A Comparison of U.S. and EU Agricultural Productivity With Implications for EU Enlargement

Susan E. Leetmaa, Carlos Arnade, and David Kelch

Farms in the United States and the European Union (EU) have increased agricultural output over the decades, mostly as a result of technical change, increased efficiency and scale of production, better skills in the management of farm operations, and the influence of government programs. An increase in agricultural output can stem from increased use of fixed inputs, such as land, and intermediate inputs such as chemicals, irrigation, and machinery, or from increases in productivity. Increasing productivity is critical for the economic viability of the farm sector given the links among productivity, per-unit costs of production and net returns, and competitiveness. This article compares and contrasts agricultural output growth and productivity growth of the EU and the United States and examines how two different geographic regions, with two different farm policy sets have coped with similar productivity pressures on their agricultural sectors. The implications for EU enlargement and agriculture policy reform of future productivity growth are also assessed.

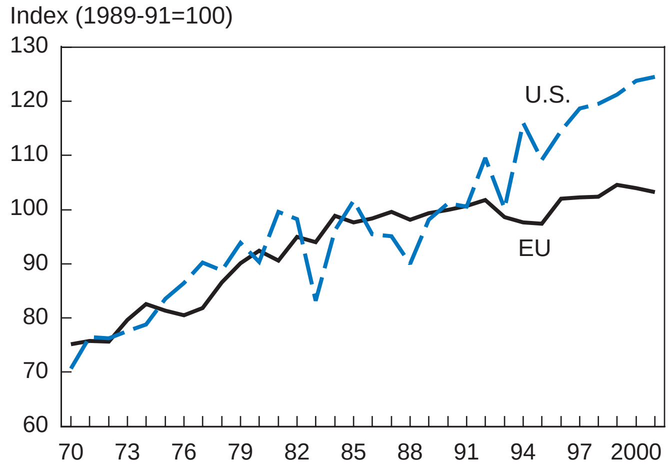
The EU and United States Are Large Agricultural Producers

In terms of production value, the EU and the United States are two of the larger agricultural producers in the world. Only China's agricultural production value is greater. In 2000, the value of crop and animal production in the EU-15 was 240 billion euros ($220 billion), which was about $25 billion larger than U.S. crop and livestock output valued at $195 billion. Six countries make up over 80 percent of EU-15 agricultural production value. France is the largest EU agricultural producer (23 percent of the value of EU-15 agricultural production), followed by Germany and Italy (both at about 15 percent), Spain (12 percent), United Kingdom (9 percent), and the Netherlands (7 percent). The remaining EU producers are all under 5 percent of the value of agriculture production.

A comparison of U.S. and EU-15 agricultural output growth over a 30-year period (fig. 1-D) indicates that the EU and the United States experienced similar agricultural output growth through the 1970s and 1980s. While the size of the agricultural sectors were similar in 2000 (as measured by value), growth in agricultural output over the 1990s was very different. Agricultural output in the EU stagnated, growing at about 0.3 percent per year, while that of the United States grew at over 2 percent per year.

An increase in agricultural output can stem from increased use of inputs or from increases in productivity (see box "Types and Sources of Change in Agricultural Output"). Productivity is the change in output that cannot be explained by changes in the level

Figure 1-D
U.S. and EU indices of agricultural production, 1970-2000



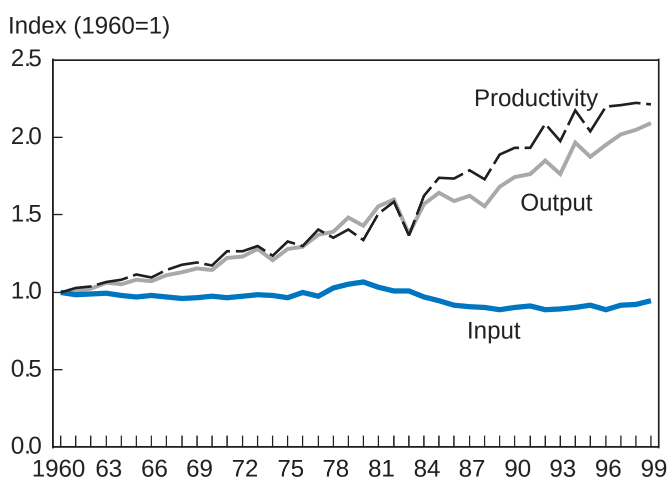
Source: FAOSTAT.

Types and sources of change in agricultural output

Changes in agricultural outputs =	Changes in agricultural inputs +	Agricultural productivity growth
Market-measured outputs:	Measured inputs:	(Change in output not accounted for by change in inputs)
Crops	<u>Intermediate</u>	Sources are:
	fertilizer pesticides energy feed and seed	
Livestock	livestock	Agricultural research and development
	<u>Labor</u>	Extension
		Education
	<u>Capital</u>	Infrastructure
	equipment real estate inventories	Government programs

of inputs used in production. Use of better farm management practices, new technology, or the more efficient use of the mix of inputs used in the production process are examples of factors that would increase growth in productivity. Sources of productivity growth in agriculture include agricultural research and development, education, infrastructure, and government programs. For example, a comparison of growth in agricultural output, input use, and productivity for the United States from 1960-1999 indicates that growth in agricultural output since the early 1980s has been heavily dependent on growth in productivity (fig. 2-D). U.S. agricultural inputs, in the aggregate, actually declined from 1980 to 1999.

Figure 2-D
Growth in U.S. agricultural productivity, output, and inputs, 1960-99



Source: Agricultural Resources and Environmental Indicators, 2000, Chapter 5, p. 6.

Measuring Agriculture Productivity

Total factor productivity (TFP) is a measure that accounts for the change in output that is not explained by changes in the level of inputs used in production. TFP measures the productivity of all factors of production combined. TFP growth can be viewed as a barometer of technology and efficiency and other factors that influence the long-term trend in output rather than the short run variations in production that can be attributed to changes in weather, input levels, and prices.

TFP growth is important because it plays a key role in increasing agricultural output over several planting seasons. Year-to-year changes in input and output prices, farm policies, and producer behavior can influence the level of inputs used annually in production. TFP growth, however, responds to prices or policies over the long run. For example, a sustained period of high prices may induce research into, and the adoption of, technologies that work to increase TFP. For any given set of input prices, a rise in TFP reflects a decrease in the per-unit cost of production. Productivity growth is, therefore, essential for the long-term economic viability of the farm sector.

Comparison of Agricultural Productivity and Growth in EU and U.S. Agriculture

Most comparative studies of TFP across countries tend to measure the growth rates of TFP, not relative levels of TFP. Data problems and dissimilarities often preclude a direct comparison of TFP levels between countries. However, Ball, et al. (2001), calculated TFP indices for nine EU countries and for the United States. By adjusting for country differences in input characteristics and quality, Ball's approach makes possible a common equivalent measure of land, capital, and other inputs between countries. This method makes it possible to directly compare the levels of productivity between countries, as well as productivity growth.

The Ball, et al. study reports relative TFP levels for the years 1973 to 1993 for the nine major EU countries and the United States. The 1973-1993 period for the Ball, et al. study is important because it allows a comparison of productivity among countries over a relatively stable policy environment. The study period is prior to the completion of the Uruguay Round of trade negotiations (1994), prior to implementation of CAP reforms in the EU (1993-95), and prior to passage of the 1996 U.S. Farm Bill (the FAIR Act). All productivity (TFP) levels (table 1) are reported relative to the TFP level for the United States for the 1990 base year set at 1.0.

According to the authors' estimates, seven of the nine EU countries had TFP levels close to or above that of the United States in 1973. The level of agricultural TFP in France, Germany, and Greece were close to that of the United States. Agricultural TFP levels for the same year for Belgium and the Netherlands were a third higher than the TFP level for the United States, while the UK and Denmark were somewhat above the level of the United States. Only Italy and Ireland's TFP levels were lower than the U.S. level for 1973. A weighted average of TFP levels among the nine EU countries, with the individual country's portion of the EU-9 value of agricultural output as the weight, indicates that the EU-9 level of TFP exceeded that of the United States until the mid-1980s (fig. 3-D). Beginning in 1985, the level of U.S. TFP exceeded that of the EU-9 and the gap widened in favor of the United States through the end of the study period in 1993.

