

## CHAPTER 3

# Global Patterns of Crop Yields and Other Partial Productivity Measures and Prices

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### 1. INTRODUCTION

More than 50 years ago Schultz (1953) and Griliches (1961) suggested that an interest in productivity stems from more fundamental concerns about the rate and sources of growth in output. The relative rates of growth of the supply and demand for food, feed, and fiber have far-reaching economic and social consequences, most readily observed through changes in commodity prices.<sup>1</sup> These issues have been in the background for some time—as food and fiber have

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<sup>1</sup>Economists have long been interested in analyzing commodity price trends and the sources of change in these trends. Among the earliest such studies in the U.S. literature are articles by Veblen (1892 and 1893) on (relative) wheat price trends and a 1922 article by Taylor titled “The Decline of Prices of Cereals.” In his 1945 book *Agriculture in an Unstable Economy*, Schultz explored the nature and causes of commodity price variability during the first half of the twentieth century, notably in a chapter titled “The Unequal Growth of the Supply and Demand for Farm Products.” Johnson (1948 and 1975) addressed similar themes, and Hathaway (1959) revisited Schultz's 1945 work. Tomek and Robinson (1977) provide a comprehensive review of the literature on agricultural prices to that point in time.

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seemed abundant and other agricultural issues have dominated the media and policy debates—but the recent turbulence in food commodity markets reminded commentators and policymakers that food prices matter and that their causes deserve attention.

During the past few years we have seen soaring food and commodity prices globally and an increase in the dismal tally of hungry people in the world.<sup>2</sup> Driven in part by the demand for biofuels, stimulated by high and rising oil prices and government responses to them, prices of corn and soybeans also rose rapidly to historical highs (at least in nominal terms) in early 2008.<sup>3</sup> The rising prices of these and other staple commodities, in particular wheat and rice, were also stimulated by the growing demand for food in India and China fueled by the general economic growth that had contributed to a rundown of grain stocks over the previous several years. These factors, combined with some unfavorable weather in important wheat-producing regions in Russia and Australia, constituted the “perfect storm” that gave rise to the spike in grain prices in mid-2008.

In a reversal of the rapid rise in the beginning of the year, between July and November 2008 the price of oil fell back to around \$50. Prices of food and feed grains have also fallen significantly. Consequently, and especially in view of financial and stock market events since mid-September 2008, the attention of many commentators has shifted from the food price crisis to the global financial crisis. Nevertheless, food commodity prices remain high relative to the experience of the past several decades, and concerns continue to be raised about the future prospects for food prices. In December 2007, *The Economist* magazine published a briefing note titled “Cheap No More” with the leader “Rising incomes in Asia and ethanol subsidies in America have put an end to a long era of falling food prices.” This view has been echoed in a range of other media and at a host of symposia on the causes and consequences of the so-called food price crisis.

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<sup>2</sup>In September 2008, the United Nation’s Food and Agriculture Organization (FAO) released a provisional set of estimates (FAO 2008) indicating that “the number of undernourished people in 2007 increased by 75 million over and above FAO’s estimate of 848 million undernourished in 2003-05, with much of this increase attributed to high food prices. This brings the number of undernourished people worldwide to 923 million in 2007, of which 907 million [are] in the developing world.” More recently, FAO (2009) estimated that an additional 100 million people are now undernourished, increasing the total to over one billion.

<sup>3</sup>The price of Brent crude oil reached an all-time high of almost \$145 per barrel in July 2008—almost twice the value in July 2007, which itself was historically high. The oil price cited here was obtained from <http://www.eia.doe.gov/emeu/international/prices.html> on November 16, 2008.

Most of the discussions have focused on the demand side of the story, emphasizing the role of economic growth in the fast-growing economies of Asia coupled with the new demand for biofuels, and treating the supply side as given. In this chapter we use graphical approaches in conjunction with newly compiled data to consider the nature of the long-term growth in the supply of food and its principal determinants to see what may be implied for the availability and price of food over the coming decades. Key to our understanding of these longer-run trends is to distinguish between possible structural shifts and realignments in the relative growth of global food supply and demand from transient factors that contribute to shorter-run instability in food prices. We document a global slowdown in growth of agricultural productivity and commodity yields, and thus in the long-term downward trend of real food commodity prices.<sup>4</sup> Before turning to the productivity evidence, we review trends in food prices throughout the twentieth century. This review helps not only to place recent commodity price spikes in a longer-run context but also to provide indirect evidence on productivity patterns and their main consequences.

