[Data Training Webinar: U.S. and International Agricultural Productivity – YouTube]

Good afternoon, everyone. My name is Ashley Murdie, your host for today's webinar. On behalf of USDA's Economic Research Service, welcome and thank you for joining us in the fifth segment of our data training webinar series. Today's webinar will feature ERS economists Sun Ling Wang and Stephen Morgan as they spotlight two ERS agricultural productivity data products, potential uses for each of these, and where to find them on the website. As part of the data training webinar series, this webinar is meant to teach those interested in ERS data how to access and fully utilize our many data products, and what better way to do so than connecting you directly with the experts. In the year ahead, this webinar series will continue to connect viewers with ERS specialists for a variety of data products. If interested, a full schedule of the series can be found on our webpage which we'll link to in the message center here shortly. Before I introduce our speakers, I'd like to remind you that this webinar is being recorded and will be posted on the ERS website next week. If you have any questions during the webinar please enter them into the chat feature at the bottom, left-hand corner of the screen, and our economists will answer them during a Q&A session following the presentation. Now, it's a pleasure to introduce our speakers, Sun Ling Wang and Stephen Morgan. Sun Ling Wang is a Senior Research Economist with the structure technology and productivity branch in our Resource and Rural Economics division. Her responsibilities include planning and implementing the U.S. agricultural productivity program and conducting evidence-based, policy-relevant economic research on the causes and effects of productivity growth. Stephen Morgan is a Research Agricultural Economist with the international trade and development branch in our Market and Trade Economics division. His research focuses on a range of applied development and environmental topics including technology adoption, international trade, agricultural innovation, agricultural productivity, producer behavior, and sustainable intensification. Thank you both for joining us today. We'll begin with opening remarks from Stephen followed by Sun Ling's overview of U.S. agricultural productivity, and then Stephen will go on to discuss international agricultural productivity. Without further ado, let's go ahead and get started. The floor is yours, Stephen.

Thank you for that introduction, Ashley, and thank you everyone for attending today's webinar. So, to get started I want to first discuss briefly a little bit about what is agricultural productivity, and what do we mean when we're discussing this term. So, in general agricultural productivity is a measure of how efficiently agricultural inputs are used to create agricultural outputs, and quite often surrounding agricultural productivity we're discussing two different measures. The first measure is called partial productivity. Partial productivity is when we're considering only one agricultural input at a time. A good example of this might be something like crop yield which is calculated when you take total crop production or output, and you divide it by the land area used to create or to produce that crop. This might result in a measure of something like bushels per acre which is going to be a measure of partial productivity related to land. The second measure that we often discuss and the one that we're going to discuss today is called total factor productivity or TFP. Total factor productivity measures the agricultural output produced by the combined set of land, labor, capital, and other material resources that could be feed or fertilizer that are used in farm production. Total factor productivity is different from partial productivity because it's considering all of the agricultural inputs and looking at how they affect production.

Agricultural productivity is an important topic for several reasons. The first reason is that agricultural productivity data helps monitor if growth in the farm sector is sustainable to meet increasing demands for food and fiber, and this increasing demand is often driven by increasing world population. The second key factor is that productivity estimates can help inform policy decisions regarding overall farm sector performance both in the U.S. and in other countries. And finally, productivity data provides relevant information for conducting evidence-based research on the causes and the effects of agricultural productivity growth.

In today's webinar, my colleague Sun Ling and I are going to discuss two different ERS data products related to agricultural productivity. For each data product we're going to- we're going to cover several key topics. These include what is the data product, what are the methods used and what are the data inputs that go into creating these data products and measuring agricultural productivity, where and how can you access the data on the ERS website, and finally how are the data being used. And with that, I'll turn the presentation over to my colleague Sun Ling.

Thank you, Stephen. Hello everyone, thank you for joining us today for the U.S. productivity data training webinar. As Stephen just mentioned, ERS has two productivity products based on the total factor productivity measurement. I will call it a TFP for brief in my following presentation. So, agricultural productivity in the U.S. data products is produced by structure, technology and productivity branch at the ERS.