TFP levels listed in table 1 can also be used to compare growth in TFP over the 1973 to 1993 period. U.S. agriculture productivity grew approximately 66 percent over the period, compared with the growth in the weighted average TFP for the EU-9 of 50 percent. Growth in TFP for the EU-9 and the United States were similar from 1973 through 1984 (fig. 4-D). From 1985 onwards, growth in TFP for the United States was consistently higher than that for the EU-9, resulting in the widening TFP gap depicted in figure 3-D.

For both the EU-9 and the United States, the rate of growth of agricultural output exceeded the rate of productivity growth in most years until the early 1980s (figs. 5-D and 6-D). In both cases it was the increase in intermediate inputs such as fertilizers, pesticides, energy, and seeds that allowed growth in agricultural output to exceed growth in productivity. After the early- to mid-1980s, productivity growth exceeded that of agricultural output, as growth in the use of intermediate inputs tapered off or declined. By the early 1990s, both the EU and the United States were almost totally dependent on growth in productivity for increasing agricultural output.

TFP Growth, Technical Change, and Efficiency

Another study by Leetmaa, et al., estimates growth rates (table 2-D) for TFP indices for the 15 member states of the EU for the period 1973-1997, although the methodology, data, and variable measurement are not comparable with the Ball, et al. study. While the two studies are not comparable, in part because the Ball study employs data of higher quality and has received more rigorous peer review, the Leetmaa, et al. study covers the period of time that could capture the initial impacts of the 1992 CAP reforms that were implemented from 1993-1995. The contribution this study makes to the understanding of productivity is that it breaks down the TFP growth indices into their component parts, efficiency (Appendix table 1), and technical change (Appendix table 2). While the United States is not included in the study, the results for the EU countries are useful in identifying the principal source of productivity growth for the EU-15 countries.

Table 1-D—Comparisons of relative levels of TFP in the EU and U.S., 1973 to 1993 1/

	Germany	France	Italy	Netherlands	Belgium	UK	Ireland	Denmark	Greece	EU	U.S.
1973	0.624	0.644	0.516	0.980	1.080	0.702	0.483	0.750	0.660	0.664	0.636
1974	0.646	0.637	0.527	1.020	1.080	0.705	0.500	0.839	0.680	0.677	0.590
1975	0.644	0.624	0.553	1.000	1.042	0.667	0.500	0.719	0.740	0.668	0.645
1976	0.629	0.609	0.536	1.020	1.000	0.655	0.500	0.727	0.706	0.656	0.635
1977	0.669	0.639	0.539	1.058	1.042	0.702	0.552	0.788	0.686	0.684	0.692
1978	0.689	0.677	0.547	1.093	1.083	0.730	0.533	0.794	0.745	0.711	0.667
1979	0.681	0.721	0.576	1.109	1.125	0.724	0.516	0.800	0.725	0.728	0.704
1980	0.696	0.722	0.609	1.105	1.125	0.763	0.533	0.824	0.804	0.747	0.665
1981	0.698	0.723	0.615	1.179	1.125	0.768	0.533	0.879	0.804	0.760	0.753
1982	0.763	0.796	0.619	1.214	1.167	0.791	0.567	0.909	0.824	0.802	0.776
1983	0.750	0.783	0.652	1.186	1.125	0.776	0.600	0.879	0.769	0.793	0.673
1984	0.783	0.828	0.637	1.263	1.208	0.851	0.633	1.000	0.788	0.835	0.797
1985	0.763	0.872	0.653	1.237	1.208	0.825	0.633	1.031	0.827	0.845	0.862
1986	0.802	0.890	0.668	1.305	1.240	0.826	0.613	1.065	0.827	0.869	0.877
1987	0.780	0.921	0.699	1.210	1.200	0.825	0.633	1.000	0.824	0.866	0.916
1988	0.813	0.928	0.699	1.242	1.240	0.823	0.633	1.100	0.863	0.886	0.901
1989	0.828	0.964	0.726	1.317	1.231	0.855	0.613	1.133	0.902	0.918	0.984
1990	0.838	0.996	0.711	1.367	1.231	0.880	0.677	1.167	0.784	0.933	1.000
1991	0.854	0.992	0.756	1.361	1.308	0.896	0.677	1.133	0.918	0.951	1.005
1992	0.890	1.073	0.790	1.371	1.346	0.933	0.710	1.100	0.918	0.992	1.073
1993	0.893	1.058	0.815	1.393	1.385	0.894	0.710	1.200	0.900	0.997	1.001
Compound growth (%)										50.6	66
Compound annual growth rate (%)										2.41	3.14

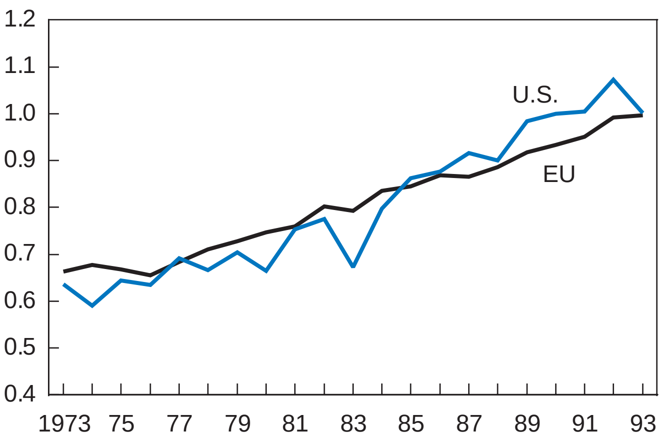
[1]Calculated TFP levels are relative to U.S. TFP in 1990. For example, the TFP level in France for 1973 was equivalent to 0.644 of U.S. TFP in 1990 (set to 1.0). Likewise, U.S. TFP in 1973 was 0.664 of the U.S. TFP level in 1990.

Source: Calculated from Ball, et al., (2001).

Figure 3-D

Relative agriculture TFP levels, U.S. and EU, 1973-1993

EU and U.S. TFP levels, relative to the U.S. in 1990

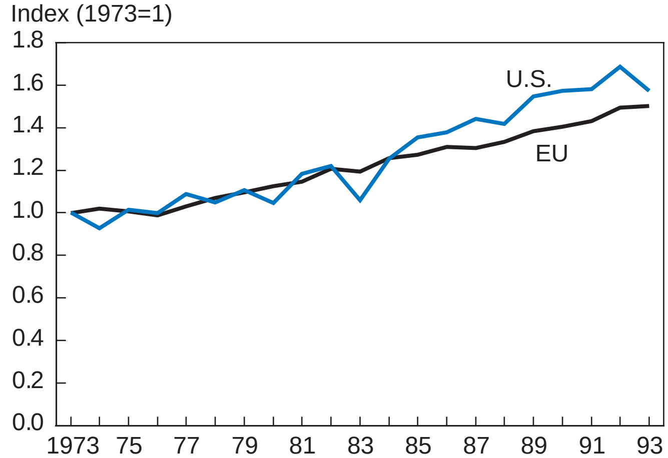


Source: Calculated from Ball, et al., 2001.

Figure 4-D

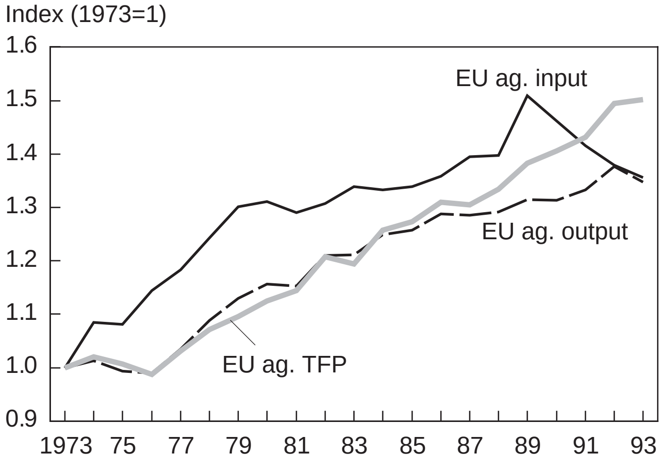
Growth of agriculture TFP for U.S. and EU, 1973-1993

Index (1973=1)



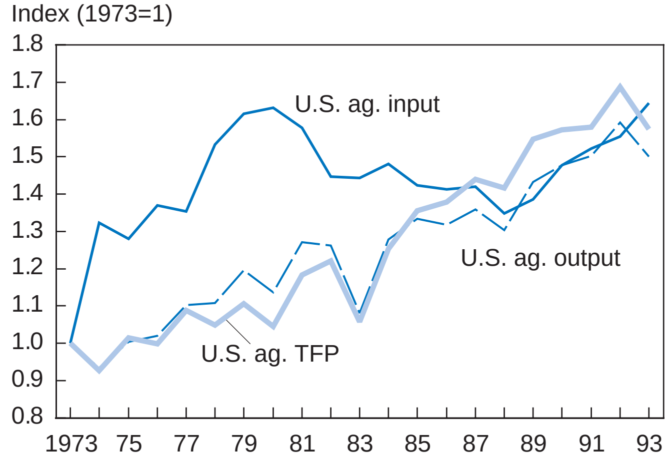
Source: Calculated from Ball, et al., 2001.