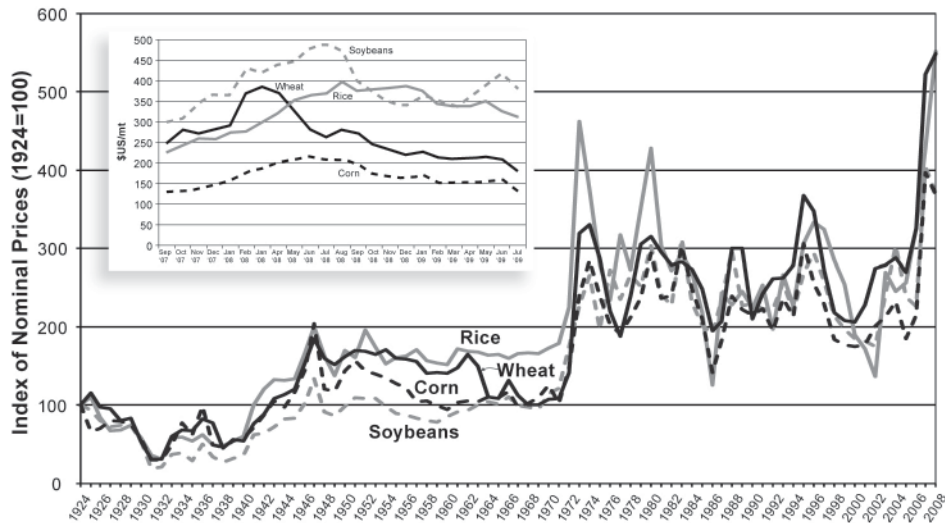
## 2. TRENDS IN COMMODITY PRICES

Over the past 50 years and longer, the supply of food commodities has grown faster than the demand, in spite of increasing population and per capita incomes. Consequently, the real (deflated) prices of food commodities have steadily trended down. Figure 3.1 shows long-term trends in indexes of average annual U.S. prices of major food and feed commodities (rice, wheat, corn, and soybeans) for the period 1924 to 2008, with an insert to show price movements over more recent months. These U.S. price indexes can be used as indicators of world market prices of these commodities. The commodity price indexes generally move together over the long term, but with significant differences over shorter periods, especially for rice.

These indexes all start at 100 in the base year of 1924. After a great deal of movement over the next 45 years, by the late 1960s the prices of wheat, soybeans, and corn had roughly returned to a nominal value of 100, but the rice

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<sup>4</sup>In making this assessment we drew on a range of evidence and used the graphical techniques recommended by Waugh, who wrote, “Fancy, super-refined mathematics and electronic computations are wonderful things, but they are of little practical use unless they describe relationships that actually exist in the real world. One of the main ways to find out about these relationships is through graphics” (1966, p. 1). Evident structural changes, especially in the price and crop yield series, limit the applicability of formal econometric approaches to analyzing these trends.