Before I introduce the data, I would like to first show you a simple but important figure. In this chart, the green line on the top is total output in the U.S. farm sector. The blue line at the bottom is total input used to produce the front output. The pink line in the middle is total factor productivity. On the left-hand side, the units on the vertical x- axis shows the relative level of individual series to their 1948 level setting. The 1948 level equals 1. So, from this chart we can see that in 1948 the total output is 1. By 19- by 2019 total output increased to 2.75 which means agriculture output increased by 175% at the annual rate of 1.42% over the study period. And total input use increased by slightly 4% at the average annual rate of 0.06%, and TFP increased by 163% with the annual rate of 1.36%. So, which means the main driver of the U.S. farm output growth is TFP in the U.S. farm sector.

So, how do we know that, and how do we measure that? So, in my following presentation I will answer some basic key questions. First, what is the U.S. agriculture productive data product -- by starting with some background information introduction and follow by talking about what can the data tell us. How- how are the input, outputs and TFP matrix in our data -- by first by briefly introducing methods and data sources. When- when are the new updates available? Where- where can the data be accessed? Who- who are using the data?

The background. So, in 1960 ERS was the first agency to introduce a multi-sector productivity measurement into the federal statistical program. To improve the quality of the data, ERS has implemented two external reviews conducted by experts. One was made by an AAEA task force in 1978. The second one was made by Shumway and panel of experts in 2014. Today, the U.S. agricultural productivity program bases its productivity statistics on a sophisticated system of production accounts.

The U.S. data product includes estimates of output, input and TFP in the U.S. farm sector from 1948 to 2019 and across 48 contiguous states from 1960 to 2004. In the output estimate, there are three broad categories: crops, livestock and products, and other farm related output and 10 sub-categories. In input estimates, there are three broad categories: capital, labor, and intermediate inputs and 12 subcategories. We also report estimates of price indices and implicit quantities in real value. In the data set, you can also find sources growth decomposition. We decompose the output growth into components including input quantity, input quality, and TFP.

So, what can the data tell us?

So, in my following presentation we are going to summarize some findings based on the U.S. data. So, on this slide we can see that all estimates are presented in their relative levels to 1948 setting 1948 equal one. The blue shift is total output. The dark blue line is capital. The yellow, orange line is intermediate input. The dark orange line is land, and at the bottom the gray line is labor. So, in 19- in 2019 the total output production was about 2.7 times its 1948 level, and labor, showing as the line at the bottom, dropped three quarters. And then, the second line from the bottom declined by about one quarter. Intermediate goods increased by 126%. So, which shows even though the total input we just saw in the first chart is quite flat over time, but the composition of input has changed dramatically over time, and capital excluding land increased by 78% on the top.

So, in our input measurement we also decompose the input changes into their quality changes and those are the quantity changes. So, in this chart the ray bars on the top indicate the quality change of labor input, and the blue bar at the bottom indicates the negative changes in the labor quantity. So, over time output annual growth rate was 1.42% and the percentage point contribution from labor input- from labor quantity was negative 0.55 percentage points. From labor quality was 0.13 percentage points. Therefore, it offsets some negative impact from the labor quantity but the total contribution from the labor input was shown as in the green line was zero- negative 0.42 percentage point to the annual output growth.

In this chart, we can see that the crops on the top increase much faster than the livestock and animal products. And within the crops category we can see that from 1948 to 2019 oil crops grew at highest rate among all crops.

In this chart we can see the relative TFP levels in 2004. The darker color indicates a higher TFP level, so California ranked the first in relative TFP level in 2004. On the right-hand side is the average annual TFP growth rate between 1960 to 2004. The darker color indicates a higher TFP growth rate. So, we can see from these two charts a higher level TFP doesn't mean it will show as the higher TFP gross rate. So, according to the second chart Oregon state ranked first in average annual TFP growth rate between 1960 and 2004.

So, how do we measure those impulse outputs in TFP? The farm sector in our measurement is defined in the same way as in the national income and production accounts. Therefore, secondary outputs that are primary to other industries were included in the primary industries output. Traces and implicit quantities for outputs and inputs by categories are constructed using detailed information.

