; my agency is implicated in nothing, but the math is the math.
Aggravating the complication is the possibility of different conceptual pathways to the same result. Recent-vintage capital accountants may not be aware that user-cost form (1) derives from the age-price or “dual” formulation of the firm’s dynamic optimization problem; they might not recognize equivalent derivations from the age-efficiency, or “primal” side. Yet the ubiquity of the dual representation puts the onus on primal practitioners to demonstrate that equivalence at both the individual and cohort levels. This note and accompanying spreadsheet aim to bridge the two sides.

A General-Purpose Approximation to Individual-Level Forms: Primal to Dual and Back

For computational ease, I will use the following “α-type” age-efficiency profile at the level of the individual machine that has idiosyncratic, known, and unavoidable lifespan $L$. At age $s \geq 0$, the profile states the machine’s efficiency relative to itself were it new:

$$\phi_\alpha(s, L) = \frac{e^{a s/L} - e^a}{1 - e^a} \quad (s \leq L, \text{ else } \phi_\alpha = 0) \quad (3)$$

...equivalently a comparison of actual to as-if-new rents. Form (3) is flexible, taking downwardly concave shapes for $\alpha > 0$ (including the one-hoss shay limiting case as $\alpha \to \infty$), convex shapes for $\alpha < 0$, and straight-line efficiency loss as $\alpha \to 0$. It resembles the better-known hyperbolic individual form:

$$\phi_\beta(s, L) = \frac{L - s}{L - \beta s} \quad (\beta \leq 1, s \leq L, \text{ else } \phi_\beta = 0) \quad (4)$$

...but is amenable to integration under a constant discount rate (and so to transformation to the dual age-price space) without recourse to higher functions or numeric integration. (Both forms will require numeric integration over $L$ when it comes time to aggregate from individuals to the cohort.) I claim some generality for (3) because it exactly solves a first-order constant-coefficient linear differential equation in $s$, so its approximation of other smooth, finitely-lived age-efficiency functions may be justified on Taylor-series grounds. For $\beta = .5$, which ERS and BLS-OPT use for equipment, $\alpha = 1.41$ offers an excellent approximation. For $\beta = .75$ (i.e., structures), $\alpha = 2.97$ is pretty good.

The individual age-price profile is the present discounted value integral of the age-efficiency profile, normalized to 1 at age 0. This has a closed-form solution in the $\alpha$-parameterization:

$$\theta_\alpha(s, L) = \frac{\int_0^L e^{-r(u-s)} \phi_\alpha(u, L) \, du}{\int_0^L e^{-r(u-\alpha)} \phi_\alpha(u, L) \, du} = \frac{e^{a s/L} - e^a}{a(1-e^{-r(L-\alpha)})} \quad (s \leq L, \text{ else } \theta_\alpha = 0) \quad (5)$$

...which happens to solve a second-degree constant-coefficient linear differential equation in $s$. The age-$s$ depreciation rate is:

$$-\frac{\partial \theta_\alpha(s, L)}{\partial s} = a \frac{e^{a s/L} - e^a}{a(1-e^{-r(L-\alpha)})} > 0 \quad (6)$$

...so the age-$s$ rental-price is:

$$p \theta_\alpha(s, L) \left( r - \frac{\partial \theta_\alpha(s, L)}{\partial s} \right) = p \frac{r(a-r L)(1-e^a)}{a(1-e^{-rL}-rL(1-e^a))} \frac{e^{a s/L} - e^a}{1-e^a}. \quad (s \leq L) \quad (7)$$
Setting \( s=0 \) on both sides leaves the shaded area as \( c(L) \), the user-cost for a lifespan-\( L \) individual, with a depreciation rate understood as the proportionate loss of value of the new-machine price. For \( s > 0 \), the factorization expresses the individual’s rental value as the product of its user-cost and its age-efficiency profile, so normalizing by the user cost, returns form (3) and brings the individual-level derivation full circle. For \( p=1 \), the present discounted value integral of (7) returns form (5), so the denominator integral in (5) is the reciprocal of the lifespan-\( L \) user-cost. Note the user-cost varies inversely with \( L \); individual-level user-costs will be important for aggregation up to the cohort level.

**Primal-Only Constructs of Individual-Level User Costs**

We have just found:

\[
c(L) = p \int_0^L e^{-r s} \phi(s, L) \, ds
\]

...as one way to express the individual-level user cost without explicit reference to an age-price profile. But the present review of the ERS productivity program calls for a particular comparison between the dual-form age-0 depreciation rate and the present discounted value integral of efficiency losses over the life of the machine. For the \( \alpha \)-parameterization, the instant, age-0 loss of value is:

\[
\frac{\partial \theta_\alpha(s=0,L)}{\partial s} = -\alpha r \frac{e^{-rL} - e^{-\alpha}}{a(1-e^{-\alpha})} < 0
\]

...while the present discounted value integral of efficiency losses is:

\[
\int_0^L e^{-r s} \frac{\partial \phi_\alpha(s,L)}{\partial s} \, ds = \int_0^L e^{-r s} \frac{ae^{as/L}}{a(1-e^{-\alpha})} L \, ds = -a \frac{e^{-rL} - e^{-\alpha}}{(a-rL)(1-e^{-\alpha})} < 0
\]

The two expressions make a nice decomposition of value loss into a price (the user-cost) and a quantity (the present discounted value of future efficiency losses):

\[
p \frac{\partial \theta_\alpha(s=0,L)}{\partial s} = p \left( r - \frac{\partial \theta_\alpha(0,L)}{\partial s} \right) = p \left( r - c(L) \int_0^L e^{-r s} \frac{\partial \phi_\alpha(s,L)}{\partial s} \right) \, ds
\]

Substitute to rewrite the individual-level user-cost as:

\[
c(L) = p \left( r - \frac{\partial \theta_\alpha(0,L)}{\partial s} \right) = p \left( r - c(L) \int_0^L e^{-r s} \frac{\partial \phi_\alpha(s,L)}{\partial s} \right) \, ds
\]

...then rearrange to find:

\[
c(L) = p \frac{r}{1 + \int_0^L e^{-r s} \frac{\partial \phi_\alpha(s,L)}{\partial s} \, ds}
\]

With different names, this is expression (19) for the user-cost of capital in Ball, et al. (2008), "Capital as a factor of production in OECD agriculture: measurement and data," *Applied Economics*, vol. 40, no. 10, pp. 1253-1277. The authors use the expression at the cohort level, and we will too, but we will build up to it from the individuals.
Aggregation across Individuals

I’ve tossed about the term "individual" quite a bit. Most statistics available for constructing capital stocks are not actually available at the individual level, but practitioners of non-geometric accounting recognize the conceptual importance of aggregating over notional individuals distinguished by their different lifespans. How such differences come about is not addressed: variations in quality at the factory are probably less important than variations in owners’ care, maintenance, and intensity of use, particularly if we insist (and I will) that the Law of One Price hold for purchases of members of a brand-new cohort. A related question is how long the individuation of lifespans takes. The models considered so far had $L$ fixed from the start. In reality, the resale-price, rental value, and even productive service-flows attributed to an individual are probably best thought of as expected values, using as weights probability density functions derived, in the sense of order statistics, from a cohort’s ultimately-revealed parent distribution of lifespans. Early in an individual’s career, when relative ignorance prevails, the parent distribution is as informative as things get. Somewhat later, an individual-specific distribution roughly centering on one’s own eventual $L$ is more believable. Still later, the domain of the individual’s own distribution narrows to a point: $\hat{L}$. Yet for the sake of computing an average across all a cohort’s members, the degree of certainty of individual lifespans hardly matters: the mean across "pre-averaged" (i.e., ignorant) individuals is the same as the mean across finely differentiated ones, so long as the same parent distribution is operative. (Higher moments are a different story.) So in what follows, I’ll treat each $L$ as a known draw from a parent probability density function, $f(L)$ for $L \geq 0$.

The cohort-average age-price profile at age $s$ is the reasonable construct:

$$\Theta(s) = \int_s^{\hat{L}} f(L) \theta(s, L) dL$$

...where the upper limit of integration, $\hat{L}$, marks the lifespan of the longest-lived individual. (I don’t rule out $\hat{L} \to \infty$.) The lower limit of integration, $s \geq 0$, says the integral is effective for live individuals. (The integral over defunct individuals, $\int_0^s f(L)0dL$, contributes nothing.) The survivors-only age-price profile:

$$\widetilde{\Theta}(s) = \int_s^{\hat{L}} f(L|L \geq s) \theta(s, L) dL = \frac{\int_s^{\hat{L}} f(L) \theta(s, L) dL}{\int_s^{\hat{L}} f(L) dL}$$

...is biased upward.

The cohort-average rental price at age $s$ is:

$$p \left( r \Theta(s) - \frac{\partial \Theta(s)}{\partial s} \right) = p \left( r \int_s^{\hat{L}} f(L) \theta(s, L) dL - \int_s^{\hat{L}} f(L) \frac{\partial \theta(s, L)}{\partial s} dL + f(s) \theta(s, s) \right)$$

$$= p \int_s^{\hat{L}} f(L) \left( r \theta(s, L) - \frac{\partial \theta(s, L)}{\partial s} \right) dL$$

$$= p \int_s^{\hat{L}} f(L) \left( r - \frac{\partial \theta(0, L)}{\partial s} \right) \phi(s, L) dL$$

The first line enacts at the cohort level the same steps performed at the individual level. (Applying Leibniz’ rule gives rise to that $f(s) \phi(s, s)$ term, which nonetheless equals zero.) Rearranging gives the
second line as a weighted average of individual rental prices. (Again, the zero rents of the defunct, \(\int_0^L f(L)0\)\(dL\), add nothing.) Multiplying and dividing each individual rental price by its own age-0 value (i.e., its user-cost) gives the third line as a weighted average of individually priced extant age-efficiency functions. Setting \(s = 0\) in (16) gives the cohort-average user cost:

\[
C = p \left( r - \frac{\partial \Theta(0)}{\partial s} \right) = p \int_0^L f(L) \left( r - \frac{\partial \phi(L)}{\partial s} \right) dL = \int_0^L f(L)c(L) dL \tag{17}
\]

Straightforward substitution for \(c(L)\) from (8) and (13) give alternative, primal-only representations of the cohort-average user cost:

\[
C = p \int_0^L \frac{f(L)}{\int_0^L e^{-rs} \phi(s,L) ds} dL = p r \int_0^L \frac{f(L)}{1 + \int_0^L e^{-rs} \frac{\partial \phi(s,L)}{\partial s} ds} dL \tag{18}
\]

None of expressions (14)-(18) should excite controversy: all are lifespan-frequency weighted averages of one or other sort of price. But what about applying lifespan frequencies to individual age-efficiency profiles? Dividing the last version of (16) by the middle version of (17) — that is, forming the ratio of aggregate age-s rents to the aggregate user-cost — would define the aggregate age-efficiency profile, \(\Phi(s)\), just as the individual efficiency profile equals its own rent- to - user-cost ratio. Several ways to express the aggregate ratio are:

\[
\Phi(s) \equiv \frac{\int_0^L f(L)c(L)\phi(s,L) dL}{\int_0^L f(L)c(L) dL} = \frac{\int_0^L f(L)(r - \frac{\partial \phi(s,L)}{\partial s})\phi(s,L) dL}{\int_0^L f(L)\phi(s,L) dL} = \frac{\int_0^L f(L)c(L)\phi(s,L) dL}{\int_0^L f(L)c(L) dL} = \frac{\int_0^L f(L)\phi(s,L) dL}{\int_0^L f(L) dL} \tag{19}
\]

All are lifespan-frequency weighted averages of priced individual age-efficiency profiles. (Alternatively, the effective weights on unpriced individual profiles are proportional to \(f(L)c(L)\), an implied distribution that is front-loaded vis-à-vis \(f(L)\), owing to the reciprocal relation between \(c(L)\) and \(L\).) Yet none of the expressions resembles the worked-out example of Ball, et al. op. cit., Table 2: "Change in efficiency of assets with varying service lives and the total replacement function," which is effectively a lifespan-frequency weighted average of unpriced extant individual age-efficiency functions:

\[
\Phi(s) = \int_s^L f(L)\phi(s,L) dL \tag{20}
\]

To decide, consider whether or not:

\[
C = \int_0^L \frac{p}{e^{-rs} \Phi(s) ds} = \frac{pr}{1 + \int_0^L e^{-rs} \frac{\partial \phi(s)}{\partial s} ds} \tag{21}
\]

at the cohort level. That is, can present-discounted value operations on cohort-level \(\Phi(s)\) and \(\Phi'(s)\) provide a primal-only aggregate user-cost that agrees with a lifespan-frequency weighted average of individual-level user-costs? In the first case:

\[
\int_0^L e^{-rs} \Phi(s) ds = \frac{\int_0^L e^{-rs} \left( \int_s^L f(L)c(L)\phi(s,L) dL \right) ds}{\int_0^L f(L)c(L) dL} = \frac{\int_0^L f(L)c(L) \left( \int_s^L e^{-rs} \phi(s,L) ds \right) dL}{\int_0^L f(L)c(L) dL} = \frac{\int_0^L f(L)c(L) \phi(L,c(L)) dL}{\int_0^L f(L)c(L) dL} = \frac{p}{\int_0^L f(L)c(L) dL}
\]
...where the second expression substitutes for \( \Phi(s) \) from (19), the third carefully exchanges the order of integration, the fourth substitutes from (8), and the fifth cleans up. Substituting that fifth expression back into the first version of (21) returns \( C = \int_0^L f(L)c(L)dL \), as per (17). By contrast, with \( \widetilde{\Phi}(s) \) from (20) instead of \( \Phi(s) \) from (19), the same steps — which use \( f(L) \) alone instead of \( f(L)c(L) \) — would return \( \widetilde{C} = 1/\left( \int_0^L f(L)/c(L) \, dL \right) \), a weighted harmonic mean of individual user-costs.

The demonstration for the second case of (21) is similar:

\[
\int_0^L e^{-rs} \frac{\partial \Phi(s)}{\partial L} ds = \int_0^L \frac{e^{-rs} \left( \int_0^L f(L)c(L) \frac{\partial \Phi(s) \partial L}{ds} \right) ds}{\int_0^L f(L)c(L) \, dL} = \int_0^L f(L)c(L) \left( \int_0^L e^{-rs} \frac{\partial \Phi(s \partial L)}{ds} ds \right) dL
\]

\[
= \int_0^L f(L)c(L) \left( r \int_0^L e^{-rs} \Phi(s \partial L) ds - 1 \right) dL = \frac{r \, p}{\int_0^L f(L)c(L) \, dL} - 1
\]

...where the second line follows from the first by integration by parts. Substituting back into (21) again gives the sensible \( C = \int_0^L f(L)c(L) \, dL \). And using \( \Phi'(s) \) in place of \( \Phi'(s) \) would again lead to a weighted harmonic mean. I conclude that while the user-cost formula (19) of Ball, Lindamood, Nehring and San Juan, op. cit. is fine, the aggregate age-efficiency function that is applied to it is mistaken.

**Worked-out Comparisons: "USDA ERS K review.xlsb"**

The attached Excel workbook puts some numbers to the arguments just made. It consists of two annotated introductory tabs, "TRACTORPlot" and "B-L-N-SJ 2008 Table2," then the main work tab, "Hyperbolic (~ERS-BLS)," that I'll describe here. The work tab's punch-line is the plot at A1:I16, which shows a cohort age-efficiency (A/E) profile (in black) per expression (20) above, such as ERS or BLS-OPT might produce, a revised cohort A/E profile (in blue) per expression (19), and a cohort age-price (A/P) profile (in red) derived from the blue cohort A/E profile. The blue line uses a type of truncated Normal distribution to weight up priced individual A/E profiles, where the prices are the user-costs of each; the black line weights up unpriced individual A/E profiles. Pricing by individual user-costs plainly matters.