**Figure 3.1. Nominal U.S. prices of corn, rice, soybeans, and wheat, 1924-2008**

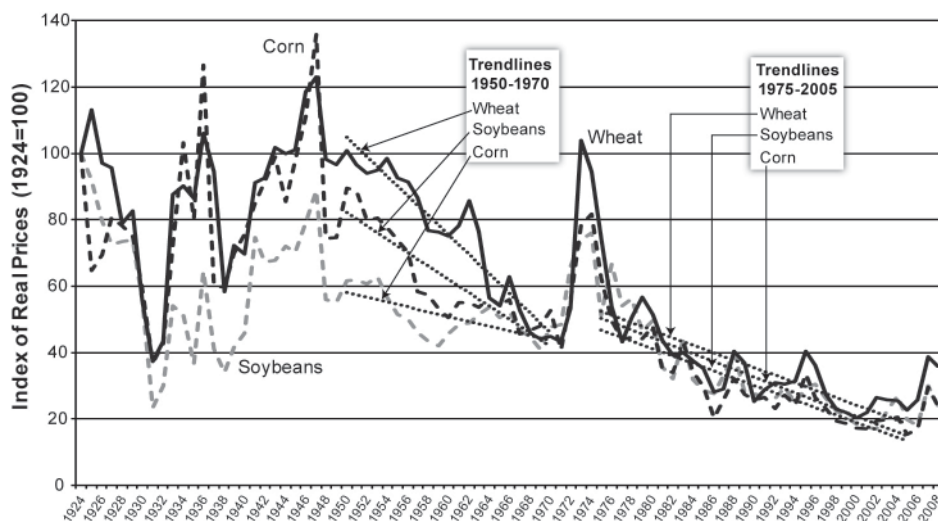
Sources: Compiled by the authors with data from Olmstead and Rhode 2006, FAOSTAT Database and USDA-NASS Agricultural Prices.

Notes: Data in the body of the graph represent annual averages of prices paid to farmers. Inset data are corresponding monthly average prices.

price remained much higher. The intervening years included a period of a general downward trend during the 1920s and through the early 1930s (including the effects of the Great Depression), and some rapid growth during the latter 1930s and early 1940s (including the effects of World War II), after which the prices fluctuated around a relatively flat trend. The commodity price spike in the early 1970s brought about a distinct shift in the pattern.<sup>5</sup> Following that price spike, the trends were again essentially flat in nominal terms but at a higher level than before 1970 (perhaps slightly trending down) until the recent price spike. Since 1975 the prices of all four commodities have tended to move together more closely than in the previous decades.

Figure 3.2 shows the price indexes for wheat, corn, and soybeans over the period 1924 to 2008, expressed in real terms by deflating by the index of prices paid by farmers. (Rice was omitted to improve the clarity of the plots. The rice prices follow a similar overall pattern to the commodity prices shown here.)

<sup>5</sup>Eckstein and Heien (1978) examined the food price inflation of 1973 and concluded that, in approximate rank order of importance, the causes were domestic monetary policy, government acreage restrictions, the Soviet grain deal, world economic conditions, devaluation of the dollar, and price control policies. Our emphasis in this chapter is on the long-term trends rather than the short-term deviations from these trends.



**Figure 3.2. Real U.S. prices of corn, soybeans, and wheat, 1924-2008**

Sources: Compiled by the authors with data from Olmstead and Rhode 2006, FAOSTAT Database and USDA 2009b.

Notes: Nominal prices were deflated using an index of farm input prices. Trend lines represent lines of OLS best fit where the respective commodity price was regressed against a linear time trend during each period.

The deflated series provides some perspective on the latest price spike, in which commodity prices roughly doubled in real terms compared with the 1970s and mid-1930s when they more than doubled. Moreover, at their recent peak, real commodity prices fell well short of the prices that prevailed during the previous price spikes. In the case of corn, for example, in real terms the peak price in June 2008 was 50% below the peak price in 1974, 66% below the peak price in 1936, and nearly 80% below the peak price in 1947. Questions remain about whether the general path of the previous price trend will be restored.

The longer trends are of interest, too. In real terms, commodity prices trended up generally (albeit with some major fluctuations during and after the Great Depression) from 1929 through the end of World War II, after which they have trended generally down. This downward trend was interrupted by the major price spike in the 1970s and again at the end of the series by the latest price spike. The trend lines in the figure show the real prices declining at different rates during the period 1950-1970, as they converged toward equality. Then following the 1970s price spike, over the period 1975-2005, they trended down at roughly equal rates.

Table 3.1 includes measures of rates of change in real and nominal prices of the four commodities over the entire period and several subperiods. The long-term trend in deflated prices has been remarkable. Over the 55 years between 1950 and 2005, in real terms rice prices fell at an average annual rate of 2.9%. On average, wheat prices declined by 2.7% per year, soybean prices by 2.1% per year, and corn prices by 3.2% per year. After the jump in the early 1970s, over the 30 years between 1975 and 2005, in real terms rice prices fell at an average rate of 4.1% per year, wheat prices by 4.0% per year, soybean prices by 3.2% per year, and corn prices by 4.7% per year. These changes in prices of staple commodities are cumulative, enduring, and economically im-