Inputs are adjusted for quality changes over time since data are available to us, and TFP is a measure based on the Tornqvist index number approach under the growth accounting framework. TFP growth is the difference between the revenue share weighted output growth and the cost share weighted input growth. Multilateral prices for input and output were contracted in the state data, and state data contained estimates of TFP growth rate and the relative TFP level.

In our data sources, we include public and unpublished confidential data from public sector and private sector. Value and the quantity of production, marketing, and inventory changes -- from the ERS farm income balance sheet and from National Agricultural Statistics Service (NASS) survey. Prices for individual outputs and inputs are drawn from NASS, Bureau of Economic Analysis, Bureau of Labor Statistics, and Department of Energy, etc.

To adjust for input quality changes, we also include data from private sector such as GfK Kynetec dataset, AMIS, NASS, and other datasets. To adjust for labor quality changes, we also rely on the micro data from American Community Survey, the Census of Population, the Agricultural Resource Management Survey (ARMS) and public data from BEA, BLS, and NASS. Such as contract labor services -- we also include the data from the National Agricultural Worker Survey and ARMS.

So, when are new updates available? National data updates occur every two years. Updates of the national data were released January 2022 this year. The next updates of the national data are expected to be released in early 2024. There is no routine schedule for updating the state data.

So, where can the data be accessed? There are two ways you can access our data product. The first one -- join the ERS webpage. You select “data products” on the menu bar, and then you select “farm economy” on the dropdown menu, following by select “agricultural productivity in the U.S.” listed on the farm economic data product page. Or you can click on the link of our website page.

When you click on that link that will lead you to our webpage directly. On the left side, there is the menu bar so you can select anything you want to check out. So, for example if you click- if you click on the “overview page” it will bring you to the overview page with brief introduction regarding the data product such as the link to each table.

So, in the table links there are national tables in two different formats. One is in excel format. One is in csv format. There are also links to state level tables. At the bottom of the page, we show the date of last update. We also provide the contact information regarding the research team working on this data product.

If you click on “summary of recent findings,” you can see a brief discussion regarding the most recent update.

If you click on the growth- “productivity growth in the U.S. agriculture,” you can find some more detailed discussion based on the historical data from 1948 to 2019.

If you are interested in how we measure our data, we have a method section providing more details regarding the measurement for individual output and also input.

If you are also interested, those papers cited in our methodology or documentation-- we also provide a reference list.

In each update we provide update and revision history, so you know what is to be expected with the current revision.

So, how do we use the data? So, we have a page “uses and publication” so you can see that, for example, external review reports use our data. The ERS topic page cited our data and also in some staff analysis. At the bottom below the staff analysis, we also provide publication in the research list. So, if you are interested in reading some top publication based on the U.S. agricultural productivity data, you can click on each link and that will direct you directly to the publication.

So, to summarize U.S. agriculture productive data are used in ERS publication, for example, Amber Waves articles, ERS research report, and also Chart of Notes, and in some external publications. So, ERS data has been widely used in the academic research, published in external or peer-reviewed journal articles, or published in books, or cited in economy reports of the president, the NASS agriculture statistic yearbook, or cited in books. So, I'm now turning over to Stephen for further introduction on the international agricultural productivity data product.

Thank you, Sun Ling. Thank you so much. So, now we're going to transition and talk about the second ERS agricultural productivity data product, and this one is focused on international agricultural productivity data.

So, just as an overview the ERS international agricultural productivity data product supports cross-country comparisons of productivity growth rates, and this is a fairly expansive data product which covers 179 different countries around the world and the time series spans 1961 through 2019. In addition to providing country level data on TFP growth rates, this data product also includes information by region, subregion, and also country income group around the world. If you look at the chart on your left what you're seeing is a chart of agricultural total factor productivity growth rates by country presenting the annual average percent change from 1971 through 2019. This is a great example of some of the key findings that can be gleaned from this data product. So, for example on this chart we see that over this time period Brazil had an average annual TFP growth rate above 2% whereas Canada had an average annual TFP growth rate between one and two percent.

As we mentioned earlier, understanding agricultural productivity growth is important for ensuring an abundant and affordable global food supply, especially as there's increasing demand for food and fiber around the world. The chart on the right reflects the relationship between agricultural production and world population. So, the line in blue represents the agricultural production index. The line in green represents the agricultural price index. The black line represents growing world populations and finally the red line represents cropland used in global agricultural production. What we see in this chart is that since 1900, uh, agricultural production has actually outpaced population growth while at the same time at real agricultural prices have in general trended downward.