Figure 5-D
EU agriculture output, intermediate inputs, and TFP, 1973-93



Source: Calculated from Ball, et al., 2001.

Figure 6-D
U.S. agricultural output, intermediate inputs, and TFP, 1973-93



Source: Calculated from Ball, et al., 2001.

Table 2-D—Indices of total factor productivity growth, EU-15, 1973-1997

	Austria	Belgium	Denmark	Germany	France	Finland	Greece	Ireland	Italy	Netherlands	Portugal	Spain	Sweden	UK
1973	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1974	1.03	1.07	1.09	1.02	1.00	1.02	0.89	1.15	1.07	1.00	1.00	1.09	1.04	1.01
1975	1.24	1.04	1.05	1.13	1.01	1.02	0.90	1.18	1.10	1.00	0.95	1.38	1.08	1.02
1976	1.25	1.08	1.03	1.06	1.04	1.02	0.88	0.92	1.04	1.03	0.99	1.74	1.11	1.01
1977	1.22	1.14	1.02	1.06	1.10	1.04	0.70	0.82	1.02	1.10	1.02	1.97	1.16	1.04
1978	1.23	1.23	1.09	1.14	1.20	1.05	0.75	0.67	0.92	1.21	1.03	2.22	1.21	1.09
1979	1.26	1.25	1.16	1.20	1.34	0.91	0.69	0.59	0.91	1.18	1.06	2.28	1.25	1.12
1980	1.23	1.31	1.23	1.25	1.35	1.22	0.75	0.56	0.97	1.13	0.92	2.54	1.30	1.18
1981	1.14	1.36	1.32	1.25	1.37	1.17	0.76	0.56	1.01	1.19	0.91	2.96	1.33	1.20
1982	1.36	1.45	1.47	1.39	1.56	1.32	0.75	0.62	1.03	1.25	0.93	3.76	1.48	1.30
1983	1.34	1.46	1.48	1.43	1.59	1.28	0.67	0.62	1.03	1.29	0.87	3.88	1.50	1.31
1984	1.30	1.52	1.65	1.52	1.70	1.24	0.61	0.68	1.04	1.32	0.90	4.94	1.60	1.43
1985	1.27	1.59	1.71	1.48	1.77	1.23	0.58	0.68	1.05	1.31	0.91	4.97	1.57	1.39
1986	1.37	1.68	1.78	1.57	1.85	1.17	0.59	0.72	1.08	1.36	1.22	4.93	1.66	1.43
1987	1.46	1.71	1.80	1.57	1.96	1.03	0.58	0.73	1.08	1.24	1.17	5.04	1.77	1.46
1988	1.45	1.78	1.94	1.62	1.97	1.08	0.60	0.71	1.04	1.25	1.05	4.96	1.54	1.46
1989	1.52	1.93	2.07	1.74	2.17	1.14	0.56	0.67	1.18	1.34	1.21	5.34	1.78	1.54
1990	1.57	2.01	2.22	1.59	2.30	1.23	0.48	0.71	1.17	1.43	0.96	5.11	1.91	1.59
1991	1.64	2.10	2.28	1.61	2.32	1.24	0.52	0.73	1.20	1.49	1.27	5.45	2.07	1.63
1992	1.68	2.30	2.29	2.00	2.56	1.27	0.49	0.67	1.23	1.53	1.45	5.27	1.90	1.69
1993	1.81	2.43	2.54	2.09	2.57	1.46	0.53	0.70	1.23	1.59	1.34	5.68	2.02	1.64
1994	1.87	2.45	2.56	2.13	2.66	1.62	0.59	0.71	1.24	1.63	1.40	5.81	1.84	1.70
1995	1.89	2.54	2.65	2.20	2.75	1.61	0.59	0.72	1.25	1.66	1.44	5.72	2.00	1.70
1996	1.82	2.56	2.67	2.33	2.93	1.73	0.56	0.71	1.28	1.66	1.52	6.59	2.06	1.72
1997	1.96	2.62	2.81	2.52	3.08	1.92	0.60	0.69	1.26	1.61	1.60	6.92	2.17	1.76

[1]Normalized to be one in the base year, 1973.
The numbers represent cumulative productivity change from the base year.
Source: Leetmaa, et al., (2000).

Efficiency refers to the use of existing inputs. Improvements in efficiency of input use can be a principal source of TFP growth. If production is based on an efficient allocation/mix of inputs, any reduction in input use would be expected to result in a reduction in output. In contrast, if production is based on an inefficient allocation/mix of inputs, producers could reduce inputs and maintain the same level of production, or even increase production by more efficient use of their inputs. Technical change embraces many potential sources of productivity growth, including such things as improved seeds, better management techniques, new crop rotation sequences, etc., all of which can reduce per-unit production costs.

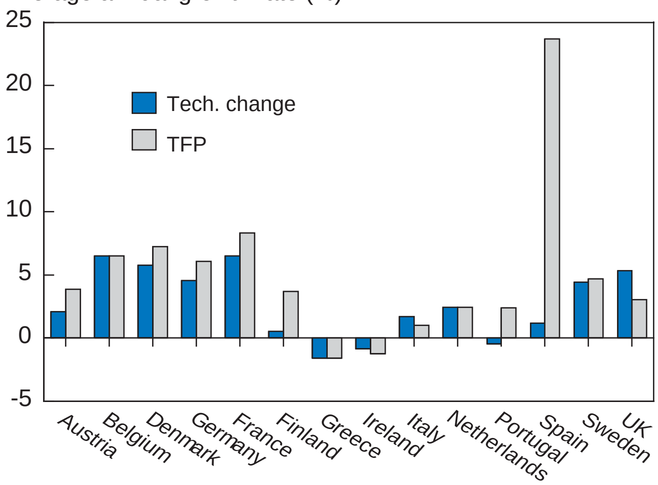
In table 2-D, the growth rates calculated from the TFP indices represent the growth rates of productivity from the 1973 base period through 1997 and are normalized at 1.0 for each country in the base period. Subtracting 1 from the index in any year represents the cumulative productivity growth from the base period. For example, table 2-D shows that the productivity of Portuguese agriculture had grown 60 percent from 1973 to 1997. In interpreting cross-country productivity indices, it is important to emphasize that each country's productivity growth begins from a different 1973 base TFP level, normalized to 1.0. Thus, the numbers in table 2-D and Appendix tables 1 and 2 do not represent differences in the productivity levels between countries, only differences in the growth of TFP.

What stands out in table 2-D is Spain's rapid productivity growth. Part of this may be attributed to Spain's initial low level of productivity. In another study, Ball, et al. (2001), found evidence of the "catch-up" hypothesis in their earlier study of EU productivity. The hypothesis states that those countries that lagged furthest behind in productivity levels should have the most to gain from the diffusion of technical knowledge, and, therefore, exhibit the most rapid rates of productivity growth. Portugal also exhibited significant growth in productivity following its accession to the EU in 1986.

The information in figure 7, developed from Leetmaa et al., compares the average annual growth in productivity (TFP) with the average annual growth in the technical change component over the 25-year period. For example, Denmark's agricultural sector experienced an average annual rate of growth in TFP of 7.2 percent over the 1973-1997 period. Much of that growth in TFP is explained by the growth in the technical change component of TFP, which grew, on average, by 5.8 percent per year. The difference between the technical change bar and the TFP bar roughly reflects the contribution of increased efficiency to TFP growth.