The plot's "controls" are at N5:N9 and are amenable to experimentation. The first governs the curvature of individual Hyperbolic A/E profiles, which are the "atoms" of this exercise. (I also have worksheets for \( \alpha \)-type individual profiles, which aren't attached.) The defaults are \( \beta = .5 \) or .75; \( \beta > 1 \) is illegal. The second is the (own) rate of return, which I have set to 6 percent. The third is the mean lifespan, which I have set to 9 years to follow the specification in "TRACTORPlot." The fourth is the standard deviation of an untruncated Normal distribution, which I have set to 49 percent of the mean (i.e., 4.41 years) in deference to stated procedures at ERS and BLS. It may be widened a tiny bit more (to 50–ε percent), or contracted. Individual lifespans range from two such standard deviations below the mean, to two above.
The fifth control (N9) governs the type of truncation. When set to 0, which I understand to be the ERS approach, the Normal distribution is truncated in the usual way: tails more than two standard deviations from the mean are lopped off, and the remaining probability density function is renormalized by 1 less the truncated tails' probability area. The renormalization amounts to dividing the surviving area by about .9545; what remains looks almost Normal enough, apart from probability "cliffs" at the lower and upper truncation points. The BLS remedy to the cliffs (at one time, anyhow) is to reduce the height of the untruncated probability density function until the lower and upper truncation points have zero probability-height, then divide by the area of what remains (around .73854). The resulting probability density function resembles a haystack, and it is without cliffs: probabilities at the upper and lower truncation points are level-continuous with the zero probabilities just outside them. For haystack weighting, set the fifth control to 1. (I'll have more to say about the choice soon.)

The worksheet uses Simpson's 1/3 and 3/8 methods to carry out three different sets of integration. Simpson weights at N17:AHL17 are used for aggregating across individuals with different lifespans. Weights at J23:K914 are used for present discounted value calculations of lifespan-specific user-costs, which are shown at N19:AHL19. (Observe that user-costs are very large for extremely short-lived assets, but small for long-lived assets.) And weights at H23:I914 are used for present discounted value calculations of the cohort A/P profile at G23:G914. This is the only age-price profile in the whole notebook, and it is the very last step. The calculations cannot be more primal.

The recognition of individual user-costs as price-weights for individual A/E profiles brings about consistency with commonsense aggregation, but it has statistical consequences beyond the retraction of the unweighted cohort A/E profile. When the lower extremity of the distribution of lifespans is close to zero, user-costs are extremely high (and indeed numeric present discounted value integrals are none too accurate in that region). When such user-costs and individual A/E profiles are combined with non-negligible probabilities, as when cell N9 is set to 0, then the aggregate A/E profile drops sharply (even below the aggregate A/P profile), as it is temporarily dominated by its shortest-lived members. The solution is not to retain the unpriced cohort A/E profile (which is not sensitive to individual user-costs because it doesn't have any, but is inconsistent with aggregation for the same reason): that would represent a victory for stovepiping. Instead, the probability mass at very low lifespans needs to be reduced, whether by tighter truncation (which feels unrealistic), or by adopting the BLS haystack approach.
In order to do growth accounting, we need to estimate the contribution of capital to growth of output. This contribution equals the elasticity of output with respect to capital services multiplied by the growth of capital services. In reality there are many types of capital goods so we need to construct an index of the growth of capital services. This requires that we estimate the user cost of each asset to use as weights, on the assumption that user costs measure marginal products.

The standard approach has been to assume that the productive capacity of capital goods declines geometrically with age. This implies that replacement is a constant fraction of the capital stock at the beginning of each period. While this approximation is a convenient one, little empirical evidence has been marshalled in its support. Accordingly, we adopt a more general approach.

The behavioral assumption underlying this approach, common to the literature on investment demand, is that firms buy and sell assets so as to maximize the present value of the firm. Let $w_K$ denote the price the firm must pay for a new unit of capital, $p$ the price the firm receives for each unit of output, and $r$ the real discount rate. An increase in the capital stock $K$ by one unit will increase output in each period by $\frac{\partial y}{\partial K}$, the marginal product of capital. Gross revenue in each period will rise by $p(\frac{\partial y}{\partial K})$, but net revenue will rise by only $p(\frac{\partial y}{\partial K}) - w(\frac{\partial R_t}{\partial K})$, where $\frac{\partial R_t}{\partial K}$ is the increase in replacement in period $t$ required to maintain the capital stock at the new level. Firms should add to their capital stock if the present value of the net revenue generated by an additional unit of capital exceeds the purchase price of the asset. This can be stated algebraically as:
To maximize their net worth, firms will continue to add to capital stock until (1) holds as an equality. This requires that:

$$p \frac{\partial y}{\partial K} + r \sum_{t=1}^{\infty} w_t \frac{\partial R}{\partial K} (1 + r)^t > w_K.$$  

The expression for $c$ is the implicit rental price of capital corresponding to the mortality distribution $m$. The rental price consists of two components. The first term, $rw_K$, represents the opportunity cost associated with the initial investment. The second term, 

$$r \sum_{t=1}^{\infty} w_t \frac{\partial R}{\partial K} (1 + r)^t,$$  

is the present value of the cost of all future replacements required to maintain the productive capacity of the capital stock.

Expression (2) can be simplified as follows. Let $F$ denote the present value of the stream of capacity depreciation on one unit of capital according to the mortality distribution $m$:

$$F = \sum_{\tau=1}^{\infty} m_{\tau} (1 + r)^{-\tau},$$  

where $m_{\tau} = -(d_{\tau} - d_{\tau-1})$ and $d_{\tau}$ is the relative efficiency of an asset $\tau$ years of age. It can be shown that

$$\sum_{t=1}^{\infty} \frac{\partial R}{\partial K} (1 + r)^t = \frac{F}{1 - F}$$  

so that

$$c = \frac{r w_K}{1 - F}.$$  

The expression in (5) holds for any pattern of depreciation. For the special case where

\[ d_t = \delta(1 - \delta)^{t-1}, \]

which has been assumed in previous studies,

\begin{equation}
F = \sum_{t=1}^{\infty} \delta(1 - \delta)^{t-1}(1 + r)^{-t} = \delta / (r + \delta)
\end{equation}

and

\begin{equation}
c = w_k (r + \delta),
\end{equation}

which is the rental price commonly found in the literature (Note that \( \delta \) in expression (7) refers to decay as opposed to economic depreciation, although the two measures will coincide when efficiency declines at a constant exponential rate).

This literature typically uses an ex post measure of the rate of return. In the ex post approach, it is assumed that the rate of return is equalized across all assets. Then this unknown rate can be found by using the condition that the sum of returns across assets (where the return on an asset is the product its user cost and the flow of services it yields) equals observed, total profits (gross operating surplus in the national accounts).

The alternative ex ante approach which we adopt employs information from financial markets with estimates of expected rather than actual price inflation. We argue that calculating ex post user costs is, in general, not correct. The reason is that unless expectations are realized, ex post rates of return will differ between assets even though ex ante they are expected to be the same, so the growth of capital services are better measured using the ex ante method.

Finally, the internal consistency of a measure of capital input requires that the same pattern of relative efficiency is employed in measuring both capital stock and the rental price of capital services. The decline in efficiency affects both the level of capital stock and the corresponding rental price. The estimates of capital stocks and rental prices that underlie our
measures of capital input are based on a hyperbolic decay function concave to the origin. The same pattern of decline in efficiency is used for both capital stock and the rental price of each asset, so that the requirement for internal consistency of the measure of capital input is met.
Appendix 1.3. Email exchange between Brian Sliker (BEA) and Eldon Ball (ERS) on capital input

From: "Sliker, Brian" <Brian.Sliker@bea.gov>
To: Barbara Fraumeni <bfraumeni@usm.maine.edu>
Date: 4/14/2014 2:06 PM
Subject: FW: user cost of capital
CC: "Ball, Eldon - ERS (EBALL@ers.usda.gov)" <EBALL@ers.usda.gov>

Hi Barbara-

Eldon Ball and I have been emailing back and forth. He has asked me to forward our conversation, which is tangled. Think of it archaeologically: the more recent strata are near the top. Not many bones, though.

-Brian

From: Ball, Eldon - ERS [mailto:EBALL@ers.usda.gov]
Sent: Monday, April 14, 2014 12:59 PM
To: Sliker, Brian
Subject: RE: user cost of capital

Brian,
I think it would be helpful if you shared your comments with Barbara/Jon.
Thanks,
Eldon

From: Sliker, Brian [mailto:Brian.Sliker@bea.gov]
Sent: Friday, April 11, 2014 7:33 PM
To: Ball, Eldon - ERS
Subject: RE: user cost of capital

Sorry, Eldon, for the very long delay. I spent a week detailing my story in a write-up and Excel workbook, which are attached.

I think Barbara was indeed thrown off by the form of the user cost (at least that is what I infer from Jon Samuels’ account). But your formula for the user cost --- say, equation (19) in Applied Economics --- looks fine to me. (In fact, in an attachment I re-derive it: see my equation (13).)

Yes, we do disagree over how to calculate the aggregate replacement function. Your method weights up individual replacement functions by service-life probabilities (e.g., equation (20) in the attachment). I’d recommend first multiplying each individual replacement function by its own user cost, and then weighting up by service-life probabilities (e.g., equation (19) in the attachment).

I’ve found a third issue, too, having to do with how truncation of the distribution of lifespans is carried out. Your method is the correct and standard one, but I think BLS has something that works better.

All is described in the attached write-up and made useable in the workbook.

-Brian
From: Ball, Eldon - ERS [mailto:EBALL@ers.usda.gov]
Sent: Friday, April 04, 2014 9:49 AM
To: Sliker, Brian
Subject: RE: user cost of capital

Good morning Brian. I think we have been talking past each other. I started this discuss focusing on the user cost, not thinking that Barbara/your focus was on the capital stock. To be sure, there are simplifying assumptions in our calculation of the user cost, but the algebra underpinning equation (19) in Applied Economics is correct. Moreover, this does not depend on the particular assumption made regarding decay. Perfectly general. And geometric is a special case. So, we are back to the capital stock. Your focus appears to be on aggregation across the possible service lives (i.e., Table 2). But in table 2, we are merely apply Simpson’s approximation to the integral. Mathematics as opposed to economic content. You prefer an alternative approach to calculating the aggregate replacement function. Is this correct? Can we agree that this is the source of our disagreement?

Thanks.

From: Sliker, Brian [mailto:Brian.Sliker@bea.gov]
Sent: Tuesday, April 01, 2014 6:07 PM
To: Ball, Eldon - ERS
Subject: RE: user cost of capital

Hi Eldon-

Let me reply to your main message here. Then I’ll try to answer your yellowed-in remarks below, one at a time, I suppose in blue.

Here, I’m going to make two arguments: the first is an extended comparison of geometric and nongeometric approaches to cohort-level age-price and age-efficiency functions; the second is about what Barb wants to see in a user-cost and what it would take to connect your work to a user-cost construct that is more familiar to most capital (and even productivity) economists.

1. When Barb hired me at BEA a long time ago, she told me she wasn’t wedded to geometric depreciation, but could make exceptions “as the data warrant.” In fact, a few assets in BEA’s stable are depreciated in non-geometric ways, whether because good data are available to support some year-to-year variation or because institutional arrangements in an industry have locked in an alternative form (e.g., straightline depreciation for nuclear fuel rods). Nonetheless, it’s safe to say geometric forms are her (and Jon’s) “base case,” because of the pervasive effects of aggregating individual assets whose lifespans aren’t all the same but are widely distributed. That is, the (lifespan-frequency) weighted average of all those individual age-price forms --- even highly concave forms --- tends toward something that is convex over very nearly its entire career: something that can be readily approximated by a geometric form. Once that approximation is made, it brings in its train great computational simplifications, including identical duality with the age-efficiency form. It is that identical duality that enables advocates of geometric depreciation to claim (correctly) that it’s the same as geometric deterioration --- the rate of a cohort’s efficiency loss. The key to it all is the “convexifying” tendency of aggregation, which allows many capital analysts to just about ignore the shape of individual-level price-loss or efficiency-loss.

It’s an uphill climb, then, for the data to warrant non-geometric depreciation of a class of assets --- not an impossible case to make, but a difficult one. One would need to show that the shapes of individual-level
depreciation and of the distribution of lifespans don’t sync-up: that the two forms’ product, integrated over the range of lifespans, isn’t approximately geometric. And one would need some actual data to back that up: persuasive evidence on individual patterns, plus a recent and relevant service-life distribution. But when actual data are scarce, most people --- and not only Barb --- would go with the model that doesn’t need many assumptions about individuals, but only one or two assumptions about a cohort. And that model would be geometric.

Now, the Excel chart you sent me of the age-price and age-efficiency patterns of a tractor cohort shows that, yes, the age-price form really almost might be nearly convex enough to be approximated by a geometric model, but that, no, the age-efficiency form is not. So maybe the geometric approximation on the price side needs to be truly excellent before it could carry over with any force on the efficiency side, right? Well, what I tried to argue below (beginning from “More troubling...”) was that the method behind your Excel chart for calculating cohort-level age-efficiency profiles is mistaken. That method takes a weighted average of individual-level age-efficiency profiles, where the weights are lifespan frequencies. A better way starts from recognizing that rents on new assets that are revealed as short-lived need to be higher from the very start than rents on new assets that are revealed as long-lived (i.e., the short-lived individuals have higher deterioration rates); both individuals can have the same-shaped age-efficiency profiles, but the proper comparison across individuals is rent-versus-rent, not efficiency-versus-efficiency, because the individual age-efficiency profile is only a comparison between a particular asset at a given age and itself if only it were age 0 again. (I make that sort of comparison every morning in the bathroom mirror, and the results aren’t good.) At the cohort level, we need a lifespan-frequency–weighted average of rents at a given common age divided by a lifespan-frequency–weighted average of rents that would prevail were the common age zero. When you cook up the cohort A/E curve this way, you get a profile that is not as concave as the red one in your chart.

My discussion needn’t clinch the case for geometric depreciation/deterioration. But if we’re going to reject the geometric form because it doesn’t work well enough for the cohort A/E schedule, let’s at least make sure the cohort A/E is correctly drawn. As it stands, it’s biased toward concavity because of how it weights up individuals.

2. I’ll confess I’ve always seen the depreciation rate in the user-cost set up as the marginal proportional loss of value of a new asset --- straight out of the age-price function. In the geometric case the loss-rate is the same (cohort-wise) at any age, and the depreciation rate of the cohort A/P profile matches the deterioration rate of the cohort A/E profile. Barb is not insisting on a geometric form, but she is asking you to make the case that a user-cost built around a summed-and-discounted sequence of efficiency losses is the same as one built around the loss of age-0 value, and not only for the geometric case. Some mathematical heavy-lifting may be involved. Below, when I referred to Bob Hall’s 1968 paper and Kenneth Arrow’s 1964 paper, I was both trying to make some argumentative space (to show that some leading lights in the field, long ago when it was a field, really did equate the NPV of future efficiency losses to value loss) and to offer you or your staff something by way of clues as to how to do the same starting from your hyperbolic form. Somebody should.

As to burden-of-proof arguments, the fact that a good many peer-reviewed papers have used your capital does weigh in favor of your user cost not being beyond the pale. But the weight is not absolute. Many reviewers aren’t capital experts; Barb is. If she says the user-cost depends on the (new) depreciation rate of the wealth stock, that should be taken as the pale, or pretty close to it. At a minimum, your argument for using the deterioration rate of the age-efficiency form needs to be couched in terms of the discounted sum of a sequence of efficiency deteriorations --- that would be the rickety rope bridge to connect to depreciation of the age-price form. In fact, that is how the 2008 Applied Economics paper does things, in the “Capital rental prices” subsection of the “Methodology” section, especially equations 15-19 and footnote 8. To say that the user-cost is a function of efficiency loss without being clear about the discounted sum of the sequence of efficiency losses is to raise hackles needlessly.
(I apologize if I’ve raised some hackles.)

