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Agricultural Productivity and the Impact of Regulation

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Abstract

As part of a cooperative agreement with the United States Department of Agriculture (USDA), the George Washington University Regulatory Studies Center produced a five-chapter report on regulatory differences between the United States (U.S.) and the European Union (EU) and their effects on agricultural productivity. Those chapters are published here as a working paper series with five parts. This chapter provides focuses on the impact of agricultural policy, specifically regulation, in influencing agricultural productivity across jurisdictions. It begins by tracing agricultural growth in the EU and U.S. to illustrate their respective trends for agricultural productivity. Then, drawing from the literature, it identifies measures and methodologies used to estimate the impact of regulation on productivity. Finally, it outlines important differences regarding how regulations can affect agricultural productivity and other measures of agricultural performance such as output and production costs in the EU and the U.S.

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[2] This five-part working paper series was sponsored by a cooperative agreement with the United States Department of Agriculture. This working paper reflects the views of the authors, and does not represent an official position of the GW Regulatory Studies Center, the George Washington University, or the United States Department of Agriculture. The Center's policy on research integrity is available at http://regulatorystudies.columbian.gwu.edu/policy-research-integrity.

Introduction

In recent years both the EU and the U.S. exhibit continued growth in agricultural output with simultaneous decreases in agricultural inputs. This suggests that productivity gains (increased output per unit of input) remain an important factor in the agriculture sector.

Unless otherwise noted, data for the EU include only the EU-15 countries prior to several rounds of enlargement that occurred after May 1, 2004. There are at least two reasons for this approach. First, holding the number of Member States constant for EU data allows for more useful comparisons between jurisdictions. For example, it allows us to illustrate changes in land area used for agriculture between jurisdictions that are likely the result of different policy choices rather than the result of adding additional member states to the EU. Second, EU-15 countries collectively make up over 80% of current EU-28 gross agricultural production value.[3] Additionally, the EU-15 countries are more similar to the U.S. (e.g., in their general economic profile) relative to other countries within the EU-28. This allows our comparisons to benefit from consistent jurisdictions while remaining highly representative of EU-wide trends.

Sources of Productivity Growth

Considering the important role of productivity in agriculture production, a crucial question is what contributes to productivity growth.[4] Wang, et al. pointed out that the major factor driving long-run productivity growth is innovation, including public and private R&D, extension activities and public infrastructure that enhance technological changes.[5] It is worth noting that in the short-term, productivity growth can be affected by a variety of random factors such as weather, pests & animal diseases, and short-term policy shifts. Furthermore, studies have decomposed agricultural productivity into technological change and technical efficiency. Sabasi and Shumway identified explanatory variables affecting each component through economic theory and prior literature.[6] They found that technological change was primarily affected by increased innovation, and efficiency change was driven by farm size, ratio of family to total labor, agro-climatic conditions, and weather.

Many of these factors are influenced, either directly or indirectly, by government regulation and policy. For example, land conservation regulations can affect farm size; pesticide use regulations

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[3] FAOSTAT. *FAOSTAT Database*. 2015. http://faostat3.fao.org/home/E (accessed May 30, 2016).

[4] There are several different measures of productivity, but all attempt to calculate a ratio of outputs to inputs.

[5] Wang, Sun Ling, Paul Heisey, David Schimmelpfennig, and Eldon Ball. *Agricultural Productivity Growth in the United States: Measurement, Trends, and Drivers*. Economic Research Report 189, Washington, DC: Economic Research Service, U.S. Department of Agrciulture, 2015.

[6] Sabasi, Darlington, and C. Richard Shumway. "Technical Change, Efficiency, and Total Factor Productivity Growth in U.S. Agriculture." 2014 Agricultural & Applied Economics Association Annual Meeting. Minneapolis, Minnesota, 2014.

can affect pest damages to crop yield; farm labor regulations can affect labor ratio; and market regulations can affect capital inputs and technological investments. Relevant regulations thus are expected to affect agricultural productivity. Leetmaa, Arnade and Kelch, in their comparative study of U.S. and EU agricultural productivity, noted that “relatively few studies have investigated the impact of government policy on agricultural productivity.”[7] However, recent studies have drawn increasing attention to empirical evidence on the correlation between regulation and agricultural productivity. This chapter attempts to shed light on that relationship by summarizing the major measures and findings through literature review in the following sections.

Trends in Agricultural Growth

The EU and the U.S. are two of the largest agricultural producers in the world, and both jurisdictions have experienced continued growth in agricultural output. The following section compares agricultural output with the use of inputs in both jurisdictions to determine whether input use explains output growth. The findings demonstrate that the overall contribution of agricultural input use to output growth is negative for both the EU and the U.S from 1981 to 2013. This implies that increased output should be attributed primarily to gains in productivity.

Agricultural Output in the U.S. and EU

Figure 1 illustrates that both the EU and the U.S. have experienced growth in total agricultural production from 1981 to 2013. Possibly due to the U.S. farm financial crisis in the early 1980s, agricultural output in the U.S. fluctuated between 1980 and 1990, while agricultural output growth in the EU-15 were relatively steady. Beginning in 1990s, growth rates in the U.S. consistently exceeded those of the EU.[8] Over the 32-year period, agricultural output in the U.S. grew at an average annual rate of 1.28% compared to a 0.42% annual rate in the EU-15. By 2013, agricultural output in the U.S. was about 42% higher than it had been in 1981, whereas agricultural output in the EU-15 had only grown by approximately 13% over that same period.

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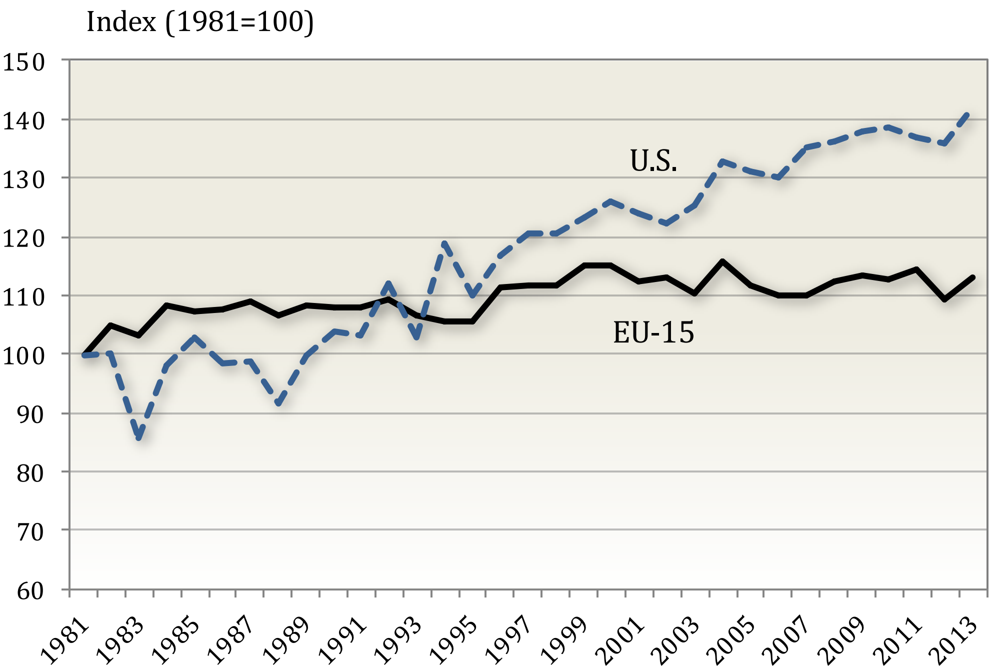
[7] Leetmaa, Susan E., Carlos Arnade, and David Kelch. *Comparison of U.S. and EU Agricultural Productivity with Implications for EU Enlargement*. Agriculture and Trade Report, Washington, DC: Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture, 2004.

[8] Two events may have played a role. In 1980, the U.S. halted grain shipments to the Soviet Union, which caused the collapse of grain prices and precipitated a 6-year decline in U.S. farmland values. (https://www.agclassroom.org/gan/timeline/1980.htm) (http://site.iptv.org/mtom/classroom/module/13999/farm-crisis?tab=background#background). In 1986 the U.S. adopted the Coordinated Framework for Biotechnology, which facilitated innovations that likely contributed to an increase in productivity beginning in the late 1980s.

Figure 1: U.S. and EU-15 indices of gross agricultural production, 1981-2013



Indices are developed by FAO using agriculture production quantities weighted by 2004-2006 average international commodity prices and summed for each year.[9]

Source: *Calculated from FAOSTAT*

Crops are particularly sensitive to short-term shocks (e.g. pests or changes in weather), but Figure 2 shows that crop production in the EU and U.S. exhibited growth patterns similar to those displayed in Figure 1 for agricultural production broadly. Output within both jurisdictions increased overall between 1981-2013, but, starting in the 1990s, rates of change in the U.S. exceeded those in Europe. On average, crop output in the EU-15 and the U.S. grew by 0.66% and 1.59% per year, respectively.