I now want to present a little bit of background about this data product. So, the international agricultural productivity data product was first published by ERS in 2013, and then it covered the years 1961 through 2010. Through a series of subsequent updates this data set has been extended um- to extend the annual time series through 2019 and also to add additional national and international data and updated estimation procedures where possible. So, for example in the most recent update in October of 2021 some innovations in this data product were that the definition of agricultural output was expanded to include aquaculture; a new definition for agricultural capital stock was adopted; new land quality adjustments for irrigated areas -- this is when irrigation is extended to previously unirrigated cropland -- were implemented; and finally agricultural output, input, and TFP indices were rebased, so they now use 2015 as the base year.

Thinking about the message used in this data product the underlying approach is a growth accounting approach to total factor productivity. This is important because this data set provides internationally consistent comparisons in total factor productivity growth rates between countries. However, we can't directly use the data set to compare total factor productivity levels given available data. So again, this data product can be used to provide these consistent comparisons and TFP growth rates. The underlying theoretical model compares the rate of change in total agricultural output with the rate of change of total agricultural inputs, and again, in the theoretical model outputs are weighted by their revenue shares or prices while inputs are weighted by their cost shares.

This data product in this methodology allows for the decomposition of agricultural output growth into several key categories. The first is land expansion, and this is when additional new cropland is brought into agricultural production. The second category is irrigation extension. As I mentioned earlier, this is when previously unirrigated land is irrigated. The third is input intensification, so this refers to agricultural labor, agricultural capital, other material inputs including feed and fertilizer and there- the relative intensity of their use in agricultural production. And then the final category is total factor productivity growth, or in other words how efficiently the other inputs are used to produce agricultural output. In the chart on the right, this breaks down this decomposition into the relevant categories where the height of the column represents agricultural output growth, and the height of the subsets of the column represent the decomposed categories. Where the area shaded in green is total factor productivity growth. These different categories are directly related to several key policy drivers. Total factor productivity is related to research and development activities also agricultural extension and education programs, market access, and institutional reforms. The other input categories are related to price and credit policies as well as land, trade policies, and market infrastructure.

Turning towards the data that goes into creating the ERS international agricultural productivity data product, the main data sources come from the Food and Agriculture Organization (FAO). Here we use the annual time series of 162 crop, 30 different livestock, and 8 agriculture commodity outputs. Additionally, on the input side FAO is the source of data for land, capital, fertilizer, and animal feed inputs. Thinking about agricultural labor, specifically headcount, this data comes from the International Labor Organization.

However, in addition to these main data sources the international agricultural productivity data set also draws on a series of other data sets to supplement the information available. This includes data provided by national and regis- regional statistical agencies which include our own USDA's National Agricultural Statistical Service and the USDA foreign agricultural service. Additionally, where available this data product incorporates estimates from other published productivity studies.

Just to provide an overview of what this data product can tell us, in the most recent data release, again in October of 2021, this data product shows that agricultural output grew at an average rate of just over 2% annually from 2011 through 2019. You can see this in the chart on the right which where the height of each column reflects the average annual output growth for the relevant time period. What we see when we're looking at this chart over time is that there's some evidence of slowing output growth and that this appears to be driven by slowing or lower total factor productivity growth represented by the shaded green area of each column. Other changes in output growth can be attributed to a slowing rate of input and irrigation extension and additionally a slightly higher rate of land use conversion in the most recent decade of data that's available.

So, now we want to spend some time thinking about how to access the ERS international agricultural productivity data product. First off, here we provide a direct link that will take you directly to the- the “data products” webpage on the ERS website. Again, the latest productivity estimates were released in October of 2021, and this update extended the data series through the year 2019. The next update of the data product is currently in progress.

If you want to navigate to the international agricultural productivity product from the ERS homepage, you should first click on the “data products” dropdown menu in the ribbon at the top of the home page. When you click on this drop- or the data products label you're going to access a dropdown menu, and you have two options. You can then select either data products, or you can select international markets and U.S. trade.