Remaining remarks are in blue below.

Best wishes,
Brian

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From: Ball, Eldon - ERS [mailto:EBALL@ers.usda.gov]
Sent: Monday, March 31, 2014 5:12 PM
To: Sliker, Brian
Subject: RE: user cost of capital

Hi Brian,
I was out Friday and am just now responding to your comments. I address your comments specifically below. As noted, I don’t always follow you. Perhaps after you see my limited response we could discuss. My real concern is that Barbara is so accustomed to invoking geometric decay that she cannot entertain other possibilities; that she will not give our approach its due. In addition to the Applied Economics paper you mention, we have used this derivation/presentation of capital user cost in numerous papers in refereed journals (including a joint paper with Frank Gollop and a paper in the Journal of Productivity Analysis that was the basis for my seminar at BEA) without objection. That does not make it “correct”, but the approach does merit some objectivity from the review panel. Barbara simply said during our meeting that it must be a function of age/price or it is wrong.

Let me know if you are interested in a follow up.

Best,
Eldon

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From: Sliker, Brian [mailto:Brian.Sliker@bea.gov]
Sent: Wednesday, March 26, 2014 6:24 PM
To: Ball, Eldon - ERS
Cc: Samuels, Jon; Barbara Fraumeni
Subject: RE: user cost of capital

Hi Eldon,

Sorry for the slow turnaround. I was out this week until this afternoon for my kid’s spring break.

I have read the quick description you sent me, as well as Ball, Lindamood, Nehring, and San Juan (2008) “Capital as a Factor of Production in OECD Agriculture: Measurement and Data,” Applied Economics (vol. 40, no. 10): 1253–77, which fleshes out the development of both the productive stock and the user cost. I’ve also heard a bit from Jon Samuels about his and Barb F.’s dislike of your use of the decay rate of the *efficiency* function, rather than of the (age-zero) resale price function, in the construction of the user cost.

…I am not sure what their objections are, but I suspect I will learn this on April 24–25. To my knowledge, no one has definitively addressed the rate of decay and, hence, the form of the user cost. Most studies eventually get around to citing Hulten and Wykoff. They rejected geometric decay but concluded that double declining balance was a good approximation to the rate of economic depreciation. Agreed. Assuming a positive discount rate, even the light bulb (or one-hoss shay decay pattern) has a convex depreciation schedule.
For a one-hoss shay individual destined to live to age \( L \), the age-efficiency profile is just \( \{1 \text{ if age } \leq L, \ 0 \text{ if age } > L\} \), so the age-price profile is \( \{\text{Integral of } e^{-r(u-s)1} \text{ from } u=s \text{ to } u=L \} / \{\text{Integral of } e^{-r(u-0)1} \text{ from } u=0 \text{ to } u=L \} \), which can be shown to equal \( \{e^{r*s} - e^{r*L} \}/ \{1 - e^{r*L} \} \) for \( s \leq L \), where \( r \) is the discount rate and \( s \) is the age. This form is concave toward the origin. For an exact geometric cohort, multiply the form by the following particular probability density function in \( L \):

\[
 f(L) = \frac{G(G+r) e^{-G*L}}{r} \frac{1 - e^{-r*L}}{r}
\]

and then integrate the product over \( L \) from \( L=s \) up through \( L \) of . The cohort result, \( e^{-G*s} \), is of course plenty convex. (That particular density has a long right tail; nobody would confuse it with a Normal.)

Suppose we continue with the one-hoss shay case and the particular probability density. Using the density to weight individual \( 1/0 \) efficiency profiles gives something conceptually close to the ERS (and BLS) treatment of the cohort age-efficiency profile. This is just \( f(L)'s \) survival function: \( 1 - \text{Integrate}[G(G+r) e^{-G*L}(1 - e^{-r*L})]/r \text{, from } L=0 \text{ to } L=s] \). This evaluates to \( e^{-G*s} [1 + (1- e^{-G*s})*G/r] \), which starts out quite concave.

To get the cohort age-efficiency function that I've prescribed, first calculate the rental-price functions at arbitrary age \( s \) and particular age \( 0 \). The first is:

\[
 r\{e^{r*s} - e^{r*L}\}/(1 - e^{r*L}) - \frac{w}{r}\{e^{r*s} - e^{r*L}\}/(1 - e^{r*L})\] , which evaluates to: \( r/(1- e^{r*L}) \). It doesn’t depend on \( s \) (that is, age), so it’s the same at age \( 0 \). So this is in fact the user-cost for the one-hoss shay individual. (Divide it through by its age-0 value, which is the same, and --- yep --- you wind up with 1: the one-hoss shay individual \( A/E \) function.)

The numerator of the prescribed cohort age-efficiency form is the weighted average: \( \text{Integrate}[f(L)*0 \text{ from } L=0 \text{ to } L=s] + \text{Integrate}[f(L)*r/(1- e^{r*L}) \text{ from } L=s \text{ through } L=\infty]. \) I keep the first part to give the defunct individuals their due.) The integral evaluates to: \( (r+G)*e^{-G*s} \). The denominator of the prescribed age-efficiency cohort is the weighted average: \( \text{Integrate}[f(L)*r/(1- e^{r*L}) \text{ from } L=0 \text{ through } L=\infty]. \) The integral evaluates to just \( r+G \). Dividing gives \( e^{-G*s} \) as the cohort age-efficiency function . . . same as the cohort age-price form.

Lotta math, sorry, but I needed to demonstrate that the choice of how to weight individuals really does matter. We mess up our intuition for cohort \( A/E \) if we take a frequency-weighted average of individual \( A/E \) functions.

The presence of the decay rate of the efficiency function in the user cost should not, as such, bother anybody. You’ve got it there, summed with plenty of discounting, so it should work out to match user-cost derivations based on the wealth stock. Bob Hall spent some time on this in his 1968 “Technical Change and Capital from the Point of View of the Dual” (Review of Economic Studies, vol. 35): 35-46, and it would seem to be traceable to Arrow’s 1964 “Optimal Capital Policy, the Cost of Capital and Myopic Decision Rules,” which I have not read. Reading between the lines of Hall’s title, I’d speculate your approach to the user-cost might have been called a “primal” method.

...Yes. The decay pattern defines the depreciation pattern.

To the limited extent that students these days are taught how to derive the user-cost, they are taught only the dual (i.e., wealth-stock) approach, and then only with a constant rate of depreciation/deterioration/replacement (which coincide only in the constant-rate case).

...I would argue that this reflects BEA’s emphasis on measuring wealth. No one would be terribly upset if you use a constant rate of economic depreciation in measuring the wealth stock. But this does not necessarily imply geometric decay.

Treating \( p \frac{\partial y}{\partial K} \) and \( w \) (the investment-goods price) as \textit{constants} in the user-cost derivation is irksome, but it wouldn’t be the first unrealistic simplification ever made in that derivation.
...Now you have lost me. Constants?

In the 2008 paper, the transition from equation (15) to (16), as shepherded by footnote 8, only works in the way shown if the value marginal product (p \( \frac{\partial y}{\partial K} \)) and the investment-goods price (w) are constant over time. If they changed, they couldn’t get pulled outside the summations. Those same two equations are equations (1) and (2) in “Review Panel_Capital.docx,” which you sent me March 19.

More troubling --- and now I’m relying on the 2008 paper, particularly the Table 2 example (“Change in efficiency of assets with varying service lives and the Total Replacement Function”) --- is the construction of a cohort-average replacement function as a weighted average of individual replacement functions, where the weights are the frequencies of each lifespan in the cohort’s original installation. The problem is: every individual replacement function (or as I grew up calling them, age-efficiency function) at age s is a ratio of that individual’s own rental value at age s to its own rental value at age 0.

...I would argue that this is backward. Your age/price function is defined by the decay function. In the above, you are defining the age/price function.

(That may be easier to see when the user-cost is calculated using dual not primal methods, but it’s true nonetheless.) Summing across ratios is OK if all the members’ denominators are equal, but in fact they’re not. If the Law of One Price for new-asset purchases is to hold even approximately, then at young ages --- in particular at age 0, which is what applies to the individual efficiency function denominator --- the user-cost (AKA rent) of a short-lived member of a cohort has to be greater than the user-cost of a long-lived member, because the short-lived member has fewer years to pay its way. A better construct for the Total Replacement Function (AKA Cohort Age-Efficiency Function) is to apply lifespan-frequency weights to all individuals’ age-s rents, then apply the same lifespan-frequency weights to all individuals’ age-0 rents, then divide the age-s weighted average by the age-0 weighted average. This amounts to saying that the proper weight on an individual replacement function in the total is proportional to the product of the individual’s age-0 user-cost and its lifespan frequency, and not proportional to the lifespan frequency alone. The upshot is to front-load the cohort A/E function --- and this does move the cohort A/E profile toward convexity (i.e., away from concavity) in the cohort’s early years. That doesn’t have to imply geometric cohort deterioration, but it does make the deterioration of the cohort, even a cohort of one-hoss shay assets, seem less different from geometric deterioration than many practitioners of aggregate productive stocks are accustomed to seeing. (I’ve mentioned this twice to BLS, which has nearly the same approach to calculating cohort A/E that the 2008 paper --- and so presumably ERS --- does, but I’ve made no headway.)

...I confess I don’t follow you. The age/price function dual to our age/efficiency function is very similar to geometric. I have attached a depiction of both for farm tractors. But the cohort age/efficiency dual in the same chart isn’t nearly so convex. My point is that the way it is set up makes it too concave artificially. Looking at it, of course we should object to a geometric approximation. If it were set up as the ratio of the two weighted sums (instead of as the weighted sum of the individual A/E ratios), it would look more convex than it does, though maybe not so convex as to favor a geometric model.

I’ll point out that the ratio-of-averages approach to the total replacement function is consistent with the cohort wealth stock in a pleasing way --- i.e., you can get either one from the other using the same steps as if you were only dealing with individual A/E and A/P functions. I don’t think the same can be said for the 2008 paper’s average-of-ratios approach.

That’s the gist of my review. If you like, I can bulk this up with formulae and spreadsheets, though it will take a
while longer to dust them off.

Very best wishes,
Brian Sliker
202-606-9649

From: Ball, Eldon - ERS [mailto:EBALL@ers.usda.gov]
Sent: Tuesday, March 25, 2014 10:28 AM
To: Sliker, Brian
Subject: RE: user cost of capital

Good morning. Please accept my apology for pressing, but could you give me your comments on the user cost of capital in the next day or two. I need to prepare for the upcoming meeting of the review panel. If a conversation would help...694-5601.
Thanks.

From: Sliker, Brian [mailto:Brian.Sliker@bea.gov]
Sent: Wednesday, March 19, 2014 6:11 PM
To: Ball, Eldon - ERS
Subject: RE: user cost of capital

Thanks!

From: Ball, Eldon - ERS [mailto:EBALL@ers.usda.gov]
Sent: Wednesday, March 19, 2014 4:39 PM
To: Sliker, Brian
Cc: Samuels, Jon
Subject: RE: user cost of capital

Brian,
We assume a concave decay pattern and normally distributed discards when measuring capital stocks. Same for BLS. Similarity ends there. Our measure of the user cost is based on equation (5) of the attached. I am happy to discuss if there are questions. And, as I said earlier, feel free to keep Barbara in the loop.
Best,
Eldon

From: Sliker, Brian [mailto:Brian.Sliker@bea.gov]
Sent: Wednesday, March 19, 2014 3:52 PM
To: Ball, Eldon - ERS
Subject: RE: user cost of capital

Is there a blow-by-blow write-up of how you do things? (FYI: The BLS’ write-up has always left me a little underwhelmed, and the fact that both BEA and BLS claim to be relying on Hulten & Wykoff’s Box-Cox results has always seemed fishy. I guess I’m picky.)

From: Ball, Eldon - ERS [mailto:EBALL@ers.usda.gov]
Sent: Wednesday, March 19, 2014 3:25 PM
To: Sliker, Brian
Subject: RE: user cost of capital
The pleasure is mine.

Steve spoke highly of you. Actually he recommended I contact you. I don’t think things have changed since Mike Harper’s day, so you are probably up to date on methodology. Barbara insists that the user cost is a function of economic depreciation (as opposed to the rate of physical decay) even though we do not assume geometric decay. I think user cost of capital is the only real source of disagreement. You should feel free to share your comments with Barbara. The panel will meet again 24-25 April. And yes I gave a talk at BEA a while back. Spoke on convergence of TFP levels across states.

Thanks for sharing your insights!

**From:** Sliker, Brian [mailto:Brian.Sliker@bea.gov]
**Sent:** Wednesday, March 19, 2014 3:10 PM
**To:** Ball, Eldon - ERS  
**Cc:** Samuels, Jon
**Subject:** RE: user cost of capital

Hi Eldon-

It’s virtually nice to meet you, too, though I think I heard you give a talk in one of BEA’s second-floor conference rooms a couple years back.

I’ve received your quick description but will need a couple days to chew it over so I can come up with a sensible discussion. I used to work at BLS (I know Steve Rosenthal and remember a thing or two about BLS’s capital program...though it may have changed), and I was Barb’s side-kick when she was chief economist at BEA. So I think I have the mistrust of both organizations.

-Brian

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**From:** Ball, Eldon - ERS [mailto:EBALL@ers.usda.gov]
**Sent:** Wednesday, March 19, 2014 2:54 PM
**To:** Sliker, Brian  
**Cc:** Samuels, Jon
**Subject:** user cost of capital

Hi Brian,

Now that we have been introduced...I am responsible for the estimates of agricultural productivity. We are currently undergoing an OMB mandated review. Jon serves on the review panel. Another panel member is Barbara Fraumeni. I assume that both of you know Barbara. She and I disagree on the matter of the user cost of capital. She endorses the methodology of BLS. Both BLS and ERS assume a concave decay pattern with normally distributed discards. But we part ways regarding calculation of the user cost. As you probably know, BLS calculates an average rate of economic depreciation as the ratio of the first difference of wealth stock less investment to the productive stock. They use productive stock rather than wealth stock in this calculation because the productive stock is relatively stable. The user cost is then a function of this average rate of economic depreciation. We, on the other hand, start with the assumption (common to the literature on investment demand) that firms will add to the capital stock so long as the marginal value product of an additional unit of capital less the discounted value of future replacement requirements exceeds the asset price. Doing the algebra, we end up with an expression for the user cost that is a function of discounted value of the stream of capacity depreciation rather than a function of economic depreciation. The same rate of physical decay enters both the calculation of the capital stock and the user cost. We argue that this approach preserves...
the internal consistency of the measure of capital input. By extension, BLS forgoes internal consistency by mixing concave and geometric decay in their calculations. I know this is very sketchy, but Steve Rosenthal says that you are one to sort thru these methodological arguments. Your views would be greatly appreciated.

Best,

Eldon

V. Eldon Ball, Ph.D.
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and

Research Associate
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Hi Richard;

My apologies for taking so long to reply. It is ridiculous; I should have immediately answered you but I did not and as a result, I lost track of your email and here we are with my very late answer.