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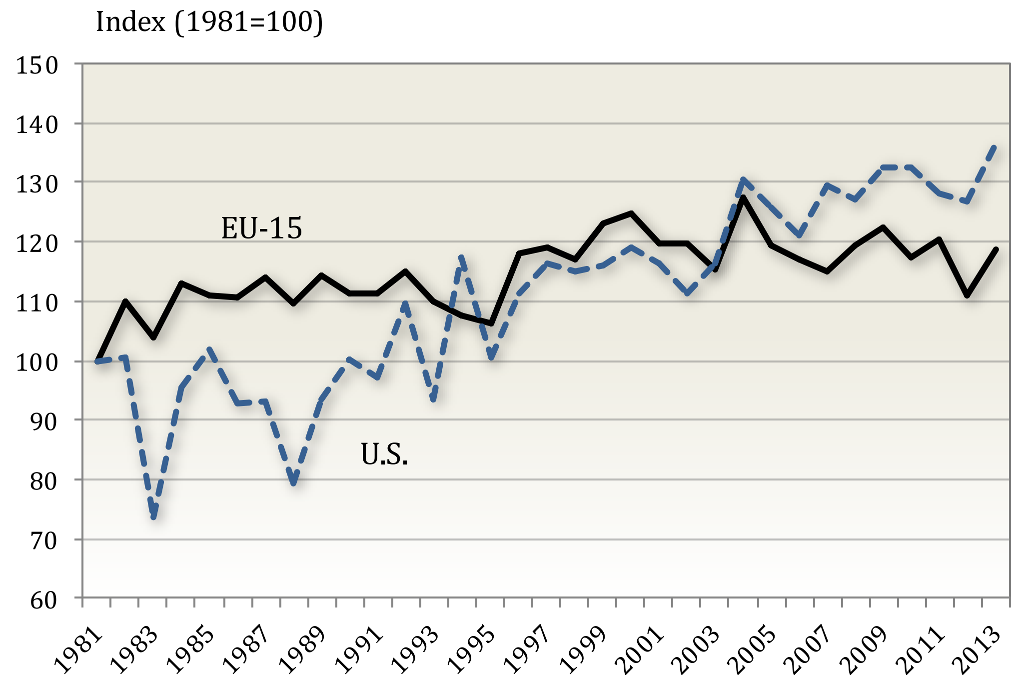
[9] Please see FAOSTAT metadata on production indices for details on the methodology http://www.fao.org/faostat/en/#data/QI/metadata

Figure 2: U.S. and EU-15 indices of gross crop production, 1981-2013



Indices are developed by FAO using agriculture production quantities weighted by 2004-2006 average international commodity prices and summed for each year.

Source: *Calculated from FAOSTAT*

It is common practice to attribute changes in agricultural output to two factors: changes in the use of agricultural inputs, and agricultural productivity growth.[10] Generally, agricultural inputs include labor, land, capital and intermediate inputs (such as fertilizer), while productivity is defined as the remaining changes in output that cannot be explained by changes in inputs.[11] The following sections further highlight the trend in agricultural inputs and productivity and their roles in driving output growth in the EU and the U.S.

Agricultural Input Use in U.S. and EU

Labor and land are two of the most important traditional inputs in agricultural production. Figures 3 and 4 show that, while output has increased since 1981, labor and land input have decreased overall in both the EU and the U.S. Agricultural land area in the EU declined by about 0.40% per year from 1981 to 2013. Similarly, the U.S. experienced a moderate but continued decrease in agricultural land area at an average annual rate of 0.17%.

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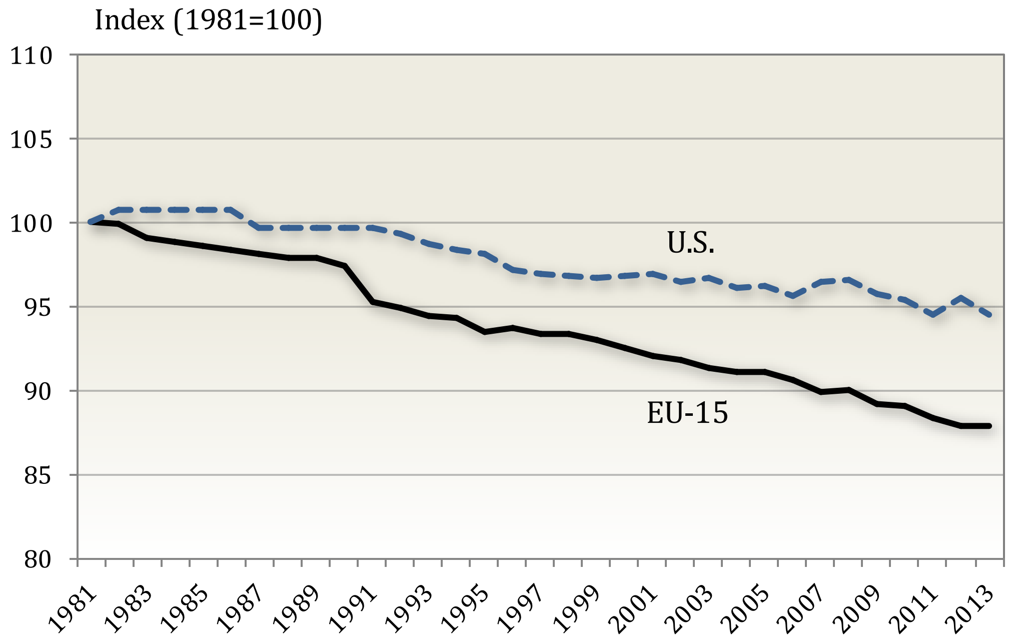
[10] Leetmaa et al (2004); Wang, et al. (2015)

[11] *Ibid*

Agricultural labor input exhibited a distinctly more significant decline in both jurisdictions beginning in 1994. Agricultural labor input[12] in the EU decreased by approximately 2.31% per year on average between 1991 and 2013. U.S. agricultural labor input decreased by 1.48% per year since 1981 and 1.09% per year since 1991.

Figure 3: U.S. and EU-15 indices of agricultural land area, 1981-2013



Source: *Calculated from FAOSTAT*

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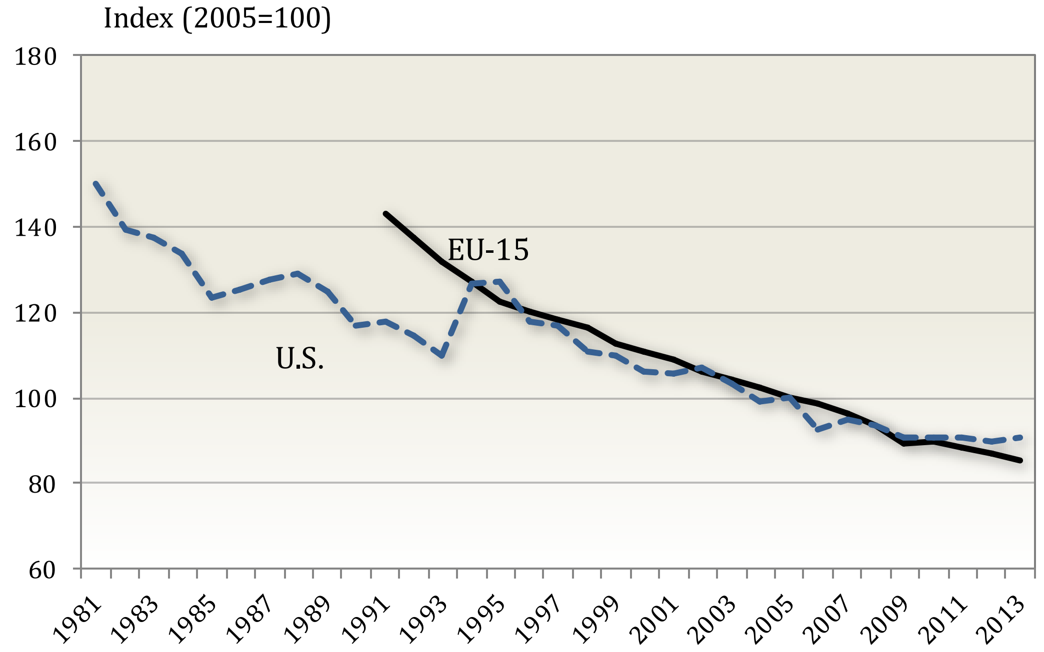
[12] Labor input for the U.S. and the EU is measured from different sources therefore it is only meant to be indicative of individual trends, and not comparable measures due to possible differences in data and methods of calculation.

Figure 4: U.S. and EU indices of agricultural labor input 1981-2013 for U.S., 1991-2013 for EU-15



Note: Labor input for the U.S. and the EU is measured from different sources and may not be comparable measures because of possible differences in data and methods of calculation.

Source: *ERS Agricultural Productivity in the U.S.; EuroStat Economic Accounts for Agriculture*

Intermediate inputs in agricultural production include seed, feed, purchased livestock, fertilizer, pesticides, energy, and purchased services.[13,14] Unlike labor and land inputs, figure 5 shows an increasing trend in total intermediate input use in agricultural production. The EU's intermediate input use increased at an average annual growth rate of 0.73% from 1993 to 2013. Intermediate input use in the U.S. grew by 0.56% per year since 1981 and 0.95% per year since 1993.