When you click on either of these links it's going to take you to a list of ERS data products. You can scroll down through this list until you find the international agricultural productivity data product that will come with a brief description. Once you click on that it will take you directly to that product webpage on the ERS website.

When you get to the “international agricultural productivity data” webpage or “data product” webpage, this is the screen that you will see. So, on the landing page, similar to Sun Ling's presentation, on the left-hand side of the screen you're going to see links to navigate to different pieces of information related to the data product. If you click the “overview” link it's going to provide you a brief description of the data product and the years that it covers. It's also going to provide you with the direct links to download the data product. If you click on the “summary findings” link this is going to provide you with a high-level overview of the most recent findings from the most recent release of the data product. So, this is a great place to start if you're looking for a summary of the data set. From the “documentations and methods” link, if you're interested in the underlying theoretical model or more details about the different data sets and how they're used in constructing this data product, you can check out that webpage. Next, we provide a link to the “update and revision history.” Here it's going to provide you with details about how the data set has evolved over time and when different releases incorporated different updates. And finally, we provide a link to the references which refer to the articles and data sources that were referenced in constructing this data product.

I want to highlight that the ERS international agricultural productivity data product is available for download in two different formats. The first is an excel workbook where different worksheets will contain the TFP indices and components for the different countries and regions of the world over the full time period that the data is available. The second format is a machine readable and long format of the TFP indices and so, you're able to download the version of the data product that works best for you.

Now, we want to provide a brief overview of what you see when you download and you open the data product. Again, this data product will provide annual total factor productivity output and input indices for all countries and regions that are covered. Here, you can see a screenshot of the Excel worksheet for the total factor productivity ind- index, and what you see here is that in the data set each country or region will be assigned to its own row, and you can read across, and you can see the index values for each year that the data set covers, again, where 2015 is the base year.

If you look down at the bottom of the worksheet or the workbook, different tabs will take you to different sheets of data related to the different components of the international ag productivity data product.

When using this data set, it's important to remember that total factor productivity represents the difference between the output and the input indices. As we discussed earlier TFP explains the efficiency of input use. Here we present a chart for Latin America and the Caribbean. So, this regional aggregate, and it graphs the output input and TFP indices for five years of the data set from 2015 through 2019. Here what you see is that, again, 2015 is the base year for the data set. So, all index values are set to index to 100. If we look at 2016, we see that the input index for this region is growing faster than the output index. This means that TFP was experiencing negative growth. However, if we look at the years 2017 through 2019 for each of these years the output index is growing faster than the input index, and that represents positive TFP growth.

Another important aspect of this data set is that in the “summary findings” link the data product provides a tool for you to view some high-level summary time series of the indices that are presented. So, specifically this tableau tool allows you to visualize total factor productivity output and input indices by country income level. If you look at the chart on the right what this graph is showing is it's plotting the three indices contained in the data set by for high-income countries, for low-income countries, and then for the world as a whole, and you're able to reference those different series side by side very quickly on the ERS website.

Finally, it's important to point out that the ERS international ag productivity data product also provides volume measures of output and inputs for each country, region, or year. This is in addition to those indices that we've been discussing earlier. So, these volume measures of output, they're quantities that are aggregated using constant 2015 prices. And, in addition to output, we provide these volume measures for inputs that include headcounts of labor, hectares of agricultural land use, and also tons of fertilizer or feed applied. The graph on the right depicts over the time series of the data that's available inorganic and organic fertilizer that was applied to soil.

Next, it's important just to note that the international agricultural productivity data product estimates may differ from other ERS productivity accounts that are specifically for the United States. These differences can be driven by differences in the assumptions, the data sources, and the methods used that help facilitate this international comparison for 179 different countries. Just to highlight, some key differences in the international ag productivity data products include that it uses global average agricultural prices, it uses labor headcounts that are unadjusted for demographic characteristics, it's adopted a measure of agricultural capital stock that assumes the same rate of depreciation across several different types of assets, and then finally it only includes two categories of intermediate inputs which are feed and fertilizer. So, when using the international agricultural productivity data product, this is best suited for comparing total factor productivity growth between the United States and other countries.