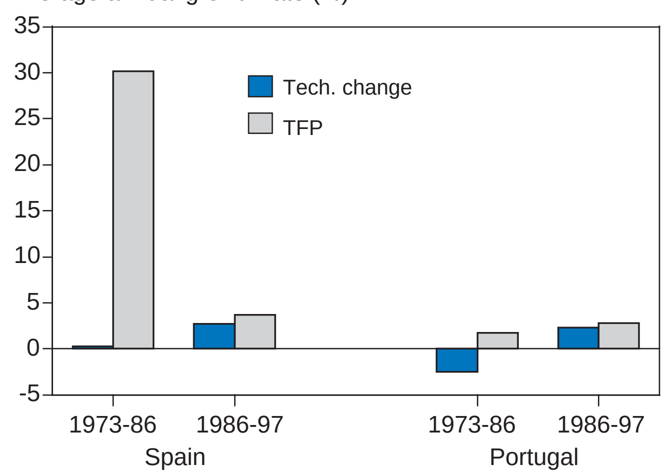
Most of Spain and Portugal's initial productivity gains came from improvement in efficiency rather than from technical change. However, splitting the entire period into pre-accession (1973-86) and post-accession (1986-97) periods show that there was virtually no growth in the technical change component of TFP in Spain over the period leading up to EU accession, and a decline in technical change in Portugal (fig. 8-D). Spain and

Figure 7-D
Contribution of technology growth to TFP growth, 1973-1997



Source: Calculated from Leetmaa, et al., 2000.

Figure 8-D
Contribution of technology growth to TFP growth, Spain and Portugal, pre- and post-EU accession



Source: Calculated from Leetmaa, et al., 2000.

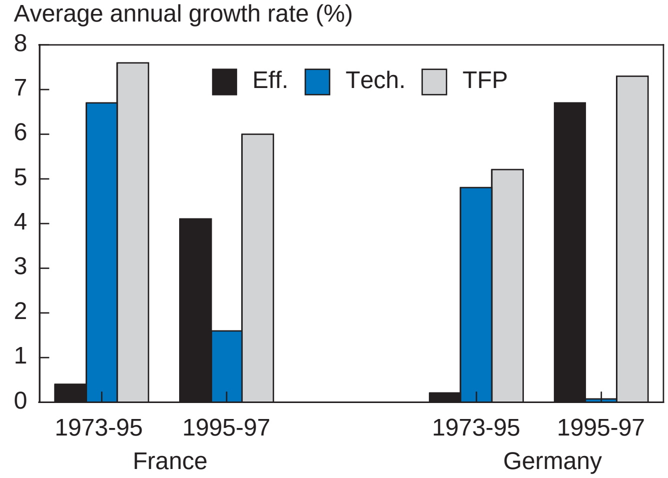
Portugal entered the EU in 1986, but their agricultural sectors underwent a significant period of reform and structural change leading up to accession, an indication of the potential importance of enlargement-driven policy reform and structural change (increase in farm size) to increasing the efficiency of production. Following accession to the EU however, technological change became the driver of productivity growth in both Portugal and Spain (fig. 8-D and Appendix table 2).

Greece presents an interesting contrast to Spain. Over time, Greece's productivity falls and the negative growth in productivity stems from a reduction in the growth of technical change rather than from falling efficiency (fig. 7-D). The falling technology index does not represent a reduction in technology use in Greece. Rather, it represents a movement to use of a less productive technology by the average producer. This may occur if there is a change in the mix of crops which are grown, a change in the mix of producers, or a change in average farm size. All three changes occurred in Greece leading up to, and following, its accession to the EU in 1981 and full adoption of CAP policies, which occurred much more quickly than other accessions. Similar arguments might explain Ireland's productivity decline after it joined the EU in 1973.

Belgium, Denmark, France, and Germany have the next highest rates of TFP growth in the EU after Spain. France and Germany are countries that have relatively large agricultural sectors in the EU, thus the high rate of TFP growth in these countries is a significant factor in overall productivity growth in EU agriculture. In contrast to Spain, all four countries' productivity growth mainly results from technical change rather than from growth in efficiency (fig. 7-D). This productivity growth probably reflects their long-term adjustment to the CAP relative to Spain that was not fully integrated into the CAP and its high prices until 1995.

While there are not enough data points to reach any definitive conclusion, it appears that the contribution of technical change to productivity growth has slowed since the MacSharry CAP reforms were fully implemented by 1995 (fig. 9-D). Estimates for France and Germany indicate an increase in the contribution of efficiency gains to overall productivity growth from 1995 to 1997. There was little growth in efficiency-based productivity gains in Germany and France relative to technical change from 1973 to 1995 (Appendix tables 1 and 2). From 1995 to 1997, Germany experienced a 14-percent gain in efficiency-based productivity gain, while France showed an 8-percent gain. By the end of the MacSharry reforms, EU grain prices had been lowered by 35 percent, motivating a more efficient use of resources.

Figure 9-D
Productivity growth



Source: Calculated from Leetmaa, et al., 2000.

The UK had a rate of growth of technical change as high as those of Germany and France, but its efficiency declined, perhaps the result of high CAP prices it adopted upon joining the EU in 1973. The high prices encouraged a change in crop mix (more wheat) and more intensive use of inputs on farms that were much larger than the EU average, thus precluding efficiency gains.

Italy was the country with the lowest positive TFP growth. Italy began to experience significant technology growth in the 1990s but its efficiency declined. In general, it is not uncommon to see a short-run decline in efficiency during the initial periods of technology growth[1] because there are adjustment costs required to adopt new technology, particularly when farm structure remains the same.

For the EU, technical change has been the major source of TFP growth relative to efficiency. The newer Mediterranean members appear to be an exception, deriving much of their productivity gains over the 25-year period from increasing efficiency. However, as pointed out above, following accession, Spain and

[1] It has been found that there are adjustment costs associated with adopting a new technology (Vasavada and Chambers).

Portugal derived most of their productivity gains from technical change.

Technical change is the main contributor to strong productivity growth in U.S. agriculture. Arnade (1998) has shown that U.S. growth in efficiency in recent decades has been small, implying that technical growth drives productivity gains in the United States. This is because the more competitive climate in the United States relative to the EU over the past few decades had already forced U.S. farms to seek out efficiency gains. Results from the same study show that the United States had a more efficient agriculture than major EU countries from 1960 to 1993.

Government Programs, Technology, And Agricultural Productivity Growth

Relatively few studies have investigated the impact of government policy on agricultural productivity, but some (Huffman and Evenson, 1993; Makki and Tweeten, 1999) find a significant and positive relationship. For example, high farm prices may encourage substitution of improved capital inputs for labor and increase the rate of new technology adoption. However, another study found a "conflicting and weak relationship between farm productivity and public commodity programs," in the United States (Makki, Tweeten, and Thraen, 1999).

Ball, et al. (2001), in their exhaustive study of productivity, found technological innovation to be embodied in EU capital and intermediate inputs, and also found a positive interaction between capital accumulation and productivity growth. The relationship between capital accumulation and productivity growth was strongest during the 1973 to 1981 period. Ball (2001) also notes that net investment in fixed capital was negative in most EU countries during the period 1982 to 1993, perhaps a contributing factor to the widening productivity gap between the United States and the EU although U.S. net investment was also negative for this period. A study by Frisvold and Lomax (1991) found a very significant and highly positive relationship between investment in research and development and farm productivity growth in U.S. agriculture.

Implications of TFP growth for EU Enlargement and Further CAP Reform

The EU is in the process of negotiating membership with 10 Central and Eastern European (CEE) countries,[2] Cyprus, and Malta.[3] The EU has undergone a number of previous enlargements since 1951, when it was established by the six charter members--Belgium, Germany, France, Italy, Luxembourg, and the Netherlands. Leetmaa, et al.'s productivity measures are estimated from 1973 to 1997, over which period the EU experienced four phases of enlargement: The UK, Ireland, and Denmark in 1973, Greece in 1981, Spain and Portugal in 1986, and Austria, Finland, and Sweden in 1995.

According to Leetmaa et al., and their decomposition of productivity, the majority of countries experienced an increase in their technology-based productivity growth after joining the EU. Only Ireland and Greece experienced declines in technology-based productivity growth following accession. Germany experienced a slight decline in efficiency-based productivity just after re-unification with East Germany (an enlargement of a kind unique to the EU), but German efficiency-based productivity growth has increased from 1992 through 1997.

The impact of expected EU accession on productivity growth during the immediate years leading up to actual membership is mixed. In those countries where more significant policy and structural adjustments were required for preparing for EU accession, significant increases in efficiency-based productivity growth were evident in the years prior to, or immediately after, actual membership, for example in Spain, Portugal, and Finland.[4] Even Ireland and Denmark showed some efficiency gains in the immediate years following accession in 1973. It is likely that in the long run, EU enlargement will result in increased productivity in the CEE. As the CEE countries make the policy and institutional adjustments necessary for accession to the EU, some efficiency-based gains in productivity are to be expected, particularly knowing that many of the agricultural sectors in these CEE countries are operating at low levels of efficiency

[2]The first set of countries expected to join are the Czech Republic, Estonia, Hungary, Poland, and Slovenia. Bulgaria, Latvia, Lithuania, Romania, and Slovakia may join at the same time or at a later date, depending on their ability to meet EU production standards and membership criteria.