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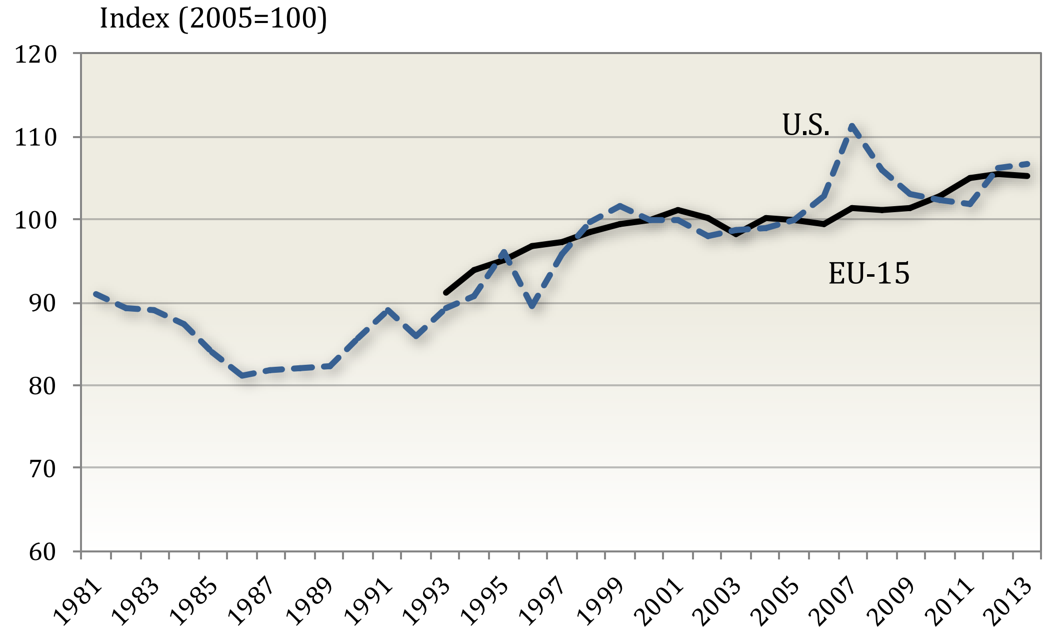
[13] Purchased services include contract labor service, capital equipment lease, custom machine work (such as tilling, plowing, field cultivation, mowing, planting, and fertilizer spreading), machinery repair, building repair, transportation and storage, veterinary services

[14] Wang, et al. (2015)

Figure 5: U.S. and EU indices of intermediate input consumption in agriculture, 1981-2013 for U.S., 1993-2013 for EU



* Intermediate inputs in the U.S. include feed and seed, energy, fertilizer and lime, pesticides, purchased services, and other intermediate. Intermediate inputs in the EU include purchases made by farmers for raw and auxiliary materials such as seeds and plantings, fertilizers, and plant protection products used for crop and animal production, and expenditure on veterinary services, repairs and maintenance, and other services. Agriculture input for indices are measured in dollars (U.S) and euro (EU) for base year 2005. The graph is intended to illustrate individual trends, not comparative perspective.

Source: *ERS Agricultural Productivity in the U.S.; EuroStat Economic Accounts for Agriculture*

The overall contribution of major agricultural input use to agricultural output growth remains slightly negative from 1981 through 2013 even accounting for increases in the use of intermediate inputs. Therefore, it is reasonable to assume that productivity increases explain recent agricultural output growth in the EU and the U.S.

Measuring Agricultural Productivity

To verify the assumption that productivity has been a major factor in agricultural output growth in the EU and the U.S., it is important to compare the trend in agricultural productivity in both jurisdictions over time. However, unlike agricultural outputs and inputs, agricultural productivity lacks a uniform definition or measure. Various measures of agricultural productivity are presented in the literature, including single-factor measures such as crop yield per acre, value-added per worker, and total factor productivity (TFP) which accounts for all agricultural inputs and outputs. Among these, TFP is considered to be the most informative and comprehensive measure.[15,16] However, there are differences in methods for measuring TFP in the U.S. and the EU.

The assumptions, data, and methods used to calculate TFP in the EU differ substantively from USDA-ERS IAP estimates, particularly in four areas: (i) measures of productivity; (ii) methodology; (iii) data sources; and (iv) subsamples. USDA-ERS measures of TFP estimate changes over time within a country, while COMPETE estimates differences in TFP levels over time between countries. Although both measures use the Törnqvist-Theil index[17] to aggregate multiple outputs and inputs, COMPETE employs a metafrontier approach[18] to estimate TFP levels, and USDA-ERS IAP uses the Cobb-Douglas production function[19] to estimate the difference between output and input growth.

Measures of TFP in the EU

In the EU, measurement of agricultural productivity has changed over the years. As part of the Common Agricultural Policy (CAP) "Agenda 2000" reform, Eurostat developed indicators for agricultural productivity, including a Multi-Factor Productivity (MFP) index that compares the growth in agricultural output to the growth in a bundle of, but not all, agricultural inputs.[20] Eurostat measured and published annual MFP growth rates for member states for several years in the early 2000s but later discontinued doing so due to a lack of data availability.

The EU expanded its efforts to develop methods for measuring agricultural productivity via COMPETE, a research project supported by the European Commission's Seventh Framework Programme between 2012 and 2015.[21] Under this project, indicators of competitiveness of European food chains including agricultural productivity were defined and estimated. Rather than measuring TFP growth rates, COMPETE estimates TFP levels using a comparative assessment of TFP differences among EU member states and data from the Farm Accounting

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[15] USDA-ERS. Methodology for Measuring International Agricultural Total Factor Productivity (TFP) Growth. October 16, 2015. http://www.ers.usda.gov/data-products/international-agricultural-productivity/documentation-and-methods.aspx (accessed May 20, 2016).

[16] Čechura, Lukáš, Aaron Grau, Heinrich Hockmann, Zdeňka Kroupová, and Inna Levkovych. "Total Factor Productivity in European Agricultural Production." *COMPETE*. October 9, 2014. http://www.compete-project.eu/publications/working-papers.html (accessed May 30, 2016).

[17] A Törnqvist price index is a weighted geometric average of the price relatives using the arithmetic averages of the value shares in the two periods as weights.

[18] A metafrontier approach calculates technical inefficiency by estimating the technology gaps between farms under different technologies and farms under potential technologies available to the industry as a whole.

[19] The Cobb–Douglas production function is used to estimate the technological relationship between inputs and the output they produce.

[20] Matthews, Alan. *What is happening to EU agricultural productivity growth?* May 4, 2014. http://capreform.eu/what-is-happening-to-eu-agricultural-productivity-growth/ (accessed May 30, 2016).

[21] Čechura et al. (2014)

Data Network (FADN) provided by the European Commission. It is not clear if TFP levels will continue to be calculated after 2015, but EU member states recognize the need for indicators to continue measuring CAP's impact on the EU's agricultural sector.[22, 23]

Measures of TFP in the U.S.

The U.S. Department of Agriculture Economic Research Service (USDA-ERS) uses a "growth accounting" approach to measure changes in agricultural TFP over time. This calculates TFP growth rates by subtracting the aggregate input growth rate from the aggregate output growth rate. Two estimates of TFP reported by ERS are: Agricultural Productivity in the U.S. (USAP) and International Agricultural Productivity (IAP). USAP measures domestic agricultural TFP growth, whereas IAP is developed for cross-nation comparisons of growth rates. It is worth noting that TFP growth reflects trends in productivity over time within a jurisdiction; therefore, IAP estimates are limited in their ability to compare relative levels of agricultural productivity between jurisdictions. Although both measures include U.S. national TFP growth, the estimates are not identical due to differences in their underlying assumptions and methodology.[24] In general, the IAP simplifies its assumptions to adjust for limited availability of data. In particular, the two estimates differ in their measurement of: (i) output growth, (ii) agricultural labor, (iii) farm capital stock, and (iv) inclusion of material inputs, as discussed below.

IAP uses global average agricultural prices from FAOSTAT, while USAP calculates output growth based on prices received by U.S. farmers. Additionally, data on labor are quality-adjusted by labor's demographic characteristics—such as sex, age, education and employment class—in the U.S., producing a more detailed measure than estimates at the international level, where these data are not available. There are also differences in the capital measurement of the respective estimates: USAP measures farm capital stock as a function of past capital expenditures, discounted for depreciation, whereas IAP measures inventory based on the number of major pieces of machinery in use on farms. The difference between the two estimates of TFP growth is also reflected in the comprehensiveness of the data on material inputs used in the U.S compared to the global level. In summary, the estimate for U.S. domestic TFP growth is based on a more detailed accounting of material inputs in comparison to its international counterpart.[25]

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[22] European Commission's Directorate General for Agriculture and Rural Development. CAP monitoring and evaluation indicators - agriculture and rural development. May 23, 2016. http://ec.europa.eu/agriculture/cap-indicators/ (accessed May 31, 2016).

[23] For more information on EU TFP methodology refer to Čechura et al. (2014) at http://www.compete-project.eu/publications/working-papers.html

[24] USDA-ERS. Methodology for Measuring International Agricultural Total Factor Productivity (TFP) Growth. October 16, 2015. http://www.ers.usda.gov/data-products/international-agricultural-productivity/documentation-and-methods.aspx (accessed May 20, 2016).

[25] For more information refer to USDA ERS IAP website: https://www.ers.usda.gov/data-products/international-agricultural-productivity/

There are also additional methodological differences in estimating EU TFP between IAP and COMPETE. IAP uses the FAOSTAT dataset on global average prices for farm output. In comparison, COMPETE uses data from FADN on farm income and the impact of CAP on 24 EU member states. Furthermore, both estimates use different samples in their calculations. COMPETE's estimates are derived from production data from three agricultural sectors—dairy, pork and cereals—whereas IAP's estimates are derived using 198 different crops and livestock.

Comparison of Agricultural Productivity

This section[26] compares agricultural productivity in the EU and the U.S. using multiple relevant TFP estimates. We compare relative levels of TFP to illustrate the differences between both jurisdictions. We then proceed to use estimates of TFP growth to highlight the development of agricultural productivity over time within each jurisdiction. Finally, the role of productivity growth in driving agricultural output growth is further discussed, and possible factors affecting agricultural productivity are briefly summarized.