**Table 3.1. Average annual percentage changes (% per year) in U.S. commodity prices, 1866-2008**

Period	Commodity			
	Corn	Wheat	Rice	Soybeans
<b>Nominal Prices</b>				
1866-2008	1.25	0.84	n.a.	n.a.
1924-2008	1.55	2.03	2.03	1.56
1950-2005	0.46	0.94	0.74	1.60
1950-1970	-0.67	-2.04	0.08	0.72
1975-2005	-0.87	-0.20	-0.29	0.64
1990-2005	-1.02	1.66	0.90	0.25
2000-2005	1.07	5.38	6.03	5.07
1950-2008	1.62	2.11	2.03	2.28
1975-2008	1.30	1.97	2.06	1.91
1975-1990	-0.72	-2.05	-1.47	1.03
1990-2008	2.98	5.32	5.01	2.65
2000-2008	9.29	12.22	13.35	8.66
<b>Deflated Prices</b>				
1924-2008	-1.70	-1.22	-1.22	-1.69
1950-2005	-3.20	-2.72	-2.91	-2.05
1950-1970	-2.67	-4.04	-1.92	-1.29
1975-2005	-4.66	-3.99	-4.08	-3.15
1990-2005	-3.43	-0.75	-1.51	-2.16
2000-2005	-2.30	2.01	2.66	1.70
1950-2008	-2.27	-1.79	-1.87	-1.62
1975-2008	-2.90	-2.23	-2.14	-2.29
1975-1990	-5.89	-7.22	-6.64	-4.15
1990-2008	-0.41	1.93	1.62	-0.74
2000-2008	4.09	7.01	8.15	3.45

Sources: Calculated by the authors based on data compiled from Olmstead and Rhode 2006, FAOSTAT Database and USDA 2008b.

Note: Deflated prices were computed by deflating nominal commodity prices by an index of farm input prices.

portant.<sup>6</sup> For comparison, Table 3.1 also includes price trends for the periods ending 2008, which includes the price increases that started in about 2006. The long-run trend of declining real prices since 1975 is muted by the recent price increases but not reversed.

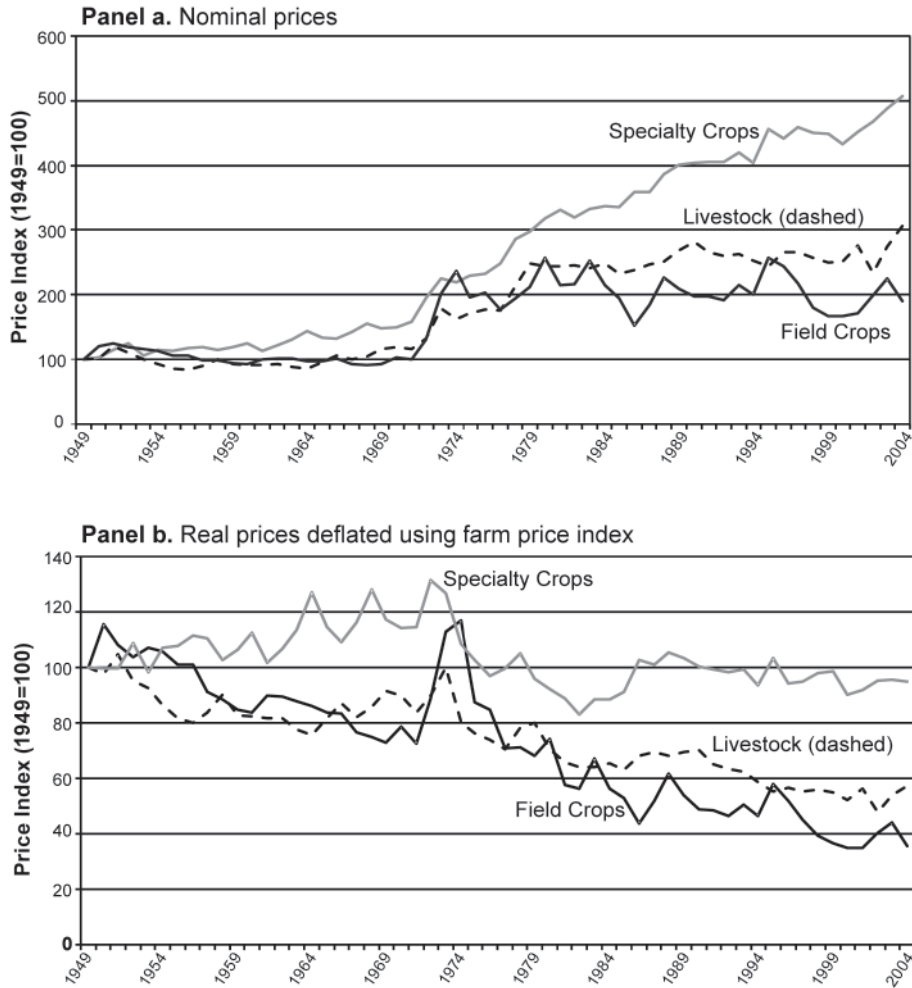
It is useful to split the period 1975-2005 into two subperiods, before and after 1990. This break point was identified in previous work by Alston et al. (2010) looking at U.S. productivity patterns. For all four commodities the real rate of decline of prices was substantially slower over the period 1990-2005 than for the previous period 1975-1990 and for the 30-year period 1975-2005. This slowdown of the rate of price decline was more pronounced for the food grains, wheat and rice, than for the feed commodities, corn and soybeans, consistent with a faster rate of productivity growth in the feed commodities that have disproportionately benefited from private research by biotech firms and seed companies. Toward the end of the period, but still before the onset of the recent price spike that became evident after 2005, the rate of decline of real prices slowed even more—in fact, between 2000 and 2005, prices increased in real terms for rice, soybeans, and wheat. Prices increased markedly for all four commodities after 2005, including the recent price spike.