At first sight, the answer is clear: land is a fixed factor and is the natural candidate to allocate the operating surplus (after subtracting an imputation for unpaid family work) as land rent. However, there is a third alternative if estimates of actual rents paid for similar farm land are available: subtract the imputed wages for unpaid family labour and subtract imputed land rents from net operating surplus and this is the return to a residual entrepreneurial factor (or just regard this residual as pure profits or losses if negative) for the farm unit. Now this residual factor could be allocated to land rent (for those who believe this is the right course of action) or to the proprietor’s labour time (for those who believe that this is the right course of action). But I think it would be best to just leave this as a separate account. It is this account which will fluctuate a lot over time due to changing crop prices and weather, and that is how it should be. Farming is a risky business and there should be a residual pure profits or losses category to reflect these risks.

Of course, if the pure profits were persistent over time, then one would expect this persistence to show up in the price of the land since another owner could probably generate a similar pattern of cash flows.

Another argument against imputing pure profits to unpaid family work is this: if the farm were sold and a professional manager took over the responsibilities of managing the farm, then farm labour would be hired, the manager would be paid a salary and any pure profits would accrue to the owners. If we had implemented the imputations for both unpaid family labour and the price of land, leaving a residual pure profits category before the family farm was sold, then the outputs and inputs for the same farm under new professional management should correspond to the pattern of inputs and outputs (prices and quantities) that prevailed under the old family farm. Thus having the three categories would lead to more consistent accounts over time.

Again my apologies for taking so long to respond!

Regards, Erwin Diewert
summarize the major issues and relevant literature for us (attached pdf). He concludes by saying that it “is still unclear which way to go when putting prices to the inputs that together make up the operating surplus.” He then recommends that we go directly to the undisputed expert – you. I should note that I have been a student and beneficiary of your research since I first studied duality theory in the late 1970s but don’t believe we have ever met.

It is clear that both groups have given careful practical thought to the selection of the residual claimant and come to very different conclusions. So our basic question is whether there are theoretical reasons that should guide the selection of the residual claimant(s) if data didn’t dictate alternatives that are 2\textsuperscript{nd} or 3\textsuperscript{rd} best?

We will be most appreciative of any guidance you can give us.
Richard

C. Richard Shumway, Regents Professor
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A Note on Residual Claimant Inputs

Sean Cahill
Research and Analysis Directorate
Agriculture and Agri-Food Canada

January, 2014

I. Introduction

This note addresses the choice of residual claimant input and valuation of this input. The aim of the note is to specify and discuss some of the issues around this choice in the context of the AAFC and ERS production accounts. The approach is non-technical; more formal treatments can be found in the cited literature and/or background documentation related to construction of the accounts.¹

Section II provides a summary of the approach used to derive the operating surplus in the AAFC and ERS production accounts and the choice of residual claimant in each case.² Since, broadly speaking, the operating surplus is equal to the sum of the return to capital input(s) and the return to operator/unpaid family labour, valuation of both types of input is an issue, since if one or more is chosen as the residual claimant the other(s) must be valued at derived service prices. The discussion in Section III therefore addresses issues around the choice of residual claimant and the challenges faced when valuing the services from this and other inputs. Section IV makes some

¹ This unpublished background documentation is not cited but is available to the interested reader.

² The operating surplus is broadly similar to mixed income as defined in the SNA93 methodology – see, for example, IWGNA(1993, p. 39) and acts as a balancing item, in the terminology of SNA93 - see IWGNA(1993, pp. 92-93).
suggestions regarding a possible codification of the measurement options available to the practitioner when choosing a residual claimant in a mixed income framework.

II. The Operating Surplus and Residual Claimants

Within the agricultural production accounts constructed by AAFC and ERS, all gross outputs and all intermediate inputs are measured either directly, e.g. as tonnes of wheat produced, or indirectly, as receipts or expenses. In the former category, price data are usually available so that a quantity/price series can be constructed for each commodity or input. In the latter category, it is usually necessary to find appropriate price index series that can be used to deflate the dollar values to get an implicit quantity/price index series for each of these commodities or inputs. Either way, it is generally the case that valuation of most of these outputs and inputs is quite straightforward. Hired labour input is similarly quite easy to measure and value, so that both the AAFC and ERS production accounts have explicit prices and quantities of hired labour services.³

The operating surplus in both the AAFC and ERS accounts has the same definition: it is equal to the value of gross output, less cost of intermediate inputs and hired labour. In each account, the surplus is allocated across the capital inputs and operator/unpaid family labour.⁴ Of these inputs, the price of all but one is determined exogenously. The input for which the price is endogenous, i.e. that is based on the value remaining after all other inputs have been priced out, is the residual claimant.

³ The ERS hired labour series adjusts the input for composition changes over time. The AAFC data are much less detailed, being limited to number of weeks worked and remuneration on a weekly basis; no adjustment is made for composition in this account.

⁴ In the AAFC production account there is a total of 24 capital asset types; thus R=25. The capital assets are: buildings, farm machinery, commercial vehicles, passenger vehicles, 10 types of breeding livestock (dairy cows, beef cows, bulls, dairy heifers, beef heifers, boars, sows, rams, ewes & wethers, calves retained for herd replacement/herd accumulation) and 10 types of land (area by province).
The AAFC and ERS production accounts differ in the choice of residual claimant. The procedures used are summarized as follows:

a) AAFC approach. Services from all of the 24 capital asset types are priced with a user cost of capital estimated with investment deflators/prices, decay rates (these are zero for land and livestock) and an exogenous fixed real rate of return. Operator/unpaid family labour is the residual claimant; the wage for this input is equal to the operating surplus, less the cost of capital services, divided by estimated hours.

b) ERS approach. Services from buildings, farm machinery, commercial vehicles, passenger vehicles and breeding livestock capital are priced with a user cost of capital estimated with investment deflators/prices, a decay component and an exogenous ex ante rate of return. Operator and unpaid family labour are valued at an opportunity cost wage. Non-land capital inputs are valued using an ex ante rate of return. Land is the residual claimant, with the value of land services equal to the operating surplus less the user cost of other types of capital and the opportunity cost of operator/unpaid family labour.

III The Residual and Opportunity Cost Approaches

There is little in the way of guidance regarding which, of the inputs that comprise the set to be valued with the operating surplus, should be chosen to be the residual claimant(s) and which should be valued with exogenous prices/rates of return, i.e. at opportunity cost. The choice of operator/unpaid family labour as residual claimant has been challenged in several fora; land is clearly favoured over labour. This preference for a capital input as residual claimant may stem from the more conventional form that the operating surplus takes (e.g. in manufacturing), where all
labour can be priced out and capital services are valued using an internal rate of return estimated with the residual. This is not the case with mixed income, and the SNA93 manual makes this clear:

“Mixed income” has already been used to describe the balancing item in the generation of income account for a sub-set of enterprises, i.e., **unincorporated enterprises owned by members of households either individually or in partnership with others in which the owners, or other members of their households, may work without receiving a wage or salary.** Owners of such enterprises must be self-employed: those with paid employees are employers, while those without paid employees are own-account workers. In a few cases it may be possible to estimate the wage or salary element implicitly included within mixed income, but there is usually not enough information available about the number of hours worked or appropriate rates of remuneration for values to be imputed systematically.

IWGNA(1993, p. 218, my emphasis)

It is fair to say that Canadian agriculture has been, and continues to be, comprised primarily of sole proprietorships and partnerships, so the SNA93 description of mixed income enterprises applies to the Canadian case. In the AAFC production account, hours of work are estimated for operators and unpaid family members, so it is possible to estimate the wage to this labour implicitly.

There are several other reasons for the choice of operator/unpaid family labour as residual in the AAFC production account. First, this choice is largely consistent with the definition of net farm income used by Statistics Canada, where operating expenses and depreciation costs are deducted from a measure of gross output (cash receipts plus value of change in inventories and income in kind). Cost of capital is

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5 While incorporated farms have grown in importance, they cannot be said to be the dominant business arrangement for the period over which the AAFC production account has been constructed (1961-2006).

reflected in depreciation costs as well as several components of operating expenses. Net farm income must therefore be remuneration of operator labour, since all other input costs are accounted for.

Second, there is some support for this choice in the literature. Hottel and Gardner (1983) note that “it is the essence of family farming that the operator’s labor and management are claimants on residual returns” (p. 553) and examine the tradeoff between operator labour and capital as alternative residual claimants. Gardner (1992) also refers to the earnings of farm operator households as a residual (p. 83).

Finally, there is the definition of Farming Income for tax purposes. In Canada, wages paid to self by sole proprietors and partners cannot be deducted from income. On the other hand, there are the usual provisions for capital expenses (capital cost allowance, etc.)

While there are therefore strong arguments for operator/unpaid family labour to be the residual claimant, it is nevertheless important to consider the alternative, namely that this labour be priced out using an opportunity cost and one or more capital inputs be chosen to be the residual claimant. Here, there are two challenges. The first is to determine an appropriate wage with which to value hours of work for operators and unpaid family members. While there is quite widespread acceptance of this opportunity cost approach, there is little in the literature to guide the practitioner.

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6 See CANSIM Tables 002-009 (Net Farm Income) and 002-0005 (Farm Operating Expenses) which can be accessed at www5.statcan.gc.ca/cansim. Capital expense items in the latter include: cash rent; share rent; interest, after rebates (this would be for all types of loans, including mortgages), repairs to buildings and fences and machinery repairs. Depreciation is the sum of depreciation on buildings and depreciation on machinery. Note that these are, together, not ideal measures of capital cost, but they do account for most of the elements implicitly accounted for in the user cost of capital estimates in the AAFC production account.
Harberger (1972, Chapter 7) has suggested that the appropriate wage is in the ‘unprotected’ sector, where in Canada this might mean anything between the minimum wage and a wage in some non-unionized enterprise. Some might argue that, because operators are entrepreneurs, their opportunity cost would be considerably higher than this. Preliminary work with household data at AAFC suggests that those operators who work off the farm tend to find work in a variety of occupations, with considerable heterogeneity across provinces.

It is not clear that an off farm wage is the appropriate way to value operator/unpaid family labour, especially when there is no off farm employment. Census of agriculture data show that the majority of operators in Canada do not work off farm at all. This may reflect a lack of alternative off-farm employment opportunities employment; the factors involved do not appear to be well understood, although there is a small literature on the decision to work off farm.\(^7\)

An alternative is to value operator/unpaid family labour at the hired wage rate. There are some arguments against this, among which is the view that the appropriate wage is the shadow price determined by the equilibrium between the farm household labour supply function and the derived demand for labour from the farm operation – see, for example, Lopez (1986). There is some indication that the shadow price may actually be appropriate, because according to Census of agriculture data, less than half the farms in Canada actually hire labour. To the extent that operators of these farms do not work off farm, there will neither be an off farm nor a hired wage to use

\(^7\) See, for example, Bollman (1979). Bollman has published a large number of studies on off-farm work in various Statistics Canada publications over the past 30 years or so.
as a reference point.\footnote{Gardner(1992) also discusses some of the issues related to the difference between returns to operator/unpaid family labour and hired labour. In the United States, both appear to have been below comparable returns elsewhere in the economy.}

Given the difficulties involved in determining the opportunity cost of operator/unpaid family labour, the choice of this input as residual claimant is a practical one. Moreover, the methodology for valuing capital with an exogenous rate of return is well known. Harper, Berndt and Wood(1989) carried out an analysis of the various options available to the practitioner when choosing a rate of return on capital. They show that a user cost of capital computed using a constant real rate of return of 3.5%, although not their preferred measure, performs quite well, based on their three criteria. The use of a real rate of return also means that the asset appreciation (or depreciation) is no longer an element of the user cost of capital, which greatly simplifies application across many asset types, as is the case in the AAFC production account.\footnote{A 3.5\% real rate of return is also used in the AAFC production account. This is consistent with a nominal bond rate of return less the overall inflation rate over the 1961-2006 period.}

To sum up, it has been argued here that there are compelling reasons to choose operator/unpaid family labour as the residual claimant for the AAFC production account, there are no doubt equally compelling reasons to choose land as the residual claimant in the ERS production account. There is no clear rule that says that one choice is better or worse than the other – the best guide appears to be ‘what works’ and ‘what data are available’. In other words, “measuring returns as a residual creates inevitable choices among alternative procedures, none of which are exactly suitable” – Hottel and Gardner(1983, p. 557).
IV. Conclusion

The quote from Hottel and Gardner seems to nicely sum up the state of things over 30 years after their paper was published. It is still unclear which way to go when putting prices to the inputs that together make up the operating surplus. Ironically, even where there is a clear way to value labour, the question of how to price capital services remains. Diewert and Yu(2012) recently measured productivity growth for the Canadian business sector and found much higher average rate of productivity growth than that reflected by than the official estimates produced by Statistics Canada. The difference hinged on the rate of return to capital, where the operating surplus was allocated over many asset types. While there is still debate about this difference in results – compare Diewert(2012) and Gu(2012), the approach suggested by Diewert points to a more formalized way to price capital services within the context of an aggregate business sector production account. It would be helpful if a similarly clear specification could be made in the case of agriculture.
References


Appendix 2. Verbatim Stakeholder Input

From: Arnaud, Carlos - ERS <CARNADE@ers.usda.gov>
Sent: Tuesday, February 25, 2014 10:28 AM
To: Shumway, C Richard
Subject: RE:

To: Shumway, C Richard
Subject:

I am writing you because you have cited work by Eldon Ball and others in which they explain construction of the USDA/ERS productivity accounts. I am writing to request your feedback on the productivity accounts.

Before answering these questions bear in mind three things
1) I work for ERS and often exchange information in the people responsible for productivity measure
2) I often review this work, internally, particularly the work of Eldon Ball
3) I have worked in TFP measurement in the past and published in this area but have not work in the area for over a decade

- How have you and others with whom you are familiar used the national, international, and/or state ERS productivity accounts?
- I have not used the international accounts but I can see many possible uses for that data in my current work. I have used some of data and indices, and capital stock measures which go into TFP measurements.
- I am familiar with most of the work, and the data that goes into it.
- 
- What are the most important features of these accounts?
  I find the intermediate data the most useful. Final Tornqvist or other indices are not as useful as the data itself, (ie capital stock measures are very useful). Some of the data is too aggregate for personal use (ie grains, or livestock).
- Do you have questions about the methodology of their construction?
I always have questions about it. That is why I end up reviewing it these papers.

Other than issues, of measurement I have questions about when the data is appropriate to use. I have seen the data used is places where it should not be.

- Are you satisfied with the manner in which they are communicated?
Not at all. But communication has gotten better over the past decade. Public salary, public good. The data should always be available online to anyone who wants to use it. Currently getting the data handed over is a bit of a chore and involves some personal lobbying. But getting access to the data is less difficult now than in the past.
- Is there additional information about the productivity accounts you would like to have provided online? Formulas for capital construction. Some of the raw data which goes into the index.
- Are there ways to make access to the accounts more convenient?

Always post all data online as soon as possible.
- Are you satisfied with the timeliness with which the productivity accounts are posted?
Of course not. Who is.

- Do you have recommendations for improving the quality of the productivity accounts or the effectiveness of their use?

If more intermediate data was provided, I think less people would be using the indices themselves. I believe that, at times, people use the indices because that is what they have.
A few answers in the text.
JC Bureau, Professor, AgroParistech, Paris

Le 20/02/2014 01:45, Shumway, C Richard a écrit:

I am writing you because you have cited work by Eldon Ball and others in which they explain
construction of the USDA/ERS productivity accounts. I am writing to request your feedback on the
productivity accounts.

The USDA Economic Research Service has convened an external committee of Spiro Stefanou, Lilyan
Fulginiti, Barbara Fraumeni, Jon Samuels, and myself (chair) to review the ERS productivity
accounts. This is the first comprehensive review these accounts have received since the joint AAEA-ERS
review chaired by Bruce Gardner in 1978 that led to a major overhaul in the procedures used to develop
the accounts. The committee has been charged to address issues of methodology in the development
of estimates, ongoing research programs to improve methodology and operations, documentation and
reporting of methods and uses of the data, and the frequency and timeliness of reporting.