Relative Levels of TFP in the U.S. and EU

As previously discussed, although IAP estimates agricultural TFP growth for multiple countries, these estimates cannot be used to directly compare agricultural productivity levels between countries. Ball, et al.[27] measured relative TFP levels for the EU and the U.S. from 1973 to 1993,[28] and updated the data in 2010. The latest results include levels of TFP for eleven EU member states relative to the U.S. from 1973 to 2002. The 1996 U.S. TFP level is used as the base year for comparison; table 1 displays the results from 1981 to 2002. The EU countries in the dataset account for roughly 75% of total EU-15 agricultural production value throughout this time period.[29]

Table 1: Comparison of relative levels of agricultural TFP in the EU and U.S. (relative to U.S. TFP in 1996), 1981-2002

	Belgium	Denmarl	Germany	Greece	Spain	France	Ireland	Italy	Nether -lands	Sweden	U.K.	EU	U.S.
1981	0.684	0.582	0.552	0.428	0.452	0.514	0.394	0.439	0.765	0.400	0.549	0.518	0.697
1982	0.692	0.624	0.592	0.446	0.486	0.560	0.423	0.448	0.785	0.430	0.562	0.548	0.720
1983	0.687	0.594	0.587	0.422	0.517	0.546	0.431	0.481	0.792	0.423	0.551	0.549	0.620

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[26] Čechura, Grau, Hockmann, Kroupová, & Levkovych, 2014

[27] Ball, V. Eldon, J.-P. Butault, Carlos San Juan, and Ricardo Mora. "Chapter 13: Agricultural Competitiveness." In *The Economic Impact of Public Support to Agrciulture*, by V. Eldon Ball, Roberto Fanfani and Luciano Gutierrez, 243-271. New York: Springer, 2010.

[28] Leetmaa et al. (2004)

[29] FAOSTAT (2015)

	Belgium	Denmarl	Germany	Greece	Spain	France	Ireland	Italy	Nether-lands	Sweden	U.K.	EU	U.S.
1984	0.720	0.695	0.604	0.441	0.576	0.565	0.474	0.462	0.789	0.473	0.595	0.573	0.739
1985	0.717	0.683	0.585	0.455	0.609	0.576	0.467	0.472	0.778	0.466	0.573	0.574	0.789
1986	0.733	0.707	0.595	0.467	0.546	0.583	0.442	0.483	0.818	0.473	0.572	0.577	0.786
1987	0.714	0.672	0.576	0.472	0.607	0.596	0.467	0.493	0.804	0.448	0.571	0.582	0.813
1988	0.731	0.722	0.584	0.494	0.642	0.599	0.478	0.461	0.830	0.460	0.563	0.588	0.783
1989	0.739	0.757	0.592	0.511	0.606	0.604	0.451	0.479	0.850	0.494	0.578	0.593	0.854
1990	0.770	0.772	0.672	0.452	0.633	0.621	0.508	0.450	0.886	0.524	0.580	0.617	0.877
1991	0.775	0.780	0.596	0.550	0.632	0.606	0.516	0.489	0.896	0.508	0.587	0.609	0.877
1992	0.834	0.752	0.620	0.538	0.641	0.647	0.549	0.494	0.906	0.490	0.595	0.628	0.955
1993	0.841	0.802	0.620	0.516	0.645	0.638	0.525	0.515	0.914	0.523	0.579	0.631	0.913
1994	0.803	0.800	0.634	0.559	0.642	0.644	0.524	0.547	0.935	0.518	0.581	0.641	0.997
1995	0.801	0.812	0.646	0.575	0.597	0.657	0.526	0.579	0.940	0.539	0.568	0.647	0.928
1996	0.814	0.814	0.657	0.570	0.731	0.680	0.548	0.614	0.931	0.568	0.564	0.677	1.000
1997	0.818	0.817	0.666	0.590	0.773	0.687	0.555	0.636	0.903	0.587	0.568	0.690	1.005
1998	0.848	0.841	0.680	0.613	0.774	0.698	0.554	0.666	0.942	0.571	0.579	0.706	1.009
1999	0.871	0.851	0.714	0.629	0.725	0.717	0.550	0.715	0.969	0.573	0.596	0.721	1.006
2000	0.873	0.850	0.694	0.635	0.789	0.709	0.572	0.701	0.974	0.590	0.616	0.727	1.045
2001	0.833	0.854	0.666	0.636	0.816	0.691	0.573	0.699	0.954	0.586	0.592	0.719	1.039
2002	0.872	0.862	0.695	0.635	0.878	0.714	0.592	0.684	0.949	0.599	0.633	0.741	1.048

Source: *Ball et al. 2010; EU levels calculated by the authors using agricultural output data from FAOSTAT.*

In 1981, only the Netherlands had higher a level of agricultural TFP than the U.S. All countries in the dataset achieved growth in TFP levels from 1981 to 2002. Beginning in 1992, U.S. TFP surpassed the Netherlands and remained higher than all other EU countries. By 2002, several EU member states had significantly increased their TFP growth rates vis-à-vis U.S. growth rates, although their absolute levels of TFP still remain lower than the U.S. Spain achieved the most significant growth in TFP levels between 1981 and 2002 with an average growth rate of 2.8% per year, slightly higher than the U.S. average annual growth rate of 2.6%.

Leetmaa, Arnade and Kelch calculated a weighted average of TFP levels for the eleven EU countries by multiplying each member state's TFP level by its respective portion of the EU-11 gross agricultural production value in a given year using FAOSTAT data.[30] The result indicates

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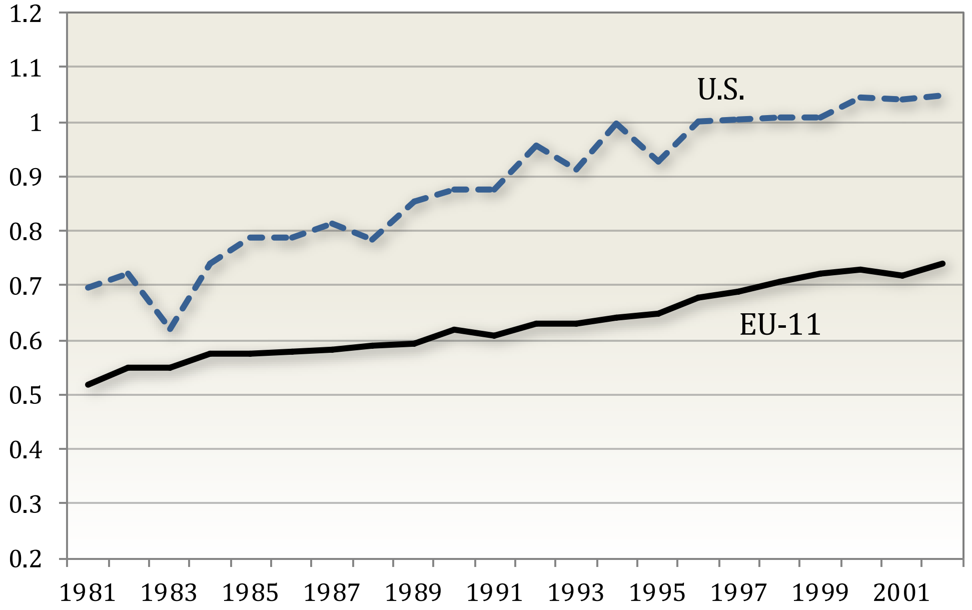
[30] Leetmaa et al. (2004)

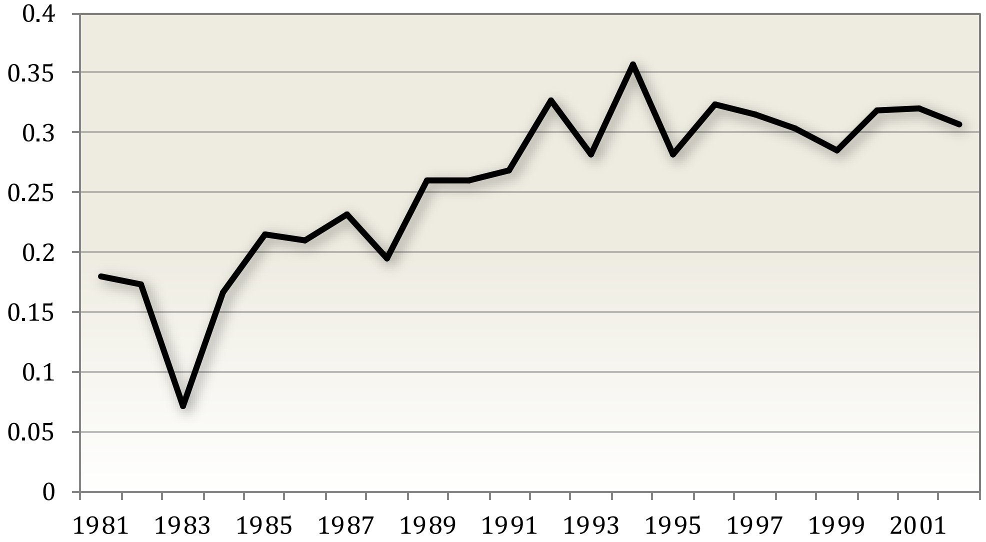
that the absolute TFP level of the EU-11 was consistently lower than that of the U.S. from 1981 through 2002. Moreover, figures 6.1 and 6.2 illustrate that the difference between the EU-11 and the U.S. appears to be slightly expanding over time.