[3]For a complete discussion on EU enlargement see the article by Cochrane in this report.

[4]Though efficiency measures increased for Austria, Finland, and Sweden, a 3-year sample may not be sufficient to determine whether the increase will be sustained.

compared with current EU members. These countries are also operating at a much lower technological level. Along the lines of the "catch-up" hypothesis discussed earlier, the new CEE members could experience the fastest technology-based productivity growth in an enlarged EU.

It also appears that an evolution of EU reform will continue to move EU policy towards more market-oriented policies and away from support prices, but with additional direct payments. Based on the Leetmaa, et al. analysis, it appears that most EU countries continued to experience technology-based productivity growth following the MacSharry reforms, but at a slower rate than before reforms. However, it is difficult to hypothesize how EU CAP reform, a shift from reliance on support prices to direct payments to stabilize farm income, will influence long-run total factor productivity growth.

In the example discussed earlier for France and Germany (fig. 9-D), the slowing of technology-based productivity gains were more than offset by efficiency-based gains over the 1995 to 1997 period. But, as with the enlargement-related cases, the efficiency-based productivity gains related to policy reform could be short-lived. Movements over a 2-year period (1995-1997) for only two EU producers (France and Germany), albeit major EU producers, does not allow any significant conclusions to be drawn. However, if a hypothesized linkage of CAP reform and slower technology-based productivity growth proves to hold, France and Germany may experience a slower growth in overall TFP over the longer term. If EU policies do continue to become more market oriented, slower rates of technology-based productivity growth, without sustained offsetting gains from efficiency-based productivity growth, could allow the current EU-15's TFP to continue to increase, but at a slower rate.

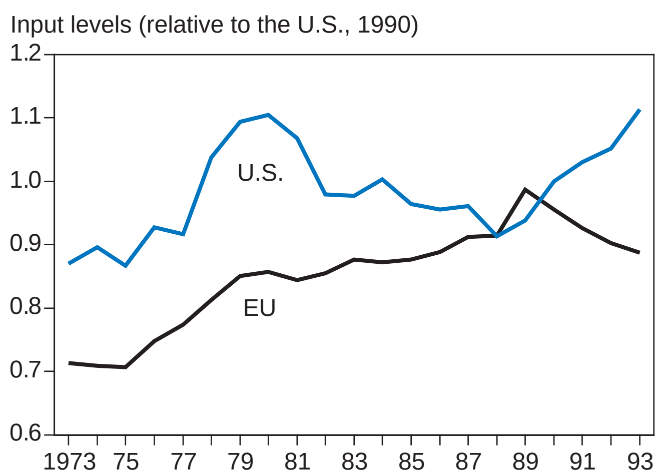
EU and U.S. Trends in Input Use

It is also important to consider trends in input use when analyzing efficiency and technical change. Major inputs to take into account are land, labor, capital, and intermediate inputs, such as fertilizer, pesticides, energy, feed and seed. With the exception of capital and intermediate inputs, long-term trends for the other input categories such as land and labor are downward sloping. The study by Ball, et al. (2001) is useful in gauging trends in the use of intermediate inputs in the United States and the EU over the 1973-93 period (fig. 10-D).

Both the EU and the United States exhibited upward trends in intermediate input use over the 21-year period. The United States had levels of intermediate input use that were higher than those of the EU-9 in all but 2 years over the 1973-1993 period. These general trends with respect to input use in the EU and the United States mask some significant differences in the movements of specific inputs (fertilizer versus feed, for example), and in year-to-year variation in the economic and program factors driving levels of input use. The principal factors affecting intermediate input use are the level and mix of planted cropland, the level and mix of livestock production, input prices, commodity prices, and farm programs (Denbaly and Vroomen, 1993).

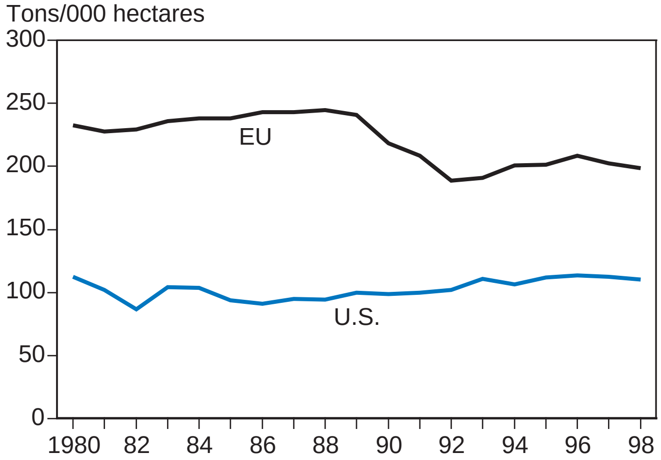
Fertilizers—Fertilizer usage is one of the intermediate inputs that tends to be responsive to many of the factors listed above. During the three seasons (1998/99-2000/01), the EU averaged almost 17 million tons of commercial fertilizer per year, a drop from peak use in 1988/89 of over 22 million tons. Average nutrient use from commercial fertilizers for the United States in the late 1990s was about 22 million tons. While the United States uses approximately 5 million tons more fertilizer than the EU, the United States has nearly three times as much agricultural production. Thus, fertilizer application rates are much lower than in the EU. EU application rates are about twice the levels in the United States (fig. 11-D).

Figure 10-D
Relative levels of intermediate input use, U.S. and EU



Source: Ball, et al., 2001.

Figure 11-D
U.S. and EU fertilizer use



Source: FAOSTAT.

In the EU, about half of all fertilizer is applied to wheat and coarse grains, nearly a quarter to grassland, and the remaining quarter to oilseeds, sugarbeets, and fruit and vegetables. In the United States, corn, wheat, and other grains account for almost 60 percent of all commercial fertilizer use. Differences in crop mix between the United States and the EU does not appear to explain the much greater fertilizer application rates in the EU. In fact, the EU has a much greater portion of its cropland in “permanent” crops, such as fruits, nuts, and olives, which use less fertilizer than grains, such as corn and wheat (table 3-D).

The ratio of the price of fertilizer to the internal price of commodity outputs perhaps does most to explain the very intensive fertilizer usage in the EU. At the peak of commercial fertilizer use in the EU (1987-1989), the average price for the most common compound fertilizer (N-P-K: 20-10-10) in the Netherlands was roughly $212 per metric ton. The average EU wheat intervention price over the 3-year period was $202 per metric ton, yielding a fertilizer-to-grain price ratio of 1.05, i.e., a ton of fertilizer cost roughly 5 percent more than a ton of wheat. In the United States over the same 1987-89 period, the average price of a common fertilizer, ammonium nitrate, was $188 per metric ton. The average farm price for wheat was $123 per metric ton, yielding a fertilizer-to-grain price ratio of 1.53 compared with the EU ratio of 1.05. The much higher EU price for wheat accounted for most of the substantial difference between the United States and the EU fertilizer/grain price ratios and encouraged a more intensive use of fertilizer by the EU. By 1998, well past the phase-in of the MacSharry reforms, the intervention price for wheat was reduced to $134 per metric ton, and the EU fertilizer/grain price ratio had increased to 1.7 making the intensive use of fertilizer less economic.

Farm programs in the United States can also influence the intensity of fertilizer use, although not nearly to the extent of the EU’s high support prices prior to the MacSharry reforms begun in 1993. For example, research by Ribaudo and Shoemaker (1995) indicates that economic incentives from participation in commodity programs caused program participants to apply fertilizer at greater rates than non-participants. Additionally, under the U.S. Federal Agriculture Improvement and Reform (FAIR) Act of 1996, declining prices for both corn and soybeans resulted in farmers’ planting decisions being partly based on the respective loan rates and expected loan deficiency payments for corn and soybeans. One analysis indicated that an additional 1.7 million acres of soybeans was expected to be planted in 1999 because of the higher loan rates for soybeans, relative to corn (Lin, 1999). Since soybeans are a less fertilizer-intensive crop than corn, aggregate and per-acre fertilizer use was likely less than expected due to a policy-related shift in the crop mix.