One of our charges is to seek stakeholder input. Since you may have used the productivity accounts, the
committee would particularly appreciate your response to such questions as the following:

- How have you and others with whom you are familiar used the national, international, and/or
  state ERS productivity accounts?

I have not worked on this topic for the last 2 years but I used to be quite familiar with the national (state
level) USDA TFP accounts, as well as the effort by E. Ball to develop international comparisons.

- What are the most important features of these accounts?

I think that ERS/USDA people do not realize what a great work they have been doing. They have focused
on TFP estimates. But the real great think is the development of a whole set of accounts. What they have
actually done is the equivalent of the Penn World Tables for US agriculture. Just to illustrate the
importance of the finding, to the question "can you quote a major discovery in economics", some 10
years ago Pr E. Malinvaud (a deserving Nobel price laureate)’s response was "the Penn World Tables",
because it changed everything we could say about macroeconomics. The USDA productivity data is the
equivalent for agricultural economists. Too bad comparison problems make the effort to have a standard
methodology across US states and other countries too difficult. But the accounts could be the workhorse
of all econometric analysis of the US farm sector if ERS realized what they have done and sold it as a
stand alone product.

- Do you have questions about the methodology of their construction?
I think that from a conceptual point of view the ERS approach is by far superior to competition that have major flaws. However, there are difficult problems in the measurement and valuation of land and family labour. And the solutions chosen by ERS are defendable, but still controversial.

- Are you satisfied with the manner in which they are communicated?

ERS communication policy on data is no longer what it used to be in the 1980s and 1990s... The agency seems to be a shadow of what it used to be. But V.E. Ball has always responded directly to any request I could have.

- Is there additional information about the productivity accounts you would like to have provided online?

A clear methodological cookbook

- Are there ways to make access to the accounts more convenient?

Do the same as the Penn world tables...

- Are you satisfied with the timeliness with which the productivity accounts are posted?

I am not aware of it. Consistency of data over time is more important than frequency

- Do you have recommendations for improving the quality of the productivity accounts or the effectiveness of their use?

Focus perhaps less on TFP and publicize more the fantastic work on the accounts that are behind TFP estimates

JC Bureau
Hi Will,

Thanks for forwarding this on. I haven't used USDA's productivity accounts in the past, other than to sometimes read the summary releases that I get on occasion, so am not a good person to provide input.

(Lilyan, I hope you are doing well!).

Sean

********************************************************************
Sean B. Cash, Ph.D.
Associate Professor
Agriculture, Food and Environment Program Friedman School of Nutrition Science and Policy Tufts University, Room 127 Jaharis
150 Harrison Avenue, Boston, MA 02111
(617) 636-6822, sean.cash@tufts.edu
Richard:
I am glad to provide some feedback.
In my view, the generation and diffusion of the productivity accounts has been a major accomplishment of USDA/ERS over the last few decades.
Best,
Jean-Paul

- How have you and others with whom you are familiar used the national, international, and/or state ERS productivity accounts?

Yes, I have used the ERS productivity accounts in my own research.

- What are the most important features of these accounts?

The accounts provide a consistent set of inputs, outputs and productivity measurements over time.

- Do you have questions about the methodology of their construction?

Yes, I have questions. My main concern relates the measurement of capital. I know that ERS has worked very hard on getting "good measures of capital". But I remain somewhat unsure whether the capital measurements are the "right ones"...

- Are you satisfied with the manner in which they are communicated?

In general, yes, I am satisfied.

- Is there additional information about the productivity accounts you would like to have provided online?

Yes, I would like to see more details about input/output statistics for both prices and quantities, and at both the US level and state levels.

- Are there ways to make access to the accounts more convenient?

One can always ask for "more convenience"...

- Are you satisfied with the timeliness with which the productivity accounts are posted?

I am reasonably satisfied...

- Do you have recommendations for improving the quality of the productivity accounts or the effectiveness of their use?
Dear Professor Shumway,

I am writing you regarding the ERS Productivity Accounts Review under your leadership, in response to your call for comments. I am Ramiro Costa, Chief Economist at Buenos Aires Grain Exchange, the oldest commercial institution in Argentina, founded in 1854. The Exchange is a non-profit civil association that serves as an intermediate service provider. I would like to provide you with our view on the ERS accounts from an international perspective.

The existing ERS-USDA agricultural productivity estimation system was initiated following Jorgenson (1974), Diewert (1976) and others. Since the late 1980s, the system has experienced several update including Ball (1985), Ball et al. (1997), Ball et al. (1999) and ERS (2009), and nowadays it has been recognised as a benchmark tool for measuring/monitor the US agricultural input, output and total factor productivity.

The U.S. Department of Agriculture has long been concerned with sectoral productivity growth. An early innovator, it was for decades the sole government agency regularly to compile and publish total factor productivity indexes. In addition to its usefulness for providing agricultural productivity measurement, the methodology used in the system has also a great influence throughout different countries.

Accurate measurement of productivity is crucial to understanding the performance of global agriculture, to assessing the potential for future growth in production, and to choosing the right policy initiatives needed to ensure growth.

The ERS-USDA agricultural productivity estimation system has also been extended to address the international comparison of agricultural productivity levels and its growth across countries. There is an ongoing effort to develop multilateral comparisons of
Agricultural productivity (Ball, 2001, 2010). These studies provide a comparison of the growth and relative levels of agricultural productivity among member states of the European Union and the United States. More recently, ERS-USDA have initiated joint work with colleagues in the Australian Bureau of Agricultural and Resource Economics (ABARE) and Agriculture and Agri-Food Canada aimed at including Australia and Canada in the comparisons.

Under these efforts, Buenos Aires Grain Exchange jointly with ARKLEMS+LAND project (Argentina branch of WorldKLEMS project) which is coordinated by Ariel Coremberg, Professor of Theory and Measurement of Economic Growth from University of Buenos Aires has been jointly working with the ERS-USDA to provide comparisons of the growth and relative levels of agricultural productivity for Argentina and the United States. The initial objective of this research is to develop productivity estimates for Argentina adopting the accounting framework outlined in the United Nations System of National Accounts (1993). This approach will ensure consistency of the accounts across countries and, hence, facilitate international comparisons. Our approach to measuring productivity is that outlined in the OECD Productivity Manual and in Ball et al. (2001, 2010). The production accounts and estimates of productivity will be integrated into the WORLD KLEMS project led by Dale Jorgenson, Harvard University.

Taking advantage of Coremberg’s experience and expertise on Source of Growth and Productivity measures, the Buenos Aires Grain Exchange has been jointly working with the ERS-USDA in Multilateral Comparisons of Agricultural Productivity research agreement.

The cooperation has opened up a range of valuable networking opportunities and has been crucial in order to quantify and analyse in Argentina the effects of recent structural changes in the agricultural sector in issues related to long-term sustainability, by thoroughly quantifying growth sources of the sector over the last two decades. At this point it’s important to highlight that prior quantifications of Argentine agricultural productivity accounts sector are few, especially if we consider those based on methodologies that make it possible to quantify productivity earnings with macroeconomic and sector-based consistency and their international comparability.

As a result of this Multilateral Agreement with ERS-USDA, in 2011 we finished the multilateral agreement with a research paper which shows main methods and series of Argentina Agricultural Total Factor Productivity for 1993-2010 period and other source of growth (Output, Land, Capital by type, Labor and Intermediate inputs) which could be
compare with US TFP and other countries who follow similar methodology (see Ball, Costa, Coremberg paper (2012) draft paper attached). Particularly, it was a fruitful experience of adapted Land input estimation as Ball-ERS method which was similar to Arklems experience for Land by hedonic econometric methods for Argentina. This issue is innovative in the context of KLEMS experience and as far as we know, it is the first time that Land is included not only in Agricultural Source of Growth but also at macroeconomic Source of Growth as ARKLEMS did.

Representing the Buenos Aires Grain Exchange I welcome this review and hope that our submission is helpful to the Review Panel.

Ramiro Costa

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Instituto de Estudios Económicos
Bolsa de Cereales
Av. Corrientes 123 (C1043AAB)
Buenos Aires, Argentina
(5411) 4311-7697/2148
Dear Jon,

The data base that you reference has been extremely important to a variety of agricultural production and agricultural policy research activities over the years. I’ll just highlight a few that seem really relevant to me. I currently have a graduate student who has used the national level data to examine the aggregate impacts of both direct payment farm policies as well as environmental related policies like the EQIP program on the relative use of different input categories as well as the mix of farm outputs at the aggregate level. There is a lot of focus on using individual data to understand farm structure (size and organizational choice) related to ag policy which is wholly appropriate (in fact the same student is using census data to drill into those effects at the farm level also). In the process of transitioning to more available individual farm data, we had the bad tendency to trash aggregate analysis. To which, I am always reminded of Zvi Griliches statement paraphrased as follows – If you are interested in the aggregate then use aggregate data and modelling and if you are interested in the disaggregate then use disaggregate data. Our logic is that the aggregate story on relative input use is key to understand because farmland changes management over time in response to a host of factors and shifts from management with different input use intensities. Simply put we want to know whether farm policy increases the relative use of capital to labor, material inputs, etc. If I’m trying to explain this to my students then I use the example of a farm who receives a direct payment and uses that to buy a new truck, tractor, combine, etc. which shifts the farm’s used of capital relative to other inputs like fertilizer. It doesn’t mean that fertilizer use doesn’t also increase but this balance of input use is important to understanding productivity growth in the aggregate over time and for agribusinesses that supply these inputs.

Evaluating the impact of public and private agricultural research and extension investments is another area where this data and data like it have been important. That is, this data at the national level can be paired with information about those public and private investments to determine to what extent those investment has increased ag productivity over time. I think this is more important that just giving universities and USDA a mechanism to justify their funding stream although, of course, we use the results to that end at times. The real value is that these impacts are delayed because investments made some time in the past are the ones that are feeding today’s growing population. It’s really difficult for the average person/voter/policy maker to connect those dots but the availability of data to substantiate the effects and graphically illustrate them to create support is essential to longer term global food security and economic stability.

Perhaps the place where the state level data is missed the most is in evaluating some nuances that are more crop specific. For example, the need to understand how relative dependence on agricultural inputs that create environmental concerns which differ by crop mix and geographical specifics is better facilitated by more locally aggregated data at the state or crop reporting district level. I’m thinking in terms of the impacts of relative prices through things like biofuels policy, direct farm policies, general economic changes, etc. that might have different impact on relative input use, for example, in the Southeast than in the Midwest. Then this spills over into differences in fragility of the surrounding environment and the nexus between rural and suburban, etc.
The data has some shortcomings that are difficult to overcome but we’ve generally found accepted ways to work around them. One is that not everyone in the world of agricultural economics can agree on how to value capital inputs. This data was highly driven by the views of Eldon Ball. There are others who prefer other accounting approaches but for the most part I view this as a minor constraint because both approaches tend to move together in terms of value over time. Another issue is that input values such as fertilizer use are “too” highly aggregated to allow addressing some questions. That is, for example, there is one total fertilizer price and quantity value which represents aggregation across crops and across fertilizer types. So, we find it difficult to use this data to answer questions like “how has increased no-till corn production effected the amount of nitrogen in ground water?” These are important questions and so we look for other data and approaches to answer them.

Finally, this sort of data is really useful in teaching analytical techniques because it is relevant to some important questions, reliably collected, well-documented, and easily accessible. That may not sound like much but I used this data for 18 years to in a phd level course that I taught to underpin several assignments and use it now in an undergraduate course for one assignment. I suspect the same is true across the country and perhaps around the globe. Renmin University in Beijing just invited me to propose a short course version of the phd course to teach there over the summer. If that happens then I will most certainly lean on this data a bit to implement that. Similar data is rare or poorly collected in other parts of the world which, I believe, gives the US a competitive advantage.

I would be happy to discuss this further if you like, but in general, I would argue that the cost-benefit on this data is highly in favor of retaining the data.

Sincerely,
Ken
Ken Foster
Professor and Head
Department of Agricultural Economics
Purdue University
(765) 494-1116

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Follow-up conversation by phone Ken Foster and Spiro:

Not much more to add other than it would be useful to see the disaggregation of the intermediate input series. He had particular interest in pulling out the pesticide component.
Dear Colleagues,

1. We have been used productivity estimates of ERS like an important reference to comparisons among counties, in special Brazil.
2. The most important features of information are the seriousness of people that work with productivity index of U.S. I would like mention, Eldon Ball, Fuglie Keith, Sun Ling, Rada Nicholas, Constanza Valdes. I have been used his papers and other publications and I think that they are very important to follow the productivity results.
3. I don’t have questions about methodology that they use to prepare the TFP estimates. But in some cases, I think that would be good to specify the index used – Torvquist, Fisher, or other.
4. Actually, I did not have problems to access the Index results.
5. It will be good if in some publications we have more information related to global agriculture in US, like: Pastures and crops area, number of persons employed.
6. I don’t have any suggestion about other ways to make access. But it will be interesting do call attention in the ERS site when there are new estimates.
7. It will be better if now we have the 2012 productivity estimates. I think that this process is so late.
8. I don’t have suggestions to improve the quality of productivity accounts. But I think that you are doing now a good job.

José García Gasques, Brazil.
ERS (Economic Research Service) Productivity Accounts Review

For the purpose of research and policy making in India, we usually make use of National Accounts Statistics of India given by Central Statistical Organization and data from Ministry of Agriculture of the Government of India, but for comparisons and for studying international trade we also use FAO data regularly. In our experience, some researchers working from outside India do sometimes use USDA’s website for accessing agricultural data of different countries including India either for the lack of option or for the interest of ensuring comparability.

ERS provides data on agricultural productivity of United States in its website. The most important feature of these accounts is that all the indices have been provided for a very long period from 1948 to 2011. The data used for deriving Agricultural TFP has also been presented, very systematically with respect to output and inputs at the aggregate as well as disaggregate level of categories. Further, price and implicit quantities have also been provided at all the disaggregated level of categories. The notes under the table take care in mentioning the details of commodities included in a particular commodity group. The methodology has also been described in detail. Capital stocks are measured using the perpetual inventory method using past data on investment on different categories of assets. The measurements are made with methods that are scientific, rigorous and transparent and that can be checked in the literature (reputed journals) for better understanding. The ERS website is reasonably user friendly. An annual growth rate for all the indicators over various sub-periods provides a quick glance of performance of farm economy of the country. In other words, productivity accounts for US are provided with satisfactory coverage, methodology and communication.
ERS’s cooperative effort at developing comparable accounts for other developed and developing countries of the world using the same specification and methodology as that used for US productivity accounts is commendable and would certainly be another striking feature of the system. The involvement of research teams of the individual countries is a promising method, helping to use the basic data from their national official sources keeping in view the country level distinctiveness of crops produced, marketing periods, pricing regimes and inputs used. The country level researchers would be more familiar with the specificities of their agriculture.

Based on Dr. Ball’s guidance and using data from our national sources (almost entirely Ministry of Agriculture, Government of India), we have been creating product accounts which are fairly exhaustive in coverage, based on rigorous methodology and laid down specifications and subjected to validation with different national and international sources. The objective is to make the results reliable, transparent and internationally comparable. Indian data as presented by our official agencies however differs from ERS data in certain specific respects such as crop coverage, methods and accounting period though methods used are largely compliant with international protocols set by United Nations System of National Accounts. The accounts created for ERS is consistent with the common cooperative protocol while drawing the basic information from national information base.