Relative agricultural TFP levels, EU-11 and U.S., 1981-2002

Figure 6.1: TFP levels, relative to U.S. TFP in 1996



6.2: Difference in TFP levels between U.S and EU-11, 1981-2002



Source: *Ball et al. 2010; EU-11 levels calculated by the authors using agricultural output data from FAOSTAT.*

TFP Growth in the U.S. and EU

As previously mentioned, TFP growth is a more widely used measure that captures changes in agricultural TFP over time within a jurisdiction. The IAP database provides internationally consistent and comparable agricultural TFP growth rates and indices for 173 countries from 1961 to 2013. This includes the U.S. and the majority of the EU-28 member states, excluding Slovenia and Croatia. It calculates agricultural TFP growth rates by subtracting aggregate agricultural input growth rate from smoothed agricultural output[31] growth rate in a given year. Because of the different methodology, data and measurement, the IAP TFP growth estimates are not comparable with the Ball, et al. estimates.

Table 2 shows the indices of agricultural TFP growth in the U.S. and the EU-15 member states from 1981 through 2013. The indices are normalized to be 100 in the base year of 1981 for each country. As shown, all countries achieved TFP growth over the period and eight EU countries achieved cumulative TFP growth rates that exceeded the U.S. rate. These countries are Belgium-Luxembourg,[32] Denmark, Germany, France, Italy, the Netherlands, Portugal, and Spain. Denmark achieved the largest growth (119%). Since the base year TFP level differs across countries, the indices do not represent the relative TFP levels between countries. It is important to note that the countries with the largest TFP growth are likely to have had initially lower TFP levels.[33] This is due to the relatively lower cost of imitation vs innovation.[34]

Figure 7 displays the weighted average of TFP growth indices for EU-15 compared to the U.S. From 1981 to 2013, the agricultural TFP growth in the EU and the U.S. followed a similar trajectory. The cumulative TFP growth of the EU-15 since 1981 reached 73%, compared with a cumulative U.S. TFP growth of 63%. However the average annual growth rate was slightly higher in the U.S. (1.75%) than in the EU-15 (1.56%). Agricultural TFP levels in the EU have been consistently lower than the U.S., although both jurisdictions have enjoyed similar growth patterns throughout the same period.

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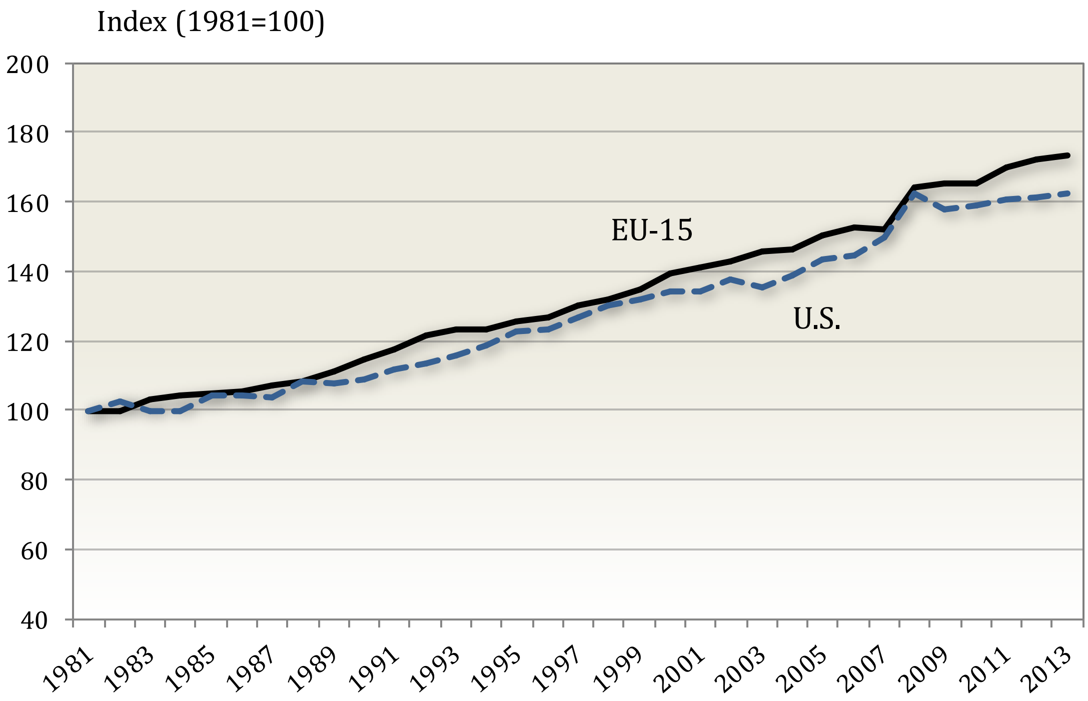
[31] Smoothed output is FAO gross agricultural output smoothed using the Hodrick-Prescott filter/decomposition (Lambda=6.25). (USDA IAP). The Hodrick-Prescott filter is a tool used to remove the cyclical component in a time-series in order to smooths the time series data to more accurately estimate a trend.

[32] Statistics in FAOSTAT are available for the Belgium-Luxembourg Economic Union as a combined entity until 1999, and for Belgium and Luxembourg respectively from 2000. Statistics in ERS IAP database are available for Belgium-Luxembourg as a combined entity for all available years.

[33] Leetmaa et al. (2004)

[34] Ball, V. Eldon, J.-P. Butault, Carlos San Juan, and Ricardo Mora. "Chapter 13: Agricultural Competitiveness." In *The Economic Impact of Public Support to Agrciulture*, by V. Eldon Ball, Roberto Fanfani and Luciano Gutierrez, 243-271. New York: Springer, 2010.

Figure 7: Indices of Agricultural TFP Growth, EU-15 and U.S., 1981-2013



Source: *Calculated from USDA-ERS IAP and FAOSTAT*

Table 2: Indices of Agriculture Total Factor Productivity Growth, EU-15 and U.S., 1981-2013

	Austria	Belgium-Luxembourg	Denmark	Germany	France	Finland	Greece	Ireland	Italy	Nether-lands	Portugal	Spain	Sweden	UK	U.S.
1981	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
1982	103.03	96.24	103.06	102.70	100.64	98.86	100.58	99.87	101.31	101.93	102.92	101.06	101.38	97.40	103.04
1983	103.25	96.11	103.60	107.17	103.73	102.55	101.04	99.20	101.36	104.70	106.88	102.98	103.04	98.97	100.78
1984	101.82	101.41	107.73	108.31	105.84	106.11	102.50	102.44	100.60	102.45	112.09	103.09	104.24	101.17	101.24
1985	102.50	100.58	112.12	108.96	105.55	105.86	101.82	109.84	102.08	101.14	112.54	104.81	108.57	102.46	104.26
1986	109.71	103.38	109.03	111.28	105.96	106.69	103.64	108.62	100.72	103.86	114.64	106.95	108.88	100.49	104.35
1987	111.98	105.65	114.99	113.86	106.65	109.26	106.06	117.64	99.94	104.25	116.83	106.66	107.81	102.41	104.17
1988	108.54	108.06	116.77	114.86	106.80	111.01	105.57	116.94	103.46	103.80	118.83	108.69	110.01	103.52	108.48
1989	113.42	111.76	117.06	117.36	108.08	111.51	107.61	121.03	107.98	115.47	127.28	111.65	110.10	104.66	107.93
1990	109.50	115.69	119.98	127.35	111.53	118.16	109.75	122.06	109.69	109.02	128.97	114.03	114.12	106.49	109.19
1991	112.19	122.83	125.37	133.36	112.27	133.24	113.59	128.70	109.70	114.91	133.25	116.30	119.53	111.10	112.19
1992	114.99	130.57	130.76	135.74	122.51	136.50	115.36	128.18	113.03	112.62	138.01	121.51	117.40	113.20	113.88
1993	117.80	139.91	134.66	136.36	121.27	140.68	121.39	125.11	116.92	119.70	136.77	119.28	114.55	114.92	115.79
1994	119.36	141.40	140.94	132.43	121.54	136.67	120.93	119.77	120.37	116.09	138.46	121.68	115.59	112.91	118.89
1995	125.70	145.26	145.13	132.80	123.52	135.21	122.55	122.57	122.16	118.86	142.71	125.90	120.36	113.86	122.95
1996	124.67	149.59	147.68	136.67	125.73	139.90	120.14	127.63	123.31	119.22	143.36	126.92	119.43	111.16	123.55
1997	124.71	152.91	150.19	140.24	128.21	141.01	123.64	127.54	128.01	127.26	145.77	131.23	121.54	110.50	127.14
1998	128.36	152.38	156.63	141.73	129.86	116.65	126.38	127.11	129.29	129.54	143.64	134.31	125.88	113.07	130.45
1999	140.06	151.66	163.28	147.24	132.67	119.63	127.60	123.14	130.72	124.68	147.66	141.11	126.44	114.00	131.99
2000	140.02	156.61	169.05	153.41	138.26	125.46	127.35	131.58	133.29	128.62	151.67	147.62	129.24	115.91	134.48
2001	138.40	155.76	175.21	157.77	135.53	127.70	129.57	129.14	135.61	123.10	153.64	153.53	130.61	113.78	134.45