It is difficult to fully explain the causal factors behind the EU’s abrupt decline in commercial fertilizer usage levels over the 1989-92 period. One complication is that in the EU, commercial fertilizers are responsible for only about half of all nutrients applied to EU cropland, the other 50 percent coming from animal and industrial wastes. In the United States, commercial fertilizers make up over 80 percent of total nutrient applications. Crop prices in the United States generally don’t make transport and handling of animal and industrial wastes over distances an economically viable option.

According to the European Fertilizer Manufacturers Association (EFMA), environmental considerations as well as farm management improvements are constantly triggering a more targeted use of nutrients on EU farms. At EU, national, and regional levels, environmental policy and programs do affect fertilizer usage, such as the EU Nitrate Directive (1992), which calls for EU producers to improve their environmental performance by using nutrient accounting and by applying codes of good agricultural practices. According to the EFMA, environmental policy and

Table 3-D—Agricultural land use in the EU and the United States, 1971-2000

Year	European Union				United States			
	Permanent Crops	Pasture	Arable	Total AgArea	Permanent Crops	Pasture	Arable	Total AgArea
	1,000 hectares							
1971	11,634	64,718	80,415	156,767	1,760	243,400	188,140	433,300
1972	11,665	64,434	80,173	156,272	1,755	243,000	187,545	432,300
1973	11,784	64,225	79,630	155,639	1,750	242,400	187,050	431,200
1974	11,867	63,738	79,653	155,258	1,746	241,940	186,472	430,158
1975	11,965	63,590	79,343	154,898	1,746	241,940	186,472	430,158
1976	11,971	62,973	79,050	153,994	1,746	241,940	186,472	430,158
1977	11,930	62,777	79,075	153,782	1,741	242,038	186,552	430,331
1978	11,956	62,523	79,319	153,798	1,869	237,539	188,755	428,163
1979	11,894	62,352	79,106	153,352	1,869	237,539	188,755	428,163
1980	11,774	62,039	78,971	152,784	1,869	237,539	188,755	428,163
1981	11,748	61,779	78,946	152,473	1,869	237,539	188,755	428,163
1982	11,729	61,535	78,950	152,214	2,034	241,600	187,765	431,399
1983	11,878	60,704	78,426	151,008	2,034	241,600	187,765	431,399
1984	11,797	60,248	78,658	150,703	2,034	241,600	187,765	431,399
1985	11,709	59,981	78,636	150,326	2,034	241,600	187,765	431,399
1986	11,642	59,689	78,637	149,968	2,034	241,600	187,765	431,399
1987	11,574	59,408	78,660	149,642	2,034	239,172	185,742	426,948
1988	11,538	59,486	78,229	149,253	2,034	239,172	185,742	426,948
1989	11,482	59,447	78,148	149,077	2,034	239,172	185,742	426,948
1990	11,486	59,082	77,970	148,538	2,034	239,172	185,742	426,948
1991	11,273	56,680	77,241	145,194	2,034	239,172	185,742	426,948
1992	11,098	56,582	76,842	144,522	2,050	239,249	184,130	425,429
1993	10,971	56,467	76,329	143,767	2,050	239,250	181,950	423,250
1994	10,949	56,901	75,755	143,605	2,050	239,250	178,950	420,250
1995	10,796	56,932	74,725	142,453	2,050	239,250	176,950	418,250
1996	10,789	56,702	75,230	142,721	2,050	239,250	176,950	418,250
1997	10,888	56,310	75,164	142,362	2,217	228,660	174,500	405,377
1998	11,035	56,592	74,698	142,325	2,217	228,660	174,500	405,377
1999	11,110	56,678	74,296	142,084	2,217	228,660	174,500	405,377
2000	11,122	56,006	73,499	140,627	2,217	228,660	174,500	405,377

Note—U.S. data from 1997 adjusted to reflect 1997 U.S. Agricultural Census.

Source: FAOSTAT Agriculture Data.

farm management improvements may have contributed most to the early 1990's decline in fertilizer use.

Another complication in the EU over this period of the early 1990s was the use by the EU Commission of an array of non-price instruments to influence market conditions. The Commission tightened standards for grain coming into intervention, accepted less tenders for export subsidies, and paid less than the listed intervention price. The effective price of grains was lowered in the EU and the amount of grains eligible for intervention was lowered, leading to some disincentives for continued intensive use of fertilizer. In addition, oilseeds had replaced some grains, thus lowering overall fertilizer use since oilseeds require less fertilizer per acre than grains.

EU application rates of fertilizer were expected to decline after the MacSharry reforms lowered grain prices. However, fertilizer use increased slightly from 1993 to 1996, in part because of a crop mix that favored grains that need more fertilizer over oilseeds. However, fertilizer application rates tapered off marginally in 1997 and 1998. Agenda 2000 brought additional reductions in price supports in the EU. The EFMA, in its latest forecast of fertilizer use, expects nitrogen, phosphorus, and potassium use in the EU to decline by 6 percent, 14 percent, and 12 percent, respectively, over the next 10 years. Among the economic factors underlying the forecasted decline in fertilizer use was the CAP reform of Agenda 2000 and an anticipated stepwise reduction in price support and market protection.

Other Chemical Inputs—Pesticide usage is more difficult to compare, as there are many types of plant protection products with many active ingredients. According to the European Environmental Agency (EEA), pesticide usage in the EU has declined since the early 1990s in terms of active ingredients in both absolute levels and in application rates. The EEA attributes the decline to the MacSharry CAP reform, as well as to improvements in pesticide effectiveness and crop-specific formulas, though they admit that pesticides have become more toxic as they have become more potent. Expenditure on herbicides is three times the expenditure of other pesticides in the EU. Pesticide use has declined because of environmental regulations and the land set-aside program of the MacSharry CAP reform.

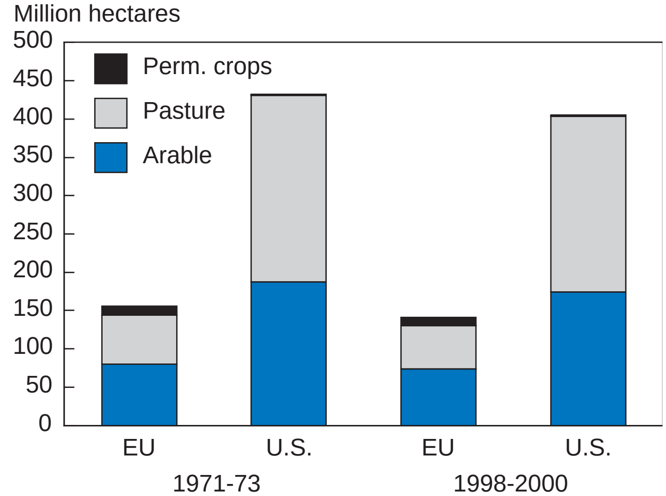
Much of the increases in crop yields throughout this century have been credited to pesticide technology. Between 1950 and 1980, U.S. herbicide use increased to nearly 100 percent of U.S. corn, soybean, cotton, and many other crop areas according to USDA's *Agricultural Resources and Environmental Indicators* report. U.S. pesticide use peaked in 1982 when area planted to crops was at a record high, a greater proportion of acres were treated with pesticides, and application rates per treated acre were high (USDA). U.S. pesticide consumption declined between 1982 and 1990 as commodity prices fell and land was idled by Federal programs, but has been increasing since then. U.S. pesticide consumption surpassed 1982 levels in 1996 and continued to increase marginally through 1997 (USDA).

Land

Agricultural area (fig. 12-D and table 3-D) declined by 9.3 percent in the EU and 6.2 percent in the United States between 1971-73 and 1998-2000, but with an agricultural area nearly three times that of the EU, the United States lost more than the EU--26.8 million hectares to the EU's 14.5 million (table 3). Permanent pasture (fig. 12-D) suffered the largest decline in the EU at 12.5 percent compared with only 5.9 percent for the United States, but the United States lost 14.2 million hectares compared with the EU at 8.5 million. Arable land declined similarly in the EU (7.3 percent) and the United States (7.0 percent), but the larger size of the United States led to a loss of 13.1 million hectares compared with 5.9 million hectares for the EU. Permanent crop area rose slightly in the United States over this period but is small compared with the EU which lost a significant amount of land in this category, presumably because of less area dedicated to olive production, particularly in Spain and Italy.

Figure 12-D

EU and U.S. agricultural land use, 1971-73 and 1998-2000



Source: FAOSTAT.