Finally, I want to highlight that the ERS international agricultural productivity data set is- has been an important tool for understanding global agricultural productivity and comparing growth rates between regions. This data product has been used in numerous ERS research reports and also in many Amber Waves articles. This data set has also been a source of analysis and several book projects and then many academic peer-reviewed journal articles.

So, with that I'm going to turn the presentation back over to Ashley as we transition into the Q&A portion of the webinar.

Thanks, Stephen. As you just mentioned, we'll go ahead and open the floor now for questions. As a reminder, questions can be submitted through the chat feature located at the bottom, left-hand corner of your screen. Before we begin, I would like to introduce Keith Fuglie, a senior economist with the structure technology and productivity branch in our Resource and Rural Economics division. Keith has joined us today to help answer questions, and Keith's work focuses on the economics of agricultural technical change, science policy, and productivity growth. Thanks for so much for joining us today, Keith. Let's see here. For our first question: will ERS be updating the state productivity accounts?

Uh, yes.

Thank you, Ashley. I think that.

Thanks Ashley, for the question. So, the main reason the state of data is suspended is because the sale of employee and unpaid family workers data were discontinued in the USDA farm labor survey. So, we currently have a research team working on finding a reliable and consistent new data source as a replacement of the self-employee and unpaid semi-worker data. So, and also, we plan to introduce some changes in the measurement of the input, output to develop new panels of state level output, input and total factor productivity. So, once the estimates are finalized and go through a peer review process, we will make the state data available to the public. However, there is no timeline for this. Thank you.

Okay thanks, and then for our next question: does rising productivity or rising TFP, that's total factor productivity, always mean higher agricultural output?

Thank you for that question, Ashley. So no, the answer is that rising agricultural productivity does not always mean increased agricultural output or production. It's possible that you can be in an- in an environment where agricultural inputs are being used more efficiently to produce output; however, at the same time the levels of agricultural inputs being used in production may decline. So, that can actually create a situation where you have increasing agricultural productivity, but you do not have increasing output.

Okay, good to know, and then how do rising wages affect TFP? Again, that's total factor productivity.

Thank you for that question, Ashley. I think we will let Sun Ling respond first, followed by Keith.

Thank you, Stephen and Ashley, for the question. So yes, so- which rate is a part of labor price for the labor input? So, for example in the U.S. agriculture productivity account- so, when price changes that will affect farmers' decision in input uses, and the changes in inputs allocation in responding to their prices will definitely affect the efficiency in transforming or inpuy use to output produced. So, since TFP growth rate is different between the output growth rate and input growth rate, so any combination changes reflected in either cost share or the input policy changes would definitely affect the TFP estimates. So, Keith, do you have anything to add?

Yeah, sure. Thank you, Sun Ling. Well, as Stephen and Sun Ling mentioned, you know, this TFP and the output and input, they're what we call quantity indexes. So, the principle behind that is we're trying to look at how real quantities change over time while holding prices fixed. So, it's kind of the flip side of a price index where you're trying to look at how prices are changing when quantities are held fixed. So, in these quantity indices, in principle, at least in the short run, a change in wage or a change in output price shouldn't affect the measurement of TFP but as Sun Ling mentioned over a long period of time when prices change or specific inputs or specific outputs, producers may also change their behavior. For example, they may try to substitute more capital for labor if labor is becoming more expensive, and so that will reflect be reflected in the trajectory for how TFP might grow. But, in principle in a short run, price changes should not affect the measurement of TFP.

Thanks, this next question asks if you can explain the difference between output growth and total factor productivity growth.

Thank you, Ashley. Keith, would you like to take this question?

Thank you, Stephen. Again, what we try to do often with these measures of TFP is we try to understand what are the drivers of growth and output of agricultural goods commodities. We want to ask ourselves how much of this is really due to expanding of resources, more land and labor and capital, and how much of it is to do to technical change and efficiency improvement to get more output from a given set of resources. So, this is what this growth decomposition is all about. So, we try to say we- from these measures, we can say okay of the growth in output from last year how much of that can be attributed to changes in the amount of resources that are being used and changes in the productivity of those resources. So, productivity is so- so output growth is really the- the mathematical sum of the growth rate in productivity plus the growth rate in input use.