Different countries across the world have been producing a wide variety of commodities even within a group such as Cereals, Vegetables, Fruits and Oilseeds. For example certain millets are grown commonly in India but are rare in many other countries. Pulses are of greater significance in India’s cropping pattern and diet than other countries. The growing and marketing periods vary among crops and differ from other countries. Similarly inputs used in agriculture, especially implements and machines used differ greatly and data collection protocols vary creating some amount of complexity. All this
makes country level inputs from researchers who are familiar with the specific issues more meaningful compared to a very centralized analysis though the final consolidation and analysis is rightly done by the coordinator. It may also be helpful to report in the website the exhaustive list of commodities produced or inputs used comprising the different groups in each country along with some details on data collection.

The estimate of TFP is very important for enabling the assessment of agricultural progress, resource-use prudence and comparative advantage although with the basic data available, the estimate can be made by a researcher. However ERS’s own estimate again ensures uniformity of method for meaningful comparisons and the estimate could be useful to non-technical users as the significance of the concept is appealing.

It is pertinent to mention here that there is also a link on International Agricultural Productivity at USDA/ERS site but the data and methodology seems to be different from that given in the link for US Agricultural Productivity. The link also gives a set of data for United States. It is not clear how this information relates to the other information in ERS website and creates confusion. For the benefit of the user the communication needs to be improved by providing more detailed clarification in this regard.

As research output is always assessed with a strong emphasis on the reliability of the data used, the ERS website data must be built up keeping compatibility with respective national accounts. It is reassuring that the methodology is deliberated upon and the whole protocol is reviewed periodically. In a dynamic market situation such reviews would also help to keep the system updated.

ERS’s effort to provide consolidated data from different countries using methodologies strongly consistent with the principles of economic theory is commendable as individual national accounts vary in method, based on their domestic considerations, expertise and their stages of data evolution. If agricultural data is provided for the different
countries with uniform, scientific and transparent methodologies, it will be very useful for research and policy making in the global context. Finally, our cooperative association also gives us an opportunity to work collaboratively with a global perspective which is important in today’s economic outlook as well as for capacity building at the global level.

Nilabja Ghosh
Anita Kumari
M. Rajeshwor
Institute of Economic Growth, Delhi, India
30th April 2014
Hi Dick,

I see you have taken on interesting task. It is not clear as to whether you are reviewing the state accounts or the national accounts. Personally, I have primarily used the data in the state accounts and have found them to be quite useful for econometric model estimation. There are lots of observations and variation to explain in these models. However, Eldon told me that because of major data problems that exist after 2004, the state accounts were not going to be updated any more. Personally, I find this to be quite unfortunate. Is your committee charged with making a recommendation about possible importance of continuing these series? Regarding the national accounts, I find them useful only for simple descriptive work. The number of observations and amount of variation are too small to do much econometrically.

I believe that it is important for the USDA to continue to collect data that enables researchers to undertake econometric analysis of agricultural productivity, using econometric, as opposed to accounting, methods. Relative to other sectors, the choice of economic activities and technologies are very much affected by geo-climatic conditions. Moreover public agricultural research is an important contributor and state agricultural experiment states, veterinary medicine schools/colleges and the USDA's ARS are the main performing institutions in the states. Without the "state agr sector" accounts it is not possible to undertake these types of analysis. Finally, having aggregate data at only the national level may make sense if you are the Netherlands or Belgium, but not for the United States (or Canada).

Regards,
Wally
Dear Richard,

Many thanks for your message. I am very pleased the ERS has undertaken a review of its program on agricultural productivity and that you have attracted an outstanding group of experts to prepare a report.

I undertook a review of the work of the ERS on agricultural productivity statistics in my T. W. Schultz Lecture, published in the *American Journal of Agricultural Economics* in 2011. Here is a link:


Since then, the Bureau of Economic Analysis, represented on your committee by Jon Samuels, has published an official industry-level production account in collaboration with the Bureau of Labor Statistics. Here is a link to the latest version:


The BEA/BLS methodology is very similar to that developed by the ERS under the leadership of Eldon Ball. My conclusion is that the ERS has played an important leadership role in the development of official statistics on agricultural productivity.

Recently, Ball and his colleagues at ERS have carried out a number of important international comparisons of agricultural productivity, many of them cited in my Schultz Lecture. This work has been very influential in the international community of agricultural economists and economic statisticians.

My Schultz Lecture also mentions the excellent work on U.S. agricultural productivity statistics by Robert Evenson and Wallace Huffman and by Philip Pardey and his collaborators. I would recommend that you consult them about the value of the ERS program.

I look forward to seeing your report; please put me on your mailing list.

With best regards,

Dale
ATTN: Dick Shumway (shumway@wsu.edu)

ERS Productivity Accounts

I am a user of the productivity accounts, and can unfortunately add nothing to the discussions regarding the series’ compilations or assumptions. The initial critique included in the AAEA analysis of 1978 resulted in improvements in the derivation of the indices, and Ball and others have done a superb job in updating the index approaches to the derivation of their series (e.g., reliance on the EKS index to ensure input and output transitivity).

- How are the national and state ERS productivity accounts being used?
- Do you use the national and/or state ERS productivity accounts?
- If so, how do you use them?
  - I have used them extensively in primarily dual models of factor demands, especially with respect to changes resulting from relative price changes of factors.

- What are the most important features of these accounts?
  - Completeness, especially the currency of the national accounts. Although the end of the state level accounts in 2004 is understood, every effort should be expended to re-start this series. State-level research that ends with the 2004 data is not informative.

- Do you have questions about the methodology of their construction?
  - No

- Are you satisfied with the manner in which they are communicated?
- Is there additional information about the productivity accounts you would like to have provided online?
- Are there ways to make access to the accounts more convenient?
  - Excel spreadsheets are good for the quantity data, but implicit price data available online would make the series more useful. ERS has been very responsive when I’ve requested the price data, but having companion price data online with the quantity data would increase the usefulness of the data.
  - I have had trouble trying to aggregate P&Q data from the disaggregated series. This is probably my fault, but it would be helpful to have the procedure for aggregating series more easily viewed by users.

- Are you satisfied with the timeliness with which the productivity accounts are posted?
  - No problem with the national data, but, as said above, updating the state data would be immensely useful for those of us trying to convince local legislators of the value of further investment in agriculture and agricultural research.

- Do you have recommendations for improving the quality of the productivity accounts or the effectiveness of their use?
Dear Lilyan,

Thanks for thinking of me.

I’ve not used them and so don’t have any informed views on them.

Best,

Will

Will Martin
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Lilyan Fulginiti ---12/06/2013 03:10:37 PM---Will: Do you have something for me on this request? We only need to have
Richard,
Answering your question about productivity accounts:

- How have you and others with whom you are familiar used the national, international, and/or state ERS productivity accounts?

We have use the national productivity accounts in a number of papers about international comparisons of TFP and competitiveness. We also use state ERS productivity accounts in our paper about State Productivity Growth in Agriculture: Catching-Up and the Business Cycle. (Journal of Productivity Analysis, 2014).

- What are the most important features of these accounts?
The accounts are an unique effort to offer long series with a clear and homogeneous methodology. I will be very happy if same day Eurostat arrive to publish same thing similar for the EU Member States!

- Do you have questions about the methodology of their construction? No
- Are you satisfied with the manner in which they are communicated? Yes
- Is there additional information about the productivity accounts you would like to have provided online? No
- Are there ways to make access to the accounts more convenient? No as far as I know.
- Are you satisfied with the timeliness with which the productivity accounts are posted? Yes
- Do you have recommendations for improving the quality of the productivity accounts or the effectiveness of their use? No really. The web is an example for other Statistical Institutes.

Saludos

Carlos San Juan Mesonada
Vicedecano de Intercambios Académicos y Relaciones Internacionales.
Universidad Carlos III de Madrid
www.uc3m.es
Dear Eldon,

The OECD is very interested in productivity statistics. Our colleagues from the Statistics Directorate produce productivity statistics for the general economy and by sector, including agriculture, forestry and fisheries, based on national account data. These are used in OECD Economic surveys. Regarding agricultural productivity statistics, the Trade and Agriculture Directorate is the main user, in policy reports such as “Agricultural Policy Monitoring and Evaluation”, in reports on productivity, and in country reviews. The framework we developed to analyse policies to improve productivity growth sustainable requires information on the policy outcome “productivity growth”. We also use the data in numerous presentations we make at meetings (mainly Ken and I).

As part of our work on Green Growth, we are developing indicators of environmentally adjusted multifactor productivity for the general economy (in ECO) and for agriculture (in TAD), which need to be compared with non-adjusted ones. The work you have done in this area was very useful.

If you need more precise references to OECD reports, I will be happy to send you the links.

I hope your productivity program will continue and expand. Our strategy is to rely on what you produce for agriculture.

Best regards

Catherine
Comments on the ERS Productivity accounts

The productivity accounts constitute a well-constructed series of output and inputs of the agricultural sector. The procedure is presented in a series of papers. This review leans on Ball et al 1997 and 1999. The papers outline the construction of the data, and provide numerical results of the TFP. The outcome is an insightful source for the study of agricultural growth, and information for further research. The ultimate objective of the exercise is the computation of TFP in agriculture. The following comments raise some points that deserve further discussions.

TFP –empirical results

Ball et al (1997) presents a series of inputs and output for American agriculture in the period 1948 -2011. The data are used to compute TFP for the period as a whole and for sub periods. The paper concludes that “Productivity growth was the principle factor responsible for economic growth in agriculture.” Such an assertion is also often made for the total economy (e.g. Prescott 1998, Easterly & Levine 2001).

The paper, however, does not support the assertion. It implies that there is not even a correlation between changes in TFP and output. For instance, the years 1973-1979 were generally good for agriculture, output grew at a rate of 2.5 percent and TFP at a rate of 1.3 percent. On the other hand, the 1980s were difficult and the respective growth rates for output and TFP were 0.86 and 2.56 percent. Thus in the high growth period TFP accounted for about 50 percent of the output growth whereas in the low growth period TFP growth was almost three times higher than the output growth.( Mundlak 2005, p1011). This comparison suggests that TFP was sensitive to other variables and thus TFP was not the sole trigger of growth. More on this below

Taking a long run view Mundlak (2005) examines the components of growth of US agriculture over two centuries, 1800-1990. It shows almost zero TFP growth for the early sub period (1800-1840) when output and TFP grew at a rate close to 4 percent while TFP grew only at rate of 0.19 percent. The output growth in the early years was accounted for by growth of land capital and labor. On the other end, the average output growth rate in the late sub period (1940 – 90) was 1.9 percent, quite close to the results reported by Ball et.al. (1997), and was exhausted by the TFP. The relative importance of TFP grew gradually over the years to the point where in the period 1940-1990 it exhausted the output growth.

Over the two centuries agriculture underwent major changes (sometimes referred to as revolutions): conversion of man power to animal power, followed by the introduction of mechanical power, and later on output growth was fostered by new chemical and biological inputs. Other important factors playing a role were the introduction of credit and changes in demand for agricultural output.

The relative importance of TFP varied not only over time but also across sectors, such as farms, states or countries. “There is much more volatility across states and among regions that can be inferred from TFP measures for the aggregate farm sector. At the same time, the evidence indicates
that productivity growth in the U.S. farm sector is wholly a function of productivity trends in the individual states”, (Ball et al 1999).

**Accounting for TFP**

The assumption that TFP triggers output growth justifies the empirical effort aimed at getting it “right”. There are numerous results, differing by level of aggregation, (firms to global) countries, periods, and methods of calculation. The variance in the results raises two questions. First, what are the policy implications of the reported estimates of TFP? And second what are the implications for empirical analysis?

The TFP is an unobserved variable and its rate of change is the difference between the rates of change of output and of inputs. Thus, an explanation of the changes in TFP is associated with the explanation of the choice of outputs and inputs. The choice, in turn, depends on the economic environment which consists of incentives, technology and constraints to be referred to as state variables. Thus, variations in the economic environment generate variations in TFP. This explains the variability of estimates reported in empirical analysis. This view also paves the road for the empirical analysis.

The underlying premise is that firms face more than one technique of production. The collection of all possible techniques constitutes the available technology. The economic problem is to choose the technique to be employed along with the choice of inputs and output. The collection of all available techniques represents the state of knowledge. Firms choose the implemented techniques subject to their constraints and the environment within which they operate. The empirical analysis reveals the implemented techniques.

This framework accounts for the variability of estimated TFP and provide a scope for policies such as augmentation of the available technology (say knowledge) and the removal of constraints. It is clear that one cannot state a typical value for TFP without providing more information on the sample. This approach puts the weight of the analysis on searching for state variables that account for the sample on hand.

**References**


Prescott E.D. 1988 “Needed a theory of total Factor productivity”. Int. Econ. Rev. 39:525-51

1 Mundlak 1988, and Mundlak et al 2012

Mundlak, Y. Butzer, R. Larson D.F, Heterogeneous technology and panel data: The case of agriculture. J Econ Development. 99 (2012) 139-149
Dear Lilyan,

I’m very willing to help with this but I’m afraid that IFPRI is not a heavy user of national and state ERS productivity accounts. As you know we have worked with ERS on issues related to R&D investment, production and productivity in developing countries but there is not much we can say about national productivity accounts. Please let me know if I’m missing something or you have any suggestions on how we can help.

Regards,

Alejandro
Dear Committee Members,

Re: ERS Productivity Accounts

Thank you for giving me an opportunity to provide some input into your review of the ERS productivity accounts. In your letter to me you raised a number of questions, and I will briefly answer them in groups:

1. How are the national and state ERS productivity accounts being used? Do you use the national and/or state ERS productivity accounts? If so, how do you use them?

I use the ERS accounts extensively, for both research and teaching purposes. I use this particular set of accounts for two reasons. First, I use U.S. farm sector data (rather than, say, mining sector data) because this sector exhibits many of the characteristics needed to develop and estimate simple but reasonably realistic models of firm behaviour (e.g., some inputs are fixed in the short run, firms are price-takers in input and output markets, firms make input decisions before output prices are known, firms choose variable inputs in order to maximise expected profits etc.). Second, when searching for data on the U.S. farm sector, I quickly came to the view that the ERS accounts are the most reliable public source of state-level data available.

The following papers use data drawn from the ERS production accounts:


Finally, each year I run one or two short-courses at the University of Queensland on productivity and efficiency measurement methods. In these short-courses, I like to use only one set of data to illustrate all manner of index number, data envelopment analysis and stochastic frontier analysis methods. The data I generally use are ERS data for 11 states from 1960 to 1989. With Eldon Ball’s permission, I have made this illustrative dataset freely available to students. It is also the illustrative dataset distributed with the DPIN software package (this is free software for Decomposing Productivity Index Numbers).

2. **What are the most important features of these accounts?**

Aside from the fact that they have been assembled so carefully, the most important feature of the particular data that I use in my teaching and research is that all quantity indexes are transitive. Transitivity means, for example, that a direct comparison of two quantity vectors will yield the same index number value as an indirect comparison via a third vector. Without transitivity (and another index number axiom I will discuss in point 5 below), it is difficult to make meaningful comparisons of output, input and productivity change. As far as I know, the ERS does not make these transitive (or “multilateral”) indexes publicly available. Of course, the ERS is in good company here: there are other state-level datasets available, but, as far as I know, the indexes in those datasets are also intransitive (e.g., the binary Fisher indexes in the InSTePP accounts).

3. **Do you have questions about the methodology of their construction?**

The papers by Ball et. al. (1997, AJAE, 79:1045-1063) and Ball et. al (2004, AJAE 86: 1315-1321) have provided me with as much information as I have ever needed on the way the accounts are constructed.

4. **Are you satisfied with the manner in which they are communicated? Is there additional information about the productivity accounts you would like to have provided online? Are there ways to make access to the accounts more convenient? Are you satisfied with the timeliness with which the productivity accounts are posted?**

I would like to congratulate the ERS on the way the accounts are communicated. For me, timeliness is not an issue. In view of that, and in view of my comments under point 2, I would like to see the ERS make a reasonable subset of the multilateral index series publicly available (e.g., all 48 states from 1960–1989).
5. Do you have recommendations for improving the quality of the productivity accounts or the effectiveness of their use?