Irrigated area accounts for a higher percentage of arable land (16.6 percent) in the EU than in the United States (12 percent), which has contributed to the EU's higher yields. U.S. irrigated area was more than twice that in the EU in 1971, but the gap has been narrowing as the EU has nearly doubled its irrigated area since 1971, while U.S. irrigated area increased by 60 percent. U.S. irrigated area was only 81 percent greater than the EU in 1998 at 22.3 million hectares compared with 12.3 million hectares in the EU.

Both the United States and the EU have implemented set-aside schemes for crops in order to control overproduction and/or promote environmental goals. EU set-aside schemes began in 1993 on a large scale with the MacSharry reform and reached a peak in 1996 when nearly 10 percent of all arable land was idled, 7.3 million hectares (EU Commission, Agricultural Situation…). Prior to the MacSharry reform, the EU had a voluntary 5-year set-aside program that is included in the 1996 total amount of set-aside. The set-aside is currently at 5.5 million hectares or 10 percent of what the EU calls its base area, which is smaller than its arable land area. The EU set-aside area is likely to remain at this level which at 7.4 percent of arable land is comparable with the U.S. figure of 7.7 percent.

The United States has a longer history of land set-aside for supply control and various programs have been in effect since the 1950s. Current programs conjoin both land-idling for supply control with environmental objectives. The principal program is the Conservation

Reserve Program (CRP) which has about 13.4 million hectares idled in this long-term program or about 7.7 percent of U.S. arable land. A wildlife habitat program has also idled about 6 million hectares of agricultural area but not all could be classified as arable land. The wetlands conservation program has idled another 380,000 hectares (USDA).

Implications for Productivity-Driven Agricultural Output Growth

Farmers in the EU and the United States have been able to continue to increase yields and agricultural output in the face of lower prices and less input use thanks to increasing productivity. That increase in productivity is based on increasing use of new technologies and better farm management practices, and the embodiment of technology in the improved quality of inputs. This steady increase in productivity growth and its effect on agricultural output growth will continue to pose challenges for both EU and U.S. policymakers.

An obvious benefit of the long-term gains in productivity growth in the United States and the EU is the potential for increasing net returns to agricultural activities and increasingly viable agricultural sectors. The relative productivity gap between the United States and the EU widened in favor of the United States in the early 1990s. There are signs, albeit statistically weak, that CAP reforms, first begun in 1993, may potentially slow the EU's rate of productivity growth. The U.S. competitive position in global markets could improve under such a trend.

Another consequence of productivity-driven increases in agricultural output is the increased government outlays that could potentially cause problems for both the United States and the EU because of WTO restrictions on support linked to production. Payments on U.S. marketing loans and loan deficiency payments (LDPs) are made on a per-unit basis, so as production increases, government expenditures increase as well. The same is true for EU expenditures on purchases into intervention stores. The EU is required to purchase as much as a farmer is willing to sell into intervention provided the commodity meets intervention quality standards. If production increases, government spending on intervention purchases could increase as well. For the EU, increased productivity growth within the new CEE members is a major concern. In addition, increases in EU and U.S. expenditures due to such production increases and consequent government outlays would be classified as amber box payments that are not allowed to increase (see WTO article).

Farmers in the EU and the United States have been able to continue to increase yields and agricultural output in the face of lower prices and less input use thanks to increasing productivity. That increase in productivity is based on increasing use of new technologies and better farm management practices, and the embodiment of technology in the improved quality of inputs. This steady increase in productivity growth and its effect on agricultural output growth will continue to pose challenges for both EU and U.S. policymakers.

The EU is reliant on subsidies for the export of many of its goods because it provides high domestic prices to its producers. Although the EU has met its WTO commitments on export subsidies in the past, it has been close to the limits for many dairy products and coarse grains. The dairy quota will help keep the EU near its bound levels for dairy products, but productivity growth in coarse grains could drive up excess supplies such that the volume bound will prevent some from being exported. This type of pressure has caused the EU to modify its policies in the past. Both the MacSharry and the Agenda 2000 reforms reduced internal prices, compensating producers with direct payments. This reduced the EU's reliance on export subsidies. As productivity increases, the pressure to reform will likely build again unless world prices rise sufficiently.

The United States also uses export subsidies to be price-competitive in targeted overseas markets where competitor countries are making subsidized sales. Nearly all of the U.S. subsidies of this nature since 1995 have been for dairy products as part of the Dairy Export Incentive Program (DEIP). The United States has been exporting at, or close to, its WTO volume limits for skim milk powder, other milk products, and cheese.

Finally, continued productivity increases will also have implications for the impending enlargement of the EU to include several Central and Eastern European countries. Productivity in many of the CEE countries has been lower than in the EU, and with adoption of EU technology and commodity prices that are generally higher than in most CEE countries, the enlarged EU could have larger surpluses of some crops. (For further discussion about EU enlargement see the article in this document by Cochrane.) The EU agricultural budget could be strained by increased CEE productivity, and WTO constraints could potentially come into play.

References

Arnade, Carlos. "Using a Programming Approach to Measure International Agricultural Efficiency and Productivity." *Journal of Agricultural Economics*. Vol. 49, No. 1. pp. 67-84, winter 1998.

Ball, E., J.C. Bureau, J.P. Butault, and R. Nehring. "Levels of Farm Sector Productivity: An International Comparison." *Journal of Productivity Analysis*. Vol. 15, pp. 5-29, 2001.

Denbaly, Mark, and Harry Vroomen, "Dynamic Fertilizer Nutrient Demands for Corn: A Cointegration and Error-Correcting System." *American Journal of Agricultural Economics*. Vol. 75, No. 1, 1993.

Economic Research Service. *Livestock, Dairy, and Poultry Outlook*. May 2002.

European Commission. Agriculture in the European Community: Statistical and Economic Information, 2001. European Union Directorate for Agriculture. February 2002.

European Commission. *Agriculture Situation in the European Community.* European Union Directorate for Agriculture. Various years, 1993-2001.

European Environment Agency. "Agriculture Report-Environmental Signals 2000." Chapter 6. <http://reports.eea.eu.int/Agriculture/en>.

European Fertilizer Manufacturers Association. "The Fertilizer Sector in Western Europe, Market Trends and Industry Outlook." Presentation to the 2nd International Conference on Chemical and Petrochemical Industries of Russia, the CIS and Central and Eastern Europe, Budapest April 23-24, 2001.

European Fertilizer Manufacturers Association. The Fertilizer Industry of the European Union. "*Fertilizer Supply and Demand in the EU*." Chapter 5. http://www.efma.org/Publications/EU Book, Section08.asp.

Food and Agriculture Organization of the United Nations. FAOSTAT Database--Agriculture.

Frisvold, George and E. Lomax. *Differences in Agricultural Research and Productivity Among 26 Countries*. Economic Research Service, USDA. Agricutural Economic Report No. 644, 1991.

Huffman, Wallace, and Robert Evenson. *Science for Agriculture: A Long-Term Perspective.* Ames, IA, Iowa State. University Press. 1993.

Kelch, David, C. Arnade, and S. Leetmaa. "Supply Response in France, Germany, and the UK: Technology and Price." *AgEcon Search: Research in Agricultural and Applied Economics*. University of Minnesota. AAEA Selected paper. April 9, 2002.

Kelch, David and S. Osborne. "Crop Production Capacity in Europe." *Agricultural Outlook.* March 2001.

Leetmaa, Susan, C. Arnade, and D. Kelch. "The Measurement of Technical Change in the European Union." Paper presented at the International Agricultural Economics Association meetings in Berlin. June 2000.

Lin, William. "With Soybean Prices Falling, Why are Planting Intentions Up?" *Agricultural Outlook*. Economic Research Service, U.S. Dept. of Agriculture. pp. 3-5, May 1999.

Makki, Shiva, Luther G. Tweeten, and Cameron S. Thraen. "Investing in Research and Education versus Commodity Programs: Implications for Agricultural Productivity." *Journal of Productivity Analysis*, Vol. 12, Kluwer Academic Publishers, Boston. pp. 77-94, 1999.

Makki, Shiva, and Luther G. Tweeten. "Impacts of Research, Extension, Commodity Programs, and Prices on Agricultural Productivity." Paper presented at the 1993 Meetings of the American Agricultural Economics Association, Orlando, FL. 1993.

Ribaudo, Marc O. and Robin Shoemaker. "Effect of Feedgrain Program Participation on Chemical Use." *Agriculture and Economic Review*. October 1995.