	Austria	Belgium-Luxembourg	Denmark	Germany	France	Finland	Greece	Ireland	Italy	Nether-lands	Portugal	Spain	Sweden	UK	U.S.
2002	144.89	154.41	178.84	162.01	136.90	130.83	129.01	124.19	136.18	125.96	157.43	155.08	132.20	115.11	138.04
2003	147.98	155.68	179.17	166.82	140.70	133.27	127.24	127.72	142.02	127.41	160.84	154.43	134.29	114.84	135.60
2004	146.82	151.10	181.84	167.44	139.99	137.09	128.09	126.30	144.33	129.34	165.02	155.70	137.19	116.24	139.17
2005	148.86	155.96	187.91	170.35	143.61	138.66	128.88	128.51	153.43	133.01	169.93	161.78	139.16	118.35	143.90
2006	152.25	155.14	189.71	176.43	146.46	142.55	130.24	129.46	155.33	132.68	175.11	161.44	145.25	118.31	144.92
2007	154.11	150.12	187.69	175.85	142.42	139.44	125.86	140.21	157.93	133.64	175.03	159.46	134.55	118.76	149.96
2008	170.70	160.97	209.09	194.41	152.86	152.73	131.33	130.00	168.59	136.47	184.08	177.07	140.88	123.67	162.42
2009	173.39	156.22	209.30	193.21	156.04	150.08	131.30	123.51	173.30	145.85	191.82	176.20	140.00	120.48	158.05
2010	162.33	159.47	209.63	192.23	152.49	149.63	131.33	126.13	175.02	149.55	194.60	177.57	145.53	121.45	159.11
2011	162.40	161.71	214.89	197.98	162.04	153.89	131.12	129.27	174.77	158.62	195.83	183.39	143.14	122.96	161.15
2012	162.50	163.31	217.20	197.80	170.29	156.06	132.23	124.65	175.09	162.09	194.80	184.93	144.51	122.11	161.44
2013	162.37	166.44	219.47	197.55	171.98	155.49	131.22	124.00	174.26	166.84	195.92	188.59	144.90	119.55	162.90

Source: *Calculated from USDA-ERS IAP*

Agricultural Output, Inputs and TFP

To further illustrate the relationship between agricultural production and productivity, we display agricultural output growth, input growth, and TFP growth using IAP data for the EU and the U.S. from 1981-2013 (table 3). As previously mentioned, limited data availability constrains the results to a weighted average of EU-15 member states.

Figure 8 shows the indices of EU-15 agricultural TFP, input, and output growth. Although it contains different data sources, the findings are mostly consistent with the above analysis: agricultural inputs decreased by nearly 34%, or 1.27% annually on average, while TFP growth drove agricultural output to increase by 13%, or 0.39% annually, between 1981 and 2013. Figure 9 indicates that the same pattern holds true for the U.S. Although the U.S. achieved slightly less growth in agricultural TFP compared to the EU, agricultural output increased by roughly 46%, or 1.20% annually on average—a much higher amount than the EU. This difference is mainly attributable to a smaller decrease in agriculture inputs in the U.S.—an approximately 10% cumulative decrease or an average annual growth rate of -0.31% from 1981 to 2013.

Table 3: Total change and average annual growth rate of EU-15 and U.S. agricultural output, input and TFP growth from 1981-2013

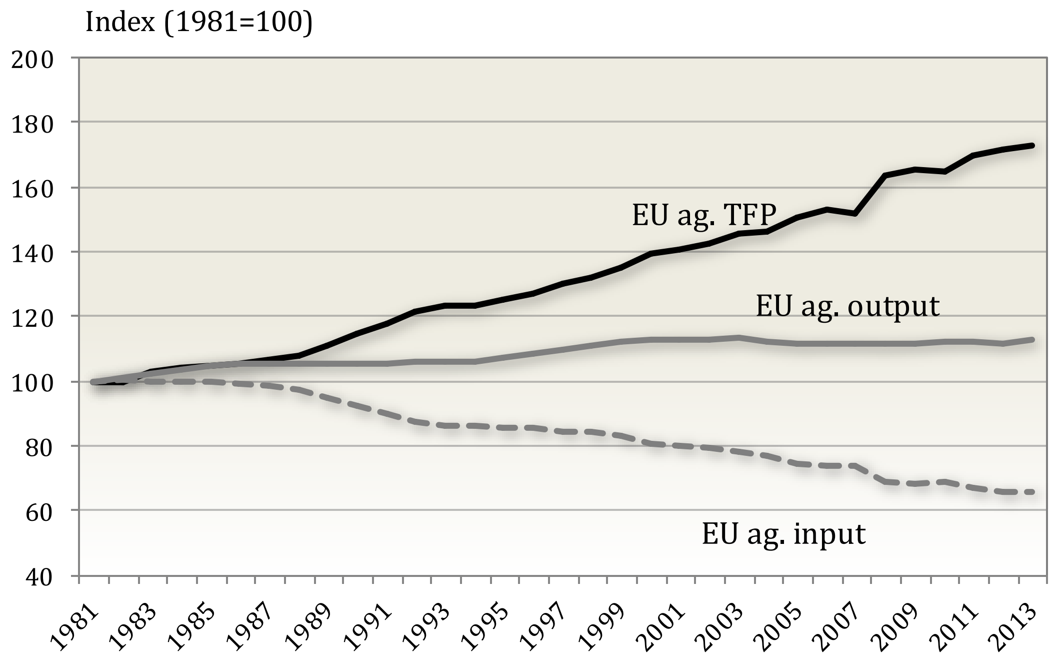
	EU-15		**U.S.**	
	Total changes (%)	**Average annual growth rate (%)**	**Total changes (%)**	**Average annual growth rate (%)**
Output growth	13.12	0.39	46.47	1.20
Input growth	-33.83	-1.27	-10.09	-0.31
TFP growth	73.44	1.56	62.90	1.75

Source: *USDA ERS IAP*

To summarize, increase in productivity was a primary factor in agricultural output growth in both the EU and the U.S. from 1981-2013. However, agricultural output increased at a significantly higher rate in the U.S. despite the fact that EU TFP growth rates were higher throughout this period. These results indicate that the much larger reduction in agricultural inputs in the EU relative to the U.S. (34% vs 10%, respectively) can explain much of the EU's lower level of output growth.

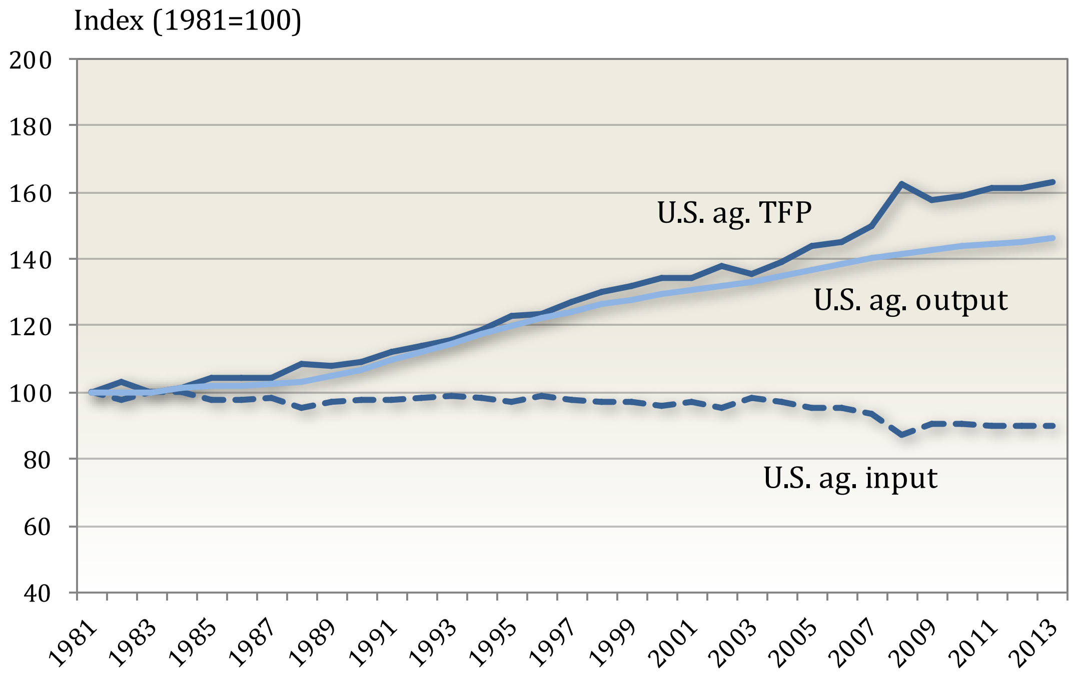
One likely contributor to differences in agricultural inputs is the level and type of regulation in the two jurisdictions. To the extent this is true, differences between regulatory regimes may be driving lower output growth in EU member states than in the U.S. This is discussed in the next section of this chapter.

Figure 8: EU-15 Agricultural TFP, Input and Output Growth, 1981-2013



Source: *Calculated from USDA-ERS IAP and FAOSTAT*

Figure 9: U.S. Agricultural TFP, Input and Output Growth, 1981-2013



Source: *Calculated from USDA-ERS IAP and FAOSTAT*

Approaches to measure the impact of regulation

The growing recognition that regulation can affect agricultural productivity and thus production has encouraged scholars to develop measures of regulatory activity that can be used in quantitative analysis. However, the complex nature of regulation makes it challenging to identify comprehensive measures and develop methods to estimate their impact. This section presents the results from a literature review conducted to understand the various measures of regulation identified by scholars and the methods used to calculate the impact of regulation on productivity and production. Its purpose is to provide an overview of measures and methods used to identify the impact of regulation on agriculture and highlight the findings on agriculture output and productivity.

The literature review specifically focused on regulations that affect agriculture production/or productivity in the U.S. and Europe. We understand that there is additional literature that measures impact of regulations on livestock, agriculture innovation, research and development, and marketing mechanism that also affect overall agriculture productivity.[35,36,37,38,39] While we acknowledge these are important areas of research, the focus of this review is limited to crop production.