Thanks, Keith. This next question asks: does ERS have research on the major factors putting downward pressure on TFP in recent decades?

Thank you, Ashley. I'll let Sun Ling respond first, followed by Keith.

I'm sorry, so Ashley, could you repeat your question?

Certainly, the question was: does ERS have research on the major factors putting downward pressure on TFP in recent decades?

So, ERS has conducted some evidence-based research projects, for example, on the agricultural input improvement or are the sources of output growth and also the drivers behind the agricultural productivity changes such as the science policy and other factors. So, regarding the question you just mentioned, I will also direct to Keith to add some more discussion on that. Keith, would you like to take something.

Yes, thank you. Well, like Sun Ling mentioned, we really do try to understand what are the drivers of TFP growth, and I think it's useful here to make a distinction between long-term trends in TFP growth and then short-term fluctuations in TFP around that trend. So, in the long term, you know, we really focus on what are- where is innovation and new technology coming from, how are farmers using that, and how are the adoption of those innovations affecting that, you know, that trend growth in TFP. And so, we really focus on- on how R & D and science policies as well as market liberalization and trade policies and so forth affect those incentives to farmers to adopt new technology and increase TFP over the long run. We're also increasingly looking at how climate change as well as, you know, short-run weather effects and weather fluctuations affect both- both long-run and short-run changes in TFP and other kinds of things that could suppress TFP or even cause TFP to go down or any kind of, you know, degradation of environmental resources including climate resources. So, this is a really good way of a strong measure for assessing long-run sustainable growth in a sector like agriculture. Because if resources are being degraded, either soil or water or climate, we will see that as lower productivity, lower TFP and if, you know, and so we're able to look at how drought, for example, might be affecting productivity this year or how in the longer term climate changes may affect trend productivity over the longer term.

Okay, for this next question: what are the intermediate inputs that have been growing?

Thank you, Ashley. Again, I think I'll allow- I'll pass the question to Sun Ling to speak to the U.S. data product and to Keith to speak to the international.

Thanks, Stephen. So, when we look at our intermediate input because we have many detailed information on each time series of the input, and we find that the agricultural chemicals such as fertilizer and pesticides they act- they actually increase much faster than other input use. So, I would let Keith follow-up to talk about the international productivity part.

Well, the- the intermediate inputs by definition are the things that are used within a production year. So, like Sun Ling mentioned fertilizer, fee- feed as opposed to what we call capital inputs-

inputs- or inputs that are used over several years like a tractor or a building or- or even land could be considered a type of capital, non-depreciating capital. So, what we find generally both in the United States and increasingly around the world is that over time land and labor resources and agriculture have been either slowing down in growth rate or particularly in labor is actually turning negative. So, fewer and fewer workers in agriculture both in the United States and around the world and more and more, the growth in inputs is coming from, you know, purchase of what we call manufactured inputs such as fertilizers, chemicals as well as capital like machinery and so forth, So, in the intermediate categories we have seen but also- also not only growth in things like fertilizer and feed but also purchase services like hired labor, contract labor, financial planning services, machinery hire services. That's also another significant type of intermediate input that is growing rather rapidly in, especially in U.S. agriculture.

Thank you both. Our next question notes that towards the beginning of the presentation a labor quality was used. How is labor quality defined and measured?

Thank you, Ashley. I’ll pass to Sun Ling.

Thank you, Stephen. Yes, so one feature in our U.S. agriculture productivity account is we try to adjust for quality changes. For example, in 1948 one hour of total of the work- the work hours produced by one labor may have different productivity than the- the same one hour in 2019. The main reason is because some demographic characteristic changes embodied in that labor force. So, for example, educational- educate- educational component changes and experience in age and agenda. So, in our account, we follow Jonathan and his peers on methodology. We consider the most demographic characteristics for labor include educational attendance and those agenda groups and also the age group and also our different employment type. So, there are about 160 something time series for different demographic groups. So, based on those data we construct the quality adjusted labor prices over time. For other inputs, for example, fertilizer and measure size we also consider a hedonic measurement to construct the quality adjust- adjusted the prices for those inputs and then we've got a quality adjusted quantity, so fertilizer and pesticides. So, those are just some examples. Thank you, for the question.