Shane, M., T. Roe, and M. Gopinath. *U.S. Agricultural Growth and Productivity*: An Economywide Perspective. Agricultural Economic Report Number 758. January 1998.

USDA. *Agricultural Resources and Environmental Indicators* 2000.

Vasavada, U., and R. G. Chambers. "Investment in U.S. Agriculture." *American Journal of Agricultural Economics*. Vol. 68, No. 4. pp. 950-960, 1986.

Vasavada, U., and R. G. Chambers. "Technical Change and Applications of Dynamic Duality to Agriculture: Reply." *American Journal of Agricultural Economics*. Vol. 1, No. 3. pp. 803-804, 1989.

Appendix Table 1-D—Indices of efficiency-based productivity growth, EU-15, 1973-1997

	Austria	Belgium	Denmark	Germany	France	Finland	Greece	Ireland	Italy	Netherlands	Portugal	Spain	Sweden	UK
							(1973=1.0)							
1973	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1974	1.10	1.00	1.15	1.08	0.95	1.07	1.00	1.31	1.07	1.00	1.28	1.11	1.01	1.00
1975	1.27	0.99	1.09	1.16	0.96	1.02	1.00	1.31	1.04	1.00	1.17	1.31	1.04	1.00
1976	1.27	0.98	1.07	1.09	0.94	1.04	1.00	1.06	1.03	1.00	1.17	1.62	1.04	0.99
1977	1.23	0.96	0.98	1.00	0.93	1.14	1.00	1.31	1.07	1.00	1.81	2.30	1.02	0.94
1978	1.16	0.95	0.96	0.99	0.93	1.01	1.00	0.94	0.93	1.00	1.58	2.25	0.97	0.90
1979	1.25	0.92	0.96	0.98	0.98	0.96	1.00	0.90	0.97	1.00	1.81	2.52	0.94	0.88
1980	1.25	0.92	0.98	0.98	0.95	1.26	1.00	0.80	0.94	1.00	1.40	2.58	0.98	0.90
1981	1.11	0.90	0.99	0.92	0.91	1.14	1.00	0.75	0.95	1.00	1.25	2.90	0.95	0.86
1982	1.26	0.92	1.06	0.99	0.99	1.24	1.00	0.81	0.97	1.00	1.27	3.64	1.01	0.89
1983	1.26	0.92	1.06	0.99	0.99	1.24	1.00	0.81	0.97	1.00	1.27	3.64	1.01	0.89
1984	1.26	0.91	1.11	0.99	1.00	1.24	1.00	0.91	1.05	1.00	1.44	4.92	1.01	0.91
1985	1.23	0.93	1.14	0.95	1.02	1.27	1.00	0.95	1.04	1.00	1.63	4.92	0.98	0.87
1986	1.28	0.93	1.12	0.96	1.01	1.17	1.00	0.95	1.07	1.00	1.81	4.75	0.98	0.85
1987	1.35	0.97	1.15	0.98	1.09	1.14	1.00	1.01	1.03	1.00	1.81	4.96	1.15	0.88
1988	1.24	0.93	1.11	0.95	1.02	1.16	1.00	0.97	0.93	0.97	1.66	4.76	0.96	0.81
1989	1.27	0.99	1.15	1.00	1.09	1.20	1.00	0.92	1.05	1.00	1.81	5.03	1.07	0.84
1990	1.22	1.00	1.15	0.86	1.09	1.28	1.00	1.06	1.01	1.00	1.81	4.90	1.14	0.82
1991	1.22	1.00	1.15	0.86	1.09	1.28	1.00	1.06	1.01	1.00	1.81	4.90	1.14	0.82
1992	1.21	1.00	1.14	1.05	1.12	1.30	0.94	0.98	0.99	1.00	1.81	4.61	0.99	0.83
1993	1.25	1.00	1.15	1.05	1.06	1.42	0.98	0.99	0.95	1.00	1.81	4.70	1.01	0.76
1994	1.24	1.00	1.15	1.04	1.08	1.51	1.00	0.95	0.89	1.00	1.81	4.60	0.89	0.77
1995	1.23	1.00	1.15	1.04	1.09	1.45	1.00	0.93	0.89	1.00	1.81	4.39	0.94	0.75
1996	1.18	1.00	1.15	1.11	1.14	1.52	1.00	0.91	0.93	1.00	1.81	5.03	0.97	0.76
1997	1.29	1.00	1.15	1.18	1.18	1.69	1.00	0.88	0.88	1.00	1.81	5.35	1.03	0.76

The numbers represent cumulative efficiency change relative to the base period.

Source: Leetmaa, et al., (2000).

Appendix Table 2-D—Indices of technology-based productivity growth, EU-15, 1973-1997

	Austria	Belgium	Den-mark	Germany	France	Fin-land	Greece	Ire-land	Italy	Nether-lands	Portugal	Spain	Sweden	UK
							(1973=1.0)							
1973	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1974	0.94	1.07	0.95	0.95	1.05	0.95	0.89	0.88	1.00	1.00	0.78	0.99	1.03	1.01
1975	0.97	1.05	0.96	0.98	1.05	1.00	0.90	0.90	1.06	1.00	0.81	1.06	1.04	1.02
1976	0.99	1.10	0.96	0.97	1.10	0.99	0.88	0.87	1.01	1.03	0.85	1.08	1.06	1.02
1977	1.00	1.18	1.04	1.06	1.18	0.92	0.70	0.63	0.95	1.10	0.56	0.86	1.14	1.10
1978	1.06	1.29	1.14	1.16	1.29	1.04	0.75	0.72	0.99	1.21	0.65	0.99	1.25	1.20
1979	1.01	1.37	1.21	1.22	1.37	0.95	0.69	0.65	0.94	1.18	0.59	0.91	1.32	1.27
1980	0.98	1.42	1.25	1.27	1.42	0.97	0.75	0.70	1.03	1.13	0.66	0.99	1.32	1.32
1981	1.03	1.51	1.34	1.36	1.51	1.02	0.76	0.74	1.06	1.19	0.72	1.02	1.41	1.41
1982	1.08	1.57	1.39	1.41	1.57	1.06	0.75	0.77	1.06	1.25	0.73	1.03	1.47	1.46
1983	1.07	1.58	1.40	1.44	1.60	1.03	0.67	0.77	1.06	1.29	0.69	1.07	1.49	1.48
1984	1.03	1.68	1.48	1.53	1.70	1.00	0.61	0.75	0.99	1.32	0.63	1.00	1.58	1.57
1985	1.03	1.70	1.50	1.55	1.73	0.97	0.58	0.72	1.00	1.31	0.56	1.01	1.60	1.59
1986	1.08	1.81	1.59	1.64	1.83	1.00	0.59	0.75	1.00	1.36	0.67	1.04	1.69	1.69
1987	1.08	1.78	1.57	1.61	1.80	0.91	0.58	0.72	1.05	1.24	0.65	1.02	1.54	1.66
1988	1.17	1.92	1.75	1.71	1.94	0.93	0.60	0.74	1.12	1.29	0.63	1.04	1.60	1.80
1989	1.20	1.95	1.80	1.74	1.98	0.94	0.56	0.73	1.13	1.34	0.67	1.06	1.67	1.84
1990	1.28	2.01	1.93	1.84	2.11	0.96	0.48	0.66	1.16	1.43	0.53	1.04	1.69	1.93
1991	1.34	2.10	1.98	1.87	2.13	0.97	0.52	0.68	1.20	1.49	0.70	1.11	1.83	1.98
1992	1.39	2.30	2.02	1.90	2.30	0.98	0.52	0.68	1.24	1.53	0.80	1.14	1.91	2.05
1993	1.45	2.43	2.21	1.99	2.42	1.02	0.54	0.71	1.29	1.59	0.74	1.21	2.00	2.17
1994	1.51	2.45	2.22	2.05	2.45	1.07	0.59	0.74	1.40	1.63	0.77	1.26	2.06	2.21
1995	1.54	2.54	2.30	2.11	2.54	1.11	0.59	0.77	1.40	1.66	0.79	1.30	2.14	2.27
1996	1.55	2.56	2.32	2.10	2.57	1.13	0.56	0.78	1.38	1.66	0.84	1.31	2.12	2.28
1997	1.53	2.62	2.44	2.14	2.62	1.14	0.60	0.79	1.43	1.61	0.88	1.29	2.11	2.34

The numbers represent cumulative change in technology since the base period.

Source: Leetmaa, et al., (2000).