Findings on Measures of Regulation

The literature on agriculture reveals a limited set of common global measures to capture the quantitative impact of government policies on agricultural productivity and/or production. These measures can be broadly categorized as: (i) subsidies and taxes, (ii) regulatory spending by government, (iii) regulatory compliance expenditures, (iv) regulatory content, and (v) binary indicators.

Subsidies or taxes can serve as an effective proxy to measure the effect of certain types of regulation. For example, Bridgman, Qi and Schmitz, Jr.[40] used the amount of U.S. subsidies

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[35] Alston, J., K. Bradford, and N. Kalaitzandonakes. 2006. The economics of horticultural biotechnology. *J. Crop Improvement* 18: 413-431.

[36] Gardner, Bruce. *American Agriculture in the Twentieth Century: How It Flourished and What It Cost.* Cambridge: Harvard University Press, 2002

[37] Kalaitzandonakes, N., J. Alston, and K. Bradford. 2007. Compliance costs for regulatory approval of new biotech crops. *Nature Biotechnology* 25:509-11.

[38] Ollinger, M., and J. Fernandez-Cornejo. 1998. "Sunk costs and regulation in the U.S. pesticide industry," *Int. J. Indust. Org*. 16: 139-168.

[39] Olmstead, A. L., and P. W. Rhode, *Arresting Contagion: Science, Policy, and Conflicts Over Animal Disease Control*, Cambridge: MA, Harvard University Press, 2015.

[40] Bridgman, Benjamin, Shi Qi, and James A. Schmitz, Jr. *Does Regulation Reduce Productivity? Evidence From Regulation of the U.S. Beet-Sugar Manufacturing Industry During the Sugar Acts, 1934-74*. Research Department Staff Report 389, Federal Reserve Bank of Minneapolis, 2007.

given to farmers and taxes levied on factory production of sugar to measure the effects of the Sugar Acts (1934–1974) on productivity. Bokusheva, Kumbhakar and Lehmann estimated the effects of environmental policy reforms implemented from 1991 to 2006 on Swiss farm productivity by using subsidies on farms' output as a proxy for the level of regulation.[41] Subsidy is the more commonly observed measure for evaluating the impact of the CAP in the EU since CAP uses the "cross-compliance method" (a combination of subsidies to reward desired behavior and taxes to discourage undesirable behavior) to implement agricultural standards and regulations.[42] However, the use of subsidies (or taxes) as a regulatory measure is limited to regulations that directly employ these tools (e.g., it does not capture the effects of a regulation restricting the use of a pesticide).

It is worth noting that the effects of regulatory cross-subsidies, such as the Renewable Fuel Standard (RFS)[43] in the U.S. or the role of carbon markets, do not appear in budgets. Different sectors often find themselves on the taxed side or the subsidized side of these regulatory cross-subsidies. Traditional metrics often miss these transfer effects.

Spending by government regulatory agencies is an additional measure used in evaluating the cumulative impact of different types of regulation in the U.S.. The on-budget costs and number of staff associated with administering regulatory agencies is available from 1960 to 2016.[44] However, there are drawbacks to using government regulatory spending as a proxy. It may not correlate well with actual regulatory impacts on productivity for several reasons, including that the forms of regulations that may be most burdensome (e.g., restrictions on use of certain products) may require relatively little regulatory spending to develop and enforce.

Compliance costs from survey data are often used to evaluate the impact of regulation on industries,[45] but these estimates can be inaccurate due to their reliance on respondents to report their costs. Another criticism is that compliance costs do not fully explain how regulation affects

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[41] Bokusheva, Raushan, Subal C. Kumbhakar, and Bernard Lehmann. "The Effect of Environmental Cross Compliance Regulations on Swiss Farm Productivity." The *84th Annual Conference of the Agricultural Economics Society*. Edinburgh, 2010.

[42] Costa, Catherine, Michelle Osborne, Xiao-guang Zhang, Pierre Boulanger, and Patrick Jomini. *Modelling the Effects of the EU Common Agricultural Policy*. Staff Working Paper, Melbourne: Productivity Commission, 2009.

[43] The RFS is a federal program in the U.S. that mandates transportation fuel sold in the U.S. to contain increasing percentages of renewable fuels. The program is administered by EPA.

[44] Dudley, Susan E., and Melinda Warren. 2016 Regulators' Budget: Increases Consistent with Growth in Fiscal Budget. May 19, 2015. https://regulatorystudies.columbian.gwu.edu/2016-regulators-budget-increases-consistent-growth-fiscal-budget (accessed May 20, 2016).

[45] Hurley, Sean P., and Jay Noel. "An Estimation of the Regulatory Cost on California Agricultural Producers." *American Agricultural Economics Association Annual Meeting*. Long Beach, 2006.

productivity because they don't capture the lost opportunity costs associated with disincentives for investment and innovation, for example.[46]

Analyzing the content of regulatory language is another proxy that scholars use to measure the effects of regulation.[47] Dawson and Seater used page counts from the CFR as a proxy to examine regulatory impacts on TFP and GDP in the U.S.[48] However, the word count measure also has limitations, as regulations that restrict output (such as the Environmental Protection Agency's ambient air quality standards) may not use the command words (shall, may not, etc.) counted in RegData. While RegData is valuable in that it provides word count data at the industry and agency level, as of now, it is only available for the U.S.; there is no comparable database for the EU.

Other studies measure regulation by constructing indices based on a weighted sum of binary indicators of whether or not given types of regulation exist.[49,50,51] This method is most commonly used in cross-nation comparisons. Many existing cross-nation indices are published and cited in the literature, including the Economic Freedom Index (The Fraser Institute), the Index of Economic Freedom (The Heritage Foundation), OECD cross-nation measures for employment and product-market regulations,[52] and the Doing Business Database (The World Bank Group).[53] However, these indices are often criticized because they capture the existence of a regulation but not their extent or complexity.[54] Another limitation is that almost all indices are built for business regulations such as product-market and employment regulations, so their application in the agricultural sector is limited. Finally, several of the indices are calculated using individual metrics that likely have little to no impact on long-term agricultural productivity, such as the time required for an entrepreneur to start a business (a measure contained in the Doing Business Database).

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[46] Crafts, Nichlas. "Regulation and Productivity Performance." *Oxford Review of Economic Policy* 22, no. 2 (2006): 186-202.

[47] This tool, Regdata, was created by Patrick McLaughlin and Omar Al-Ubaydli. It is available at: http://regdata.org/

[48] Dawson, John W., and John J. Seater. "Federal Regulation and Aggregate Economic Growth." *Journal of Economic Growth* 18, no. 2 (2013): 137-177.

[49] Djankov, Simeon, Rafael La Porta, Florencio Lopez-de-Silanes, and Andrei Shleifer. "The Regulation of Entry." *The Quarterly Journal of Economics* CXVII, no. 1 (2002).

[50] Djankov, Simeon, Caralee McLiesh, and Rita Ramalho. *Regulation and Growth*. Washington, DC: The World Bank, 2006.

[51] Loayza, Norman V., Ana María Oviedo, and Luis Servén. *The Impact of Regulation on Growth and Informality: Cross-Country Evidence*. Policy Research Working Paper, The World Bank, 2005.

[52] Crafts (2006)

[53] Loayza, Oviedo and Servén (2005)

[54] Dawson and Seater (2013)

Findings on Methods of Measuring the Impact of Regulation

Upon choosing a measure of regulation or relevant policy, the next question is how to measure the impact of regulation on agricultural productivity and/or production; more specifically, how to design an appropriate model to explain the relationship between regulation and output. The economic models developed in the literature can be broadly classified into four categories: (i) the traditional approach, (ii) two-step approach, (iii) facilitating approach, and (iv) the non-parametric approach.

The traditional approach treats regulation as one of the traditional inputs (e.g. land, labor and capital) in the production function to identify its direct influence on productivity. However, this approach has certain limitations, as policy is unlike traditional inputs in that it is not necessary for production of output, and it cannot produce any output.[55,56]

In contrast, the facilitating approach perceives regulation, measured using subsidies, as a "facilitating" input that affects the output indirectly by changing the productivity of traditional inputs, shifting the rate of technological change, and/or affecting technical efficiency.[57] Facilitating inputs are not considered essential for production. Bokusheva, Kumbhakar, and Lehmann[58] and Sipiläinen and Kumbhakar[59] used this approach to measure the impact of agricultural policy on farm productivity in European countries. However, the modeling design is often more complex and requires specific, farm-level data on subsidy payments.

The two-step approach is most commonly used in the literature. In this approach, productivity is first estimated or obtained from existing data sources and then regressed on factors expected to affect productivity, including regulation. For example, Arovuori and Yrjölä measured the impact of CAP reforms on agricultural labor productivity in the EU-15.[60] For this purpose, labor

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[55] Kumbhakar, Subal C., and Gudbrand Lien. "Chapter 6: Impact of Subsidies on Farm Productivity and Efficiency." In *The Economic Impact of Public Support to Agriculture*, edited by V. Eldon Ball, Roberto Fanfani and Luciano Gutierrez, 109-124. New York: Springer, 2010.

[56] Banga, Rashmi. *Impact of Green Box Subsidies on Agricultural Productivity, Production and International Trade*. Background Paper No. RVC-11, Geneva: Unit of Economic Cooperation and Integration among Developing Countries, UNCTAD, 2014.