Thank you. All right, the next question asks: how does TFP or total factor productivity treat or account for environmental effects from agriculture?

Thank you for that question, Ashley. That's a really great point. So, overall total factor productivity doesn't directly include non-market goods and services. That might include water quality or air quality or other environmental measures. However, what TFP does include are market goods like land or livestock or fertilizer, and these could be related to different environmental outcomes. So, when we're thinking about TFP to the extent that TFP is measuring more efficient use of these market inputs like land, livestock, and fertilizer improvements in TSB- TFP could be associated with improved environmental outcomes. Sun Ling or Keith, do you have anything to add to that?

Yes, so like Stephen mentioned, we only consider factors with market prices in the productivity estimate. However, we also consider some environmental factors in our land measurement in the state productivity accounts based on the hedonic measurement. So, to capture the land quality heterogeneity among states- so yeah, as estimates quality adjusted land prices using hedonic approach for 48 contiguous states. So, the land characteristics include such as soil acidity, some salinity, and moisture stress among others, So, that's just one example. So, Keith do you have anything to add?

Yeah, I think those are very- very comprehensive answers. I will just add that this is an active area of ERS research to really understand how productivity is affected by or affects the use and quality of environmental resources. So, this is- this is a- a really important issue for us to understand these relationships, and so it's an active area of ongoing research.

All right, thank you all. Our- our next question is: what is the difference between TFP growth and the growth in the quality of inputs? Also, how is the quality of inputs defined?

Thank you, Ashley, for that question. Again, Sun Ling, would you like to start with the U.S. data product and Keith follow up with the international? Thanks, Stephen. Yes, so we can think about the quality, some kind of like a composition changes, the demographic of characteristics embodied in one unit of input, like I just mentioned on the labor demographic changes over time. And also, for example, like the different composition of one input. So, if you think as a composition shift over time then on the- the total input changes divided by those quantity change, the difference between those are the quality changes. However, to remain- to measure those quality changes, there are different ways such as the index number approach or hedonic price approach. So, in our account for the fertilizer and the culture pesticides, we rely on the hedonic price approach and for the labor quality changes we rely on the index number approach. Those are just examples. I'm now turning over to Keith.

Yeah no, I think that's very good. I think in the international agricultural productivity data product we are not able to control for input quality nearly to the extent that we are able to do that in the U.S. agricultural productivity data product simply because we don't have enough information comparable across all of these countries. The one input that we really do make an attempt to control for quality is in land. So, if you think of agricultural land, you have pasture or range land which generally is, you know, often kind of low-quality land, not- not maybe enough- not enough rainfall to grow crops, and then you have cropland rain fed crop land as well as irrigated crop land which also have very different underlying productivity potentials. So, what we do is we assign different weights to those three types of land to come up with a quality adjusted measure in what we call rain fed cropland equivalent hectares and that allows us to at least account for how those factors contribute to differences in productivity across countries. If you don't introduce those quality adjustments then you end up assigning all those productivities simply, they all fall into your TFP category, and what we really want to do is say, you know, can we explain more of what's driving what- what- what's causing productivity growth or productivity levels across countries or across states or over time to change, and so that's why we introduced these quality adjustments to try to better explain how these factors are contributing to changes in agricultural performance over time and across space.

Okay, thank you both. That's actually all the time we have for today. Thank you, Sun Ling, Stephen, and Keith for your presentations and insight on our U.S. and international agricultural productivity data products. I'd also like to thank our listeners for joining us today. We hope this has been helpful.

Before closing, we'd also like to invite you to the next segment of our data training webinar series in September. This webinar will spotlight our food availability data system which includes three distinct but related data series on food and nutrient availability for consumption, food availability data, loss-adjusted food availability data, and nutrient availability data. So, stay tuned for more details as they become available.

And if you haven't done so already, check out our new ERS Charts of Note mobile apps.

My apologies, there we go, and if you haven't done so already, check out our new ERS chart signate mobile app. With this app, available free of cost on Apple and Android devices, you can receive digital snapshots of ERS research straight to your mobile device. You can also search ERS's full library of charts, mark your favorites, and share them on social media.

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