I understand that the ERS quantity indexes are implicit indexes computed by dividing values by EKS price indexes. Unfortunately, EKS price indexes do not satisfy a circularity axiom. This means, for example, that prices in 2006 could be exactly the same as they had been in 2003, but the EKS index will say they are different. The fact that EKS price indexes do not satisfy this common sense axiom means they are not proper indexes in the sense of O'Donnell (2012, CEPA Working Paper WP05/2012, [http://www.uq.edu.au/economics/cepa/docs/ WP/WP052012.pdf](http://www.uq.edu.au/economics/cepa/docs/WP/WP052012.pdf)). Consequently, the implicit quantity indexes are not proper. I would encourage the ERS to consider the use of proper price and quantity indexes (e.g., Lowe, geometric Young). Alternatively, publish the component price and quantity series so that researchers can compute proper indexes for themselves.

One final comment I would make is that, in my view, continuation and improvement of the ERS production accounts is enormously important for both academic researchers and government policy makers. Without these types of accounts, it would be impossible to identify the drivers of profitability and productivity change in U.S. agriculture. For reasons I give in some of my papers, the ability to identify these drivers is critically important for good evidence-based public policy-making.

I apologise for not having provided these comments earlier. Please let me know if there is any other information I can provide that will assist you in your review.

Sincerely,

Christopher J. O'Donnell
Professor of Econometrics and
Director, Centre for Efficiency and Productivity Analysis
Richard,

Distinction between irrigated and non-irrigated crops and livestock would improve the quality, effectiveness and usefulness of the productivity accounts in policy analysis, as would distinction between specialty crops and other crops. Thank you.

Beau Olen
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Hi Dick,

I'm finally responding to your request (today is our deadline!!), after talking with Lilyan about some of the issues last night.

1. I've used the state accounts every year for one reason or another – sometimes to access the price series, to estimate supply functions, in examining land use change, etc. I probably access the national numbers every other year or so, for similar reasons.

2. The accounts provide easy access to state-level data on input indexes.

3. 4 and 5. I have all kinds of questions about how the capital and land series are aggregated, and about how the price series are constructed. This should all be explained in detail on the website, so that anyone could duplicate the process to obtain the numbers, which is the standard for academic documentation, and should be even more important for government data.

6. Accessibility of information that is provided is pretty good.

7. Timeliness could be improved. Maybe the timeliness of the BEA's national productivity accounts should be the target?

8. Some general comments about the accounts:

**Price Indexes**
There can be no doubt that the quality of farm inputs has been rising. If this increase is not fully captured in sectoral TFP measurements, the farm input index will be too low and measured productivity will be too high, while at the same time, the input supply sector output index will be too low, as will its measured productivity. Because adjustments for input quality are implemented by dividing observed expenditures by quality-adjusted price indexes, these price indexes play a role in allocating productivity between the farm input supply sectors and the farm sector itself. Quality-adjusted price indexes thus deserve a lot of attention.

**TFP should be zero?**
The prevailing philosophy underlying productivity measurement has been that of the Solow residual – identify increases in output beyond what would have been expected from nominally-measured changes in input quantities. But an alternative philosophy of productivity measurement was expressed at the same time by Schultz: productivity derives from human activity, not manna from heaven, and the Solow residual is simply a measure of our ignorance regarding whence it came.
In practice, TFP measurement is Solow-based, but haunted by Schultz’s challenge to reduce measured productivity growth to zero by properly accounting for its sources. Adjustments for input quality reflect Schultzian efforts to reduce our ignorance, thus reducing measured TFP. Should we continue in this
direction until TFP disappears, or was there something else we really wanted to measure with TFP?

Best regards,
Dick

Richard K. Perrin
Jim Roberts College Professor
Robert B. Daugherty Water for Food Institute Fellow
Chair, Departmental Graduate Committee
Department of Agricultural Economics
University of Nebraska, Lincoln

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Eldon has been helpful to me and I so appreciate his desire to create and improve productivity accounts at ERS. However, I guess the main issue I have with all of ERS created data is whether they have a desire to support public use. I've never clearly understood this point. I wish the ERS were similar to BLS with an eager desire to make available data (and methods used to create the data) which would improve academic research of all kinds. I've never felt like they had that spirit perhaps because of NASS and perhaps part because of the cooperative agreements program.

Cheers! Rulon
Hi Jon:

I polled my divisions and they do not use ERS productivity statistics. Here are a couple of replies:

Major sector MFP: The only data we take from USDA is land value data that we use to construct our estimates of land stock and deflators. We then construct our own productivity estimates based on BEA data.

Major sector LP and Division of Industry Productivity Studies do not use ERS productivity data. However, we have occasionally directed interested customers to it, since DIPS does not measure productivity for industries in agriculture.

It’s our belief that the ERS measures originated in a project in which Michael Harper collaborated with Eldon Ball of USDA some years ago.

John
Richard,

I am not a heavy user of ERS productivity data... more of a casual user. I like to look over the data a couple of times per year as it relates to congressionally related issues such as returns to federal research dollars and long-term US agricultural sector competitiveness both within the general economy and internationally against other nation’s agricultural sectors.

My biggest concerns are

1. Timeliness—I understand the vast amount of information that underlies a national aggregate statistic necessarily means it will be a bit dated by the time it is released but it also means that, if it is 3 or 4 years removed from the current setting, it won’t reflect recent events which is what interests Congress the most; and
2. Coverage—I wish there was more commodity sector and regional detail, but I will take what I can get.

Another concern would be lay-accessibility. ERS has made substantial improvements in this respect in recent years and the web interface now provides access to much better information, although timeliness remains an issue for the state-level estimates. In addition, ERS has made great strides in dissemination of research results via the Amber Waves and other more lay-oriented outlets. This type of outreach should play an essential role in facilitating access and improving understanding of agricultural productivity issues for the lay audience—as a goal, Amber Waves and/or Choices should have at least one article annually related to agricultural productivity and that article should get shopped around and prominently displayed as part of the interface on the ERS agricultural productivity website.

Agricultural Productivity, as a concept, is easily confused by lay audiences as it encompasses far more than simple yield growth. The linkage of federal research funding dollars and agricultural productivity can be indirect and lagged over several years, but ERS work on agricultural productivity is critical to promulgating the importance of continued federal investment in agricultural research. I became familiar with the ERS agricultural productivity research and data products while serving as Economics Editor for the ERS Outlook magazine—precursor to the Amber Waves—back in the 1990s. Had I not had that experience, I wonder if I would have become aware of or a user of the data.

Randy Schnepf
Richard Shumway,

I am constructing Input, Output and TFP index for 6 Northern Great Plain states (ND, SD, NE, KS, MN and MT) and will be done by early next year as part of my Hatch project. I would like to know more about the issues associated with productivity measures.

I talked to Eldon Ball on richness of the land, labor and capital measures. Eldon Ball was kind enough to email the data.

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It is neither wealth nor splendor, but tranquility and occupation, which gives happiness-- Jefferson
Comment on the ERS’s Total Factor Productivity Research

By Rachel Soloveichik

To: Jon Samuels, in his capacity as a member of the External Committee to Review the USDA Agricultural Productivity Accounts.

This memo is a response to the request for stakeholder input on the ERS Agricultural Productivity Accounts. My comments below only represent my own views and research, and do not represent the views of the Bureau of Economic Analysis (BEA).

I am a Research Economist at BEA, currently studying BEA’s treatment of farm animals, long-lived farm plants, land improvements, and other types of farm assets in the National Income and Product Accounts (NIPA’s). I have made use of ERS and other USDA data in my research.

My current research is focused on developing more comprehensive measures of farm output, investment and capital stock for the NIPA’s. My research has uncovered potential areas for improvement in BEA’s measurement of farm assets. Some of my proposed improvements to BEA’s accounts also have potential implications for ERS’s total factor productivity (TFP) accounts. Based on my preliminary research, I estimate that measured TFP growth would fall slightly if ERS used my revised numbers for farm assets. For discussion purposes, I have included a few graphs showing the potential impacts on measured TFP in the farm industry.

So far, none of my changes on the output side, or in the capital accounts have yet been incorporated into official BEA statistics. As you probably know, BEA does not compute official capital services estimates. In the remainder of this note, I have estimated the impact on TFP for research purposes only, not as an alternative official statistics. I welcome discussions with ERS staff on measuring farm assets and other research related to farm output and productivity.
Working Farm Animals As Capital Assets

ERS currently publishes data on four separate capital categories: durable equipment, service buildings, land, and farm inventories. As noted in the international guidelines for national accounts, the System of National Accounts (SNA), it would also be conceptually appropriate to include working farm animals as a new capital asset category. Animals raised for meat would be added to the asset category ‘farm inventories’. Unlike machinery and computers, working animals are generally produced within the farm sector rather than bought from outside industries. Therefore, working farm animals are both a capital input and a type of farm output.

I investigated how measured TFP might change with different treatments of working farm animals using the following steps:

Step 1) Livestock Inventories: I recalculated ERS’s productivity statistics if livestock inventories are counted as an asset yielding capital services. At this step, my livestock inventory numbers are based on a count of animals in each category and their average value.

Step 2) New Quality Measures: Some animal categories have become much more productive over time. For example, modern dairy cows give more than twice the milk they did in 1948. At this step, I adjusted the simple count for quality improvement over time.

Step 3) Capitalizing Long-Lived Working Animals: This step reclassifies long-lived farm animals from inventory to capital stock. Livestock investment is added to gross value-

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1 The graphs in this memo are all calculated using a fixed 7% real rate of return on inventory and capital stock. When re-estimating TFP, nominal shares for new categories are estimated first. Existing categories of outputs and inputs are then rescaled proportionally in order to keep other relative shares fixed.

2 ERS’s current numbers for meat output include both livestock sold for slaughter and livestock inventory changes. Some of the steps in this memo may have implications for ‘livestock inventory changes’, but the size and direction of the revision is difficult to calculate. For simplicity, I do not adjust meat output for potential implications to ‘livestock inventory change’ in the exercises below.
added and livestock depreciation is added to capital services. The impact on net value-added and productivity change over time is, theoretically, ambiguous, but my estimation suggests that this step leads to a small downward adjustment to TFP growth.

Step 4) **Higher Investment for Dairy Cows and Breeding Beef Cows**: Previous conversations with ERS staff suggest that my preliminary capital investment numbers used in Step 3) might underestimate cow investment. I am currently working with ERS staff to measure cow investment more precisely. To illustrate how this factor may matter, I recalculated TFP with revised numbers for cow investment. This is still a work in progress.

**Figure 1: Impact of Working Animals on Measured TFP**

Figure 1 shows that adding farm animals to capital stock reduces measured TFP growth. Average annual TFP growth is 1.42% under ERS’s current methodology, 1.42% with step 1), 1.39% with step 2), 1.38% with step 3) and 1.36% with step 4).

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3 I also add farm horses and bees to capital stock. Both categories are small, so they have little impact on TFP.
Long-Lived Farm Plants As Capital Assets

Like working farm animals, long-lived plants yield a flow of services over time and it would be conceptually appropriate to treat them as capital assets. I estimated capital investment and capital services for four categories of long-lived plants: a) orchards and bushes producing fruit, nuts and syrup; b) alfalfa pastures; c) clover pastures and d) grass pastures. At first glance, pastures do not appear to be a long-lived asset. Individual grass stems are typically grazed or mowed for hay within a month or two. However, the root system for the pasture survives for years, suggesting that pasture investment should be treated as capital. Results with pastures excluded are available upon request.

I investigated how measured TFP might change with different treatments of long-lived farm plants using the following steps:

Step 1) **Long-Lived Plant Inventories**: I recalculated ERS’s productivity statistics as if long-lived farm plants were treated as an inventory asset. I used a variety of data sources to estimate acreage, prices and lifespans for orchards and farm pastures.

On the output side, this change increases farm output when the real inventories of long-lived farm plants increases and decreases farm output if the real inventory decreases. ERS’s TFP statistics currently include capital services from farm inventory, so measured capital services unambiguously increase when long-lived farm plants are added to existing farm inventories.

Step 2) **Capitalizing Long-Lived Farm Plants**: This step reclassifies long-lived farm plants from inventory to capital stock. Plant investment is added to gross value-added and plant
depreciation is added to capital services. The impact on net value-added and productivity change over time is theoretically ambiguous.

Step 3) **Adjusting Capital Services from Land**: ERS’s current calculations assume that long-lived farm plants are included with land. When long-lived plants are tracked separately, they may be double-counted. At this step, I adjust land services to prevent any double-counting.

**Figure 2: Impact of Farm Plants on Measured TFP**

![Figure 2: Impact of Farm Plants on Measured TFP](image)

Figure 2 shows that capitalizing long-lived plants has little impact on measured TFP. Average annual TFP growth is 1.42% under ERS’s current methodology, 1.41% with step 1); 1.40% with step 2) and 1.39% with step 3).
Land Improvements As Capital Assets

According to the ERS’s website, ERS uses the following methodology to measure land:

To obtain a constant-quality land stock, we first construct intertemporal price indexes of land in farms. The stock of land is then constructed implicitly as the ratio of the value of land in farms to the intertemporal price index. We assume that land in each county is homogeneous, hence aggregation is at the county level.

This methodology appears to assume that land quality is fixed over time, and therefore misses long-lived land improvements like irrigation, drainage or fences. I propose that ERS include land improvements as a separate capital input when calculating TFP. 4 Like working animals and farm plants, land improvements are both a capital input and a type of farm output.

I investigated how measured TFP might change with different treatments of land improvement using the following steps:

Step 1) Land Improvement Inventories: I recalculated ERS’s productivity statistics if land improvement is treated as an inventory asset. At this step, my land improvement numbers are based on ERS’s capital expenditure data. 5 This change unambiguously increases capital services input and may increase or decrease farm output.

Step 2) Including Do-It-Yourself Land Improvement: ERS’s current numbers are taken from the Agriculture Resources Management Survey (ARMS), which only measures out-of-pocket spending on land improvement. Self-employed farmers often do land improvements

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4 Alternatively, ERS could combine land improvements with the existing category ‘service buildings’ or ‘land’. Measured TFP will be the same with land improvements combined and land improvements tracked separately.

5 I use BEA’s 2.8% depreciation rate and BEA’s price index to calculate aggregate values for land improvement.
themselves, without any out-of-pocket spending on hired labor. To get total land improvement costs, I estimated the value of farmers’ time and added that time value to out-of-pocket spending.

Step 3) **Capitalizing Land Improvements**: This step reclassifies land improvements from inventory to capital stock. Land improvement investment is added to gross value-added and land improvement depreciation is added to capital services.

Step 4) **Adjusting Capital Services from Land**: ERS’s current calculations assume that land improvements are included with land. When land improvements are tracked separately, they may be double-counted. At this step, I adjust land services to prevent any double-counting.

**Figure 3: Impact of Land Improvements on Measured TFP**

Figure 3 shows that capitalizing land improvements has little impact on measured TFP. Average annual TFP growth is 1.42% under ERS’s current methodology, 1.41% with step 1), 1.44% with step 2), 1.43% with step 3) and 1.41% with step 4).
Own-Account Barn Construction

In the past, it was very common for farmers to build barns and other service buildings themselves. ERS currently excludes barns constructed by farmers from measured farm output. ERS also excludes purchased construction materials from intermediate goods used by the farm sector. However, ERS includes time spent on construction in measured farm labor and equipment used for construction in measured farm capital.

I suggest two separate solutions for the inconsistency: a) ERS could revise farm labor to exclude time spent building barns and revise farm capital to exclude equipment used for construction; b) ERS could revise farm output to include own-account construction and revise intermediate goods to include purchased materials.