[57] Kumbhakar and Lien (2010)

[58] Bokusheva, Raushan, Subal C. Kumbhakar, and Bernard Lehmann. "The Effect of Environmental Cross Compliance Regulations on Swiss Farm Productivity." *The 84th Annual Conference of the Agricultural Economics Society*. Edinburgh, 2010.

[59] Sipiläinen, Timo, and Subal C. Kumbhakar. *Effects of Direct Payments on Farm Perfomance: The Case of Dairy Farms in Northern EU Countries*. Discussion Papers No. 43, Helsinki: University of Helsinki, 2010.

[60] Arovuori, Kyösti, and Tapani Yrjölä. "The Impact of the CAP and its Reforms on the Productivity Growth in Agriculture." *The 147th EAAE Seminar 'CAP Impact on Economic Growth and Sustainability of Agriculture and Rural Areas'*. Sofia: European Association of Agricultural Economists, 2015.

productivity was first calculated as agricultural value added per worker.[61] Then labor productivity was regressed on policy variables that include the nominal rate of assistance, dummy variables indicating additional CAP reforms, as well as a vector of control variables that capture the economic and structural development. This approach has also been used in studies examining the effects of other types of regulation on productivity, both in the agricultural and non-agricultural sectors.[62,63,64] One limitation of this approach is that it does not account for the direct impact of regulation on agricultural output, since output and input are only used to estimate productivity but not included in the regression model. In addition, it does not measure the impact of regulation on disaggregated components of productivity (i.e. technical efficiency and technological change).

Finally, a non-parametric approach was used by Banga. Here, agricultural TFP growth was calculated for 26 countries for the period 1995-2007 using Malmquist indices, where total agricultural output and three inputs (land, labor and capital) were included.[65] The same method was then used with subsidies as an additional output along with the total agricultural output. The difference between the two TFP estimates yields the impact of subsidies on agricultural productivity.

Findings on the Impact of Regulation

Different methods and measures trying to capture the effects of regulation on agricultural performance lack a consensus regarding its effects. The regulatory frameworks for agriculture and the available data necessary to measure their outcomes vary between the U.S. and the EU. In the European Union, most agricultural regulations are embedded in the cross-compliance component of the CAP as opposed to the U.S. where agriculture requirements are set forth in several individual regulations administered by USDA, EPA, and state governments. Most studies examining U.S. regulations have focused on individual command-and-control measures (e.g. pesticide bans), while EU studies are mostly related to CAP, which combines regulatory

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[61] Agriculture Value Added Per Worker is a measure of agricultural productivity. Value added in agriculture measures the output of the agricultural sector less the value of intermediate inputs. (Social and Economic Development Department 2005).

[62] Zárate-Marco, Anabel, and Jaime Vallés-Giménez. "Environmental Tax and Productivity in a Decentralized Context: New Findings on the Porter Hypothesis." *European Journal of Law and Economics* 40, no. 2 (2015): 313-339.

[63] Mary, Sebastien. "Assessing the Impacts of Pillar 1 and 2 Subsidies on TFP in Frech Crop Farms." *Journal of Agricultural Economics* 64, no. 1 (2013): 133-144.

[64] Greenstone, Michael, John List, and Chad Syverson. *The Effects of Environmental Regulation on the Competitiveness of U.S. Manufacturing.* Working Paper No. 18392, Cambridge: National Bureau of Economic Research, 2012.

[65] Banga, Rashmi. *Impact of Green Box Subsidies on Agricultural Productivity, Production and International Trade.* Background Paper No. RVC-11, Geneva: Unit of Economic Cooperation and Integration among Developing Countries, UNCTAD, 2014.

requirements with incentive-based measures. In general, the literature suggests that studies estimating the effects of EU regulations tend to find a positive impact on agricultural productivity while U.S. studies tend to find a negative correlation between increased regulation and productivity.

Findings of U.S.-Focused Studies

The cumulative impact of U.S. regulations on agricultural productivity is difficult to measure because of multiple individual regulations administered by different agencies. Therefore, the findings are presented separately for individual regulations such as pesticides and cumulative agri-environmental regulations.

Studies that focus on individual regulations in the U.S. generally find they have a negative impact on agricultural productivity. Fernandez-Cornejo, Jans, and Smith presented a synthesis of empirical evidence for understanding the economic effects on agricultural productivity if pesticide use is restricted.[66] They observed that in 1996 farmers in the U.S. spent $8.3 billion on pesticides with a marginal pesticide return of more than $1 for every dollar spent on pesticides. The economic loss of regulating pesticide is measured for general bans and limitations on pesticide use in agricultural production. The impact of regulations is estimated using a partial budgeting method in which the economic value of production lost is calculated assuming constant output prices.[67] Their findings indicate that a partial ban on the use of certain pesticides would lead to a production loss of $2–3 million for agriculture sector, and could result in a loss of several billions in the event of a complete ban.

Similarly, Carpenter, Gianessi, and Lynch conducted a study to understand the potential economic impact of phasing out methyl bromide on crop production and farm revenue.[68] The result for each crop was different based on the input costs and alternative production possibilities but all results indicated negative effects on production and revenue.

Findings of EU-Focused Studies

Agricultural production, particularly crop production, is considered to be primarily affected by environmental and food safety legislation in the EU. This legislation mostly takes the form of a Directive or a Regulation,[69] such as the Nitrates Directive (91/676/EEC), the Directive on the sustainable use of pesticides (2009/128/EC), the General Food Law Regulation (178/2002), and

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[66] Fernandez-Cornejo, Jorge, Sharon Jans, and Mark Smith. "Issues in the Economics of Pesticide Use in Agriculture: A Review of the Empirical Evidence." *Review of Agricultural Economic* 20, no. 2 (1998): 462-488.

[67] *Ibid*

[68] Carpenter, Janet, Leonard Gianessi, and Lori Lynch. The Economic Impact of the Scheduled U.S. Phaseout of Methyl Bromide. Washington, DC: National Center for Food and Agricultural Policy, 2000.

[69] For details concerning EU legislation, see Chapters 3 and 4 of this report.

the Regulation on the hygiene of foodstuffs (852/2004). Due to recent CAP reforms, many of these directives and regulations are currently implemented through cross-compliance mechanisms. In addition to these existing legislative requirements, cross-compliance also requires Good Agricultural and Environmental Conditions (GAECs)—a range of standards related to soil protection, habitat protection, and water management—on farms receiving direct payments. Because of the linkage between CAP and environmental and food safety legislation, few studies have examined the impact of individual directives or regulations on agricultural production in the EU, but most studies have focused on the impact of CAP or cross-compliance as a whole. A review of these studies suggests mixed empirical findings.

Several studies found that CAP had an overall positive impact on EU agriculture. Rhode used the 2004 EU enlargement as a natural experiment in examining the overall effects of CAP on agricultural productivity.[70] The model was based on the assumption that CAP would affect agricultural productivity through increases in returns of scale, input availability, and increases in the efficiency of land use due to the fact that CAP affects the average farm size, fallow land area, organic farming area, and GDP growth. The findings suggest that joining the EU (i.e. subject to CAP) leads to an increase in agricultural productivity. Costa, et al. found that CAP increased the size of agricultural output by about 8% in the EU-15 due to support for the agricultural sector through its direct payments, export subsidies, and border protection.[71]

Since cross-compliance was introduced in the 2003 CAP farms are required to comply with additional requirements in order to receive direct payments and certain rural development payments. Several studies have examined the effects of this change on agricultural performance. Sipiläinen and Kumbhakar found that the average overall effect of direct payments on the output of Danish, Finnish and Swedish dairy farms for the period 1997-2003 was small but positive in all regions except for Central Sweden.[72] They found that adoption of environmental cross-compliance had a negative effect on crop output after 1999, but caused an increase in the productivity of input use in crop farms. LMC International evaluated the GAEC requirements applied under cross-compliance in the cereal sector, and found that GAECs were correlated with small changes in the production of cereals.[73]

A study conducted by CRPA (commissioned by DG Agriculture) estimated the costs that EU farmers bear due to compliance with a comprehensive set of 40 directives and regulations as well

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[70] Rhode, Flemming Schneider. *The Impact of the Common Agricultural Policy on Agricultural Productivity*. Honors Theses, Richmond: University of Richmond, 2008.

[71] Costa, et al. (2009)

[72] Sipiläinen, Timo, and Subal C. Kumbhakar. *Effects of Direct Payments on Farm Perfomance: The Case of Dairy Farms in Northern EU Countries*. Discussion Papers No. 43, Helsinki: University of Helsinki, 2010.

[73] LMC International. *Evaluation of Measures Applied Under the Common Agricultural Policy to the Cereals Sector*. Brussels: European Commission, 2012.

as GAECs in the field of the environment, animal welfare and food safety.[74] The result suggests varied compliance costs across different products and countries. Specifically, with regard to the crop sector, the study found that: (i) typical crop farms (e.g. wheat, apples, and wine grapes) faced significant compliance costs with environmental legislation but limited influence from food safety legislation; (ii) the compliance costs ranged from 1% to 3.5% of total production costs, with the greatest effect from the Nitrates Directive (91/676/EEC) and the regulation on plant protection products (1107/2009/EEC); (iii) GAECs only had a minor impact on costs; and (iv) compliance with legislation did not increase costs of wheat and apple production in the EU relative to non-EU countries, but the EU faced higher compliance costs in wine grape production which might affect its competitiveness, internationally.[75]

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[74] Menghi, Alberto, Kees de Roest, Andrea Porcelluzzi, and et al. *Assessing farmers' cost of compliance with EU legislation in the fields of environment, animal welfare and food safety*. Final Report, Brussels: European Union, 2011.

[75] *Ibid*.