I investigated how measured TFP might change with different treatments of own-account construction using the following steps:

Step 1) **Own-Account Barn Construction by Hired Farm Workers**: The Economic Census has tracked farm buildings produced by the construction sector since 1967. And ERS has estimates of total out-of-pocket spending on non-residential farm buildings. I calculate:

\[(\text{Own Account Barns}) = (\text{Total Barn Spending}) - (\text{Barns Produced by the Construction Industry})\]

Step 2) **Including Do-It-Yourself Barn Building**: Many self-employed farmers construct barns themselves without hiring outside workers. I estimated the value of farmers’ do-it-yourself time and added that time value to out-of-pocket costs.

Step 3) **Capital Services from Do-It-Yourself Barns**: ERS’s current capital numbers are based only on out-of-pocket spending. I add in capital services from do-it-yourself barns.
Figures 4 and 5 both show that measured TFP growth is slightly lower when own-account construction is handled consistently. Average annual TFP growth is 1.42% under ERS’s current methodology, 1.42% when own-account construction materials are excluded from input and 1.40% when own-account construction is included in output.
Measuring Farmland Acreage

According to the ERS’s website, ERS uses the following methodology to measure land:

*To obtain a constant-quality land stock, we first construct intertemporal price indexes of land in farms.*

*The stock of land is then constructed implicitly as the ratio of the value of land in farms to the intertemporal price index. We assume that land in each county is homogeneous, hence aggregation is at the county level.*

As part of my current research, I tested whether alternative methods of measuring land usage might change the aggregate land quantity index. The Census of Agriculture has tracked farmland usage by category and county back to the 1800’s. However, the pdf’s before 1987 cannot be digitized automatically and must be entered by hand. In order to save time, I focus on land usage from 1987 to 2012 in this memo.

Step 1) **Alternative Data:** To start out, I tried to replicate ERS’s existing methodology using data from the published Censuses of Agriculture. At this step, I used 2000 as a fixed base year. Results were similar if I used other base years or chained my quantity index over time.

Step 2) **Heterogeneous Land Quality Within Counties:** The Census of Agriculture reports four separate categories of farmland: planted cropland, other cropland, pastureland and woodland. In 2012, planted cropland accounted for 37% of usable farmland, other cropland

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6 Ideally, I would like to track plantable cropland rather than planted cropland. Unfortunately, the Census of Agriculture does not report which land is suitable for planting. For now, I assume that all (plantable cropland) = (harvested cropland + failed cropland – cropland harvested for wild hay). Governments sometimes pay farmers to keep plantable cropland out of production for ecological benefits and other reasons. If the plantable acreage kept out of production has changed over time, then my quantity index will show an erroneous change. I am working to study this issue further.
accounted for 5%, pasture accounted for 49% and woodland accounted for the remaining 9%.\textsuperscript{7} Based on average rental rates reported in the USDA’s ‘Land Value and Rental Rates Survey’, I weight planted cropland ten times as heavily as all other land types. This treatment is similar to ERS’s previous methodology for 11 Western states, where they split farmland into irrigated cropland, dry cropland, pasture land and other land (Ball et al 1997).

Step 3) **Homogenous Land Across Counties, by Land Category:** As a simplification, I tried using national aggregates for each land category instead. These national aggregates are readily available and require only a few hours of work to enter.

Figure 6: Land Quantity Indexes Over Time

Figure 6 shows that my land quantities from step 1) match ERS’s published data closely. Both methods show a gradual drop in land usage from 1987 to 2011. In contrast, step 2) shows no consistent drop in land usage over that time period. The simplified quantity index shown in step 3) tracks the county-level quantity index reasonably closely. If ERS does not have the time to implement step 2), they might consider using step 3) instead.

\textsuperscript{7}There is a fourth land category ‘land in house lots, ponds, roads, wasteland, etc.’, which ERS currently excludes from farmland entirely. I follow ERS’s treatment. Results are similar if I give it the same weight as non-cropland.
Other Issues of Potential Interest

This section identifies possible topics for future research. If USDA chooses to pursue these topics, I would be interested in collaboration.

1) **Adjusting pesticide quality for pest evolution**

   When a new pesticide is first introduced, it is generally very effective at killing insects. Over time, farm pests generally adapt and become less vulnerable. Therefore, the same pound of chemicals provides less ‘pesticide services’ than it did at first. Conceptually, this is very similar to clothing pricing. New fashions consistently sell for more than last year’s fashions. Yet we can’t conclude that clothing quality is continually increasing.

2) **Adjusting for Seed Quality Growth**

   I propose that ERS develop a hedonic price index for seeds just like they do for pesticides. Modern seeds are much more productive than seeds were in the past. This adjustment will unambiguously raise farm inputs. The effect on farm outputs depends on which industry is producing the improved seeds.

2) **Adjusting Farm Production for Safety Increases**

   Modern farm workers are less likely to be killed or injured on the job than they were in 1948. Modern farms also produce less pollution and other environmental damage. It would be interesting to include these safety improvements in measured TFP.
December 6, 2013

Professor Richard Shumway  
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Pullman, Washington  
USA 99164-6210

Dear Professor Shumway,

I am writing you regarding the ERS Productivity Accounts Review that you are leading. In particular, I would like to provide you with a Canadian perspective on the ERS accounts that you may find useful. I would also like to offer you an update to the section on Canada that was included in the 1980 Review. In this latter respect, I am working on the assumption that the current review committee may want to incorporate similar elements to the 1980 Review in its report on the current state of the ERS accounts.

The ERS productivity accounts program has played an important role in the development of Agriculture and Agri-food Canada's (AAFC) Production Account for Canadian Agriculture as it stands today (hereafter referred to simply as the AAFC production account). Since the mid-1990's, ERS staff have assisted AAFC staff in the development of a theoretically consistent and comprehensive database for Canadian agriculture. The collection and derivation of data has involved a wide range of variables on both output and input sides of the account, including price, quantities and policies for individual outputs, investment in fixed capital for several asset types, land area, hired and unpaid operator/family labour input and quantities and prices for individual farm produced and purchased intermediate inputs. ERS staff have provided feedback and suggestions for improvement at all stages of this process and have thereby been instrumental in assisting the Government of Canada in the development of a production account that meets the standards set by the United Nations and other international organizations. ERS staff have also identified areas where improvements could be made in the measurement methodologies used by AAFC and this has led to several significant advances in the state of our production account over the course of time.
The ERS program has also been important in providing a benchmark with which the Canadian data can be compared, particularly in terms of productivity growth rates, but also with respect to the data series used to construct implicit constant dollar quantities of gross output and input. The value of the ERS production account as a reference point has become particularly apparent in the data validation process that is part of the bilateral and international productivity comparisons work currently under way at ERS and AAFC. The two accounts have also been used to examine the returns to operator and unpaid family labour in both countries; ready access to data at the ERS website and the willingness of ERS staff to provide custom aggregations with U.S. data were essential to the completion of this research. The result of this work has been presented at AAEA and IATRC conferences.

A final observation to make about the ERS productivity accounts program is that collaboration between ERS and AAFC staff has opened up a range of valuable networking opportunities. In particular, this collaboration has made it possible for AAFC staff to participate in the IATRC Symposium on Productivity and its Impacts on Global Trade, the second World KLEMS conference, the Farm Foundation Productivity Growth conference, the USDA/ERS/NC208 conference on productivity measurement, the World Bank-OECD Purchasing Power Parities conference and a NBER Conference on Research in Income and Wealth. There have similarly been opportunities, through ERS contacts, to have discussions with a wide range of specialists in the area of productivity research and, most recently, to contribute to a book edited by ERS staff in which a chapter is dedicated to a description of the AAFC production account.

Turning now to the AAFC production account, I will make two some general observations, leaving the details to an Annex. First, in the 1980 Review, the section on Canada reflects an approach that is quite different in most regards from that taken in the AAFC production account. The Annex addresses some of the measurement elements that appear on pp. 19-21 of the 1980 Review, contrasting them with our current approach. Should you decide to include a section on Canada in your report, I would encourage you to use Cahill and Rich (2012) as your reference.

My second general observation is with respect to some differences in measurement between the AAFC production account and the ERS production account. In particular, these differences relate to measurement of capital services input, quality adjustment and the input chosen to clear the account; details are also provided in the Annex. These are the areas where the two accounts are least comparable and reflect, to some extent, our preferences rather than a serious disagreement with the ERS methodologies.
To conclude, I wish to reiterate that the ERS productivity program has been influential in the development of an agricultural productivity research program at AAFC. We view a continued relationship with ERS to be essential to our future work, both in terms of analysis and in terms of improvements to the AAFC production account. Should you wish to learn anything further about the AAFC production account and the links between our research and that being carried out at ERS, do not hesitate to contact me.

Sincerely,

[Signature]

Greg Strain

c.c. James MacDonald, ERS
Fred Gorrell, Director General, Market Access Secretariat
Brad Wood, Embassy of Canada, Washington D.C.
Michael Hawkins, Embassy of Canada, Washington D.C.
ANNEX

I. A comparison between the AAFC production account and the approach described in the 1980 Review

The approach used to construct agricultural productivity indexes in Canada was summarized on pp. 19-21 of the 1980 Review. This summary reflects the fact that, at that time, staff at the Department of Agriculture in Ottawa were relying upon pre-computed output and input aggregates as the main components of their estimated productivity indexes. The AAFC production account differs in several fundamental ways from this earlier approach, including:

- the construction of an index of gross farm output using individual gross output, output price and output policies rather than use of an index of farm production as constructed by Statistics Canada
- the construction of input indexes using data for individual series wherever possible, particularly for labour and farm-produced inputs, rather than with deflated farm expense data
- the estimation of operator and unpaid family labour input using Census of Agriculture rather than survey data from the Labour Force Survey (LFS), which tends to underestimate hours devoted to farm labour
- the calculation of hired labour input using data from the Census of Agriculture rather than from the LFS
- the construction of capital stocks and user costs of capital to measure the flow of capital services rather than use of deflated farm expense data

We therefore believe that the AAFC production account represents a significant improvement over the approach described in the 1980 Review. The review committee can find further information about the account in Cahill and Rich (2012).

II. Details regarding some differences in measurement between the AAFC production account and the ERS production account

The methodology described in Cahill and Rich is largely the same as that used to construct the ERS account, as documented in Ball et al. (1997). The two accounts

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are nevertheless quite different in some respects; the most significant of these differences are now addressed.

In the AAFC production account, capital service flows from buildings, farm machinery and vehicles are taken to be proportional to the constant dollar capital stocks of these assets. The stocks are calculated with historic data for current dollar investments and investment deflators using geometric decay schedules – this is in contrast to the ERS approach which uses the assumption of hyperbolic decay. Both decay types have been used at AAFC (the latter involving the use of cumulative truncated normal distributions) but we have chosen the geometric approach primarily because of the simplicity of this method.

The geometric approach has the added advantage of being consistent with a separable farm-household framework, where the household finances incremental investments in farm assets out of savings and where the rental income from an on-farm investment must equal the return to an alternative investment available to the household. All costs of capital, like those of all other inputs (and outputs) in the AAFC production account, are in before tax terms.

The second main difference between the ERS and AAFC production accounts is in the area quality adjustment. In the AAFC production account, no quality or compositional adjustment is made in the measurement of labour, land or farm chemical inputs, whereas in the ERS production account, all three of these input types are adjusted. The data are left in their unadjusted form in the AAFC production account for several reasons, but most particularly because of limitations posed by data quality. We have had to carry out significant imputation exercises in the case of labour and land. In the former case, input from all three types of labour in the account is estimated using Census of Agriculture data, so that intercensal observations are imputed using linear interpolations. While labour survey data do exist, we have concluded that our approach, despite its limitations, yields better estimates than those made with survey data. Similarly, land input is calculated simply as area of all types, since it is almost impossible to separate land that is actually used in some capacity (e.g. rough pasture) from land that is not (e.g. swamp, rock, etc.). Actual area is only observed for each census year, so intercensal area must be interpolated (we use linear interpolation). The price of land is also imputed by separating the value of land from the value of land and buildings using a proportion drawn from a secondary source. Given the imputations and interpolations that are needed to derive annual labour and land inputs, we are reticent to test the limits of this information with quality adjustments.

The third main difference between the AAFC production account and the ERS production account is with respect to the input chosen to `clear' the account, given
that the price of at least one input must adjust so that the total value of gross output equals the cost of all inputs. For the AAFC production account, this ‘residual claimant’ input is chosen to be operator/unpaid family labour, whereas for ERS it is land (more specifically, the return to owners of land). We believe that there is merit in both approaches; there is a classical argument for land as residual claimant and there are certainly some practitioners who are of the view that any ‘profits’ should show up in land rents. We remain of the opinion, however, that operator/unpaid family labour is the more appropriate choice for a residual claimant since it is consistent with the usual definition of net farm income, where all but operator/unpaid family labour is accounted for. The choice of operator/unpaid family labour as residual claimant is also consistent with Canada’s federal tax provisions for non-incorporated farms, where the only expense that cannot be deducted from income is the value of the operator’s labour.
Hi Jon,

I have not used these data in my own work, but am aware that others outside of ERS have used them, primarily university-based ag economists studying agricultural productivity. It’s too bad the state statistics have been suspended. I would think Dick Shumway would be quite familiar with such uses, but if not, I believe Ken Foster, Head of the Agricultural Economics Department at Purdue university (copied on this email) would have more insight into the academic uses of these data.

Best wishes,

Sally
Dear Lilyan,

I have checked with colleagues in the Environment and Production Technology Division of IFPRI and in the Economic and Social Development Department of FAO. They are aware of the USDA productivity numbers but have not used them, as the focus of their work is international, and in particular the developing countries, so they had no further feedback to provide.

Best wishes for your review.

Keith
Hi Richard, please see my answers below next to the questions.

Best regards,

Margaret Zeigler

Ms. Ziegler,

I understand that you have used the USDA/ERS productivity accounts, so I am writing you with a request for feedback.

The USDA Economic Research Service has convened an external committee of Spiro Stefanou, Lilyan Fulginiti, Barbara Fraumeni, Jon Samuels, and myself (chair) to review the ERS productivity accounts. This is the first comprehensive review these accounts have received since the joint AAEA-ERS review chaired by Bruce Gardner in 1978 that led to a major overhaul in the procedures used to develop the accounts. The committee has been charged to address issues of methodology in the development of estimates, ongoing research programs to improve methodology and operations, documentation and reporting of methods and uses of the data, and the frequency and timeliness of reporting.

One of our charges is to seek stakeholder input. Since you have used the productivity accounts, the committee would appreciate your response to such questions as the following:

- How have you and others with whom you are familiar used the national, international, and/or state ERS productivity accounts? The Global Harvest Initiative has used the national, state, and international data sets to develop our annual GAP Reports (Global Agricultural Productivity Reports) and GAP Index for the years 2010, 2011, 2012, 2013, and are in process of developing the 2014 Report. See our link here: http://www.globalharvestinitiative.org/index.php/gap-report-gap-index/

- What are the most important features of these accounts? They are very easy to use, and clear with good explanations about assumptions
- Do you have questions about the methodology of their construction? I would like to see in the future if additional issues could be covered (fisheries, aquaculture output and input) in the future as aquaculture may be small but growing source of food and feed product
- Are you satisfied with the manner in which they are communicated? yes
- Is there additional information about the productivity accounts you would like to have provided online?
- Are there ways to make access to the accounts more convenient? I am not sure if many users are familiar with them globally outside the AG statistical community.....
- Are you satisfied with the timeliness with which the productivity accounts are posted? yes
- Do you have recommendations for improving the quality of the productivity accounts or the effectiveness of their use? see note about possibly including aquaculture stats