In summary, the period since World War II includes three distinct subperiods. First, over the 20-year-period 1950-1970, prices for rice, corn, and soybeans declined relatively slowly, while wheat prices declined fairly rapidly. Next, following the price spike of the early 1970s, over the years 1975-1990, real prices for all four commodities declined relatively rapidly. Finally, over the years 1990-2005, the rate of price decline slowed for all four commodities, especially toward the end of that period. The question yet to be resolved is whether, in general, we have entered a new era in which real commodity prices will no longer be falling rapidly or even a new era of rising real commodity prices.

Figure 3.3 shows some comparable price indexes for field crops, specialty crops, and livestock products over the period 1949-2004 for which detailed index numbers are available from the work of Alston et al. (2010). Panel a shows the nominal indexes. The prices of specialty crops have grown both absolutely and

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<sup>6</sup>As Hulten (1986) and Roeger (1995) illustrate, under certain conditions, the rate of decline of an output-input price ratio such as the deflated commodity price series presented here corresponds to a dual measure of the rate of multifactor productivity growth, and so the declines in these deflated price trends reflect substantial and rapid productivity growth. The correspondence is closer if the deflator corresponds more closely to the appropriate price index for the inputs used to produce the output. Deflating by the implicit GDP deflator or the consumer price index rather than the index of prices paid by farmers for inputs in practice results in generally similar patterns of change overall in the real price trends for each commodity (but with differences in some of the details).



**Figure 3.3. U.S. prices of specialty crops, field crops, and livestock, 1949-2004**  
 Source: Adapted from Alston and Pardey 2008.

relative to field crops and livestock products, which have had fairly static nominal prices for the 20 years prior to 2004 in spite of general input price inflation. As discussed by Alston, Sumner, and Vosti (2006), some of the price increases for specialty crops might reflect premia for changes in quality, variety, or seasonal availability that were not fully addressed in the indexing procedure. Figure 3.3, Panel b, shows the same price series deflated by an index of prices paid by farmers for inputs. Real prices received by farmers for all crop categories trended down, but at different rates. Over the period 1949-2004, in real terms prices for field crops fell by 64.5%, prices for livestock fell by 42.7%, and prices for spe-



cialty crops fell by 5.3% (8.6% for vegetables, 3.0% for fruits and nuts, and 0.2% for nursery and greenhouse).

These price trends reflect the fact that global supply has been growing faster than global demand, and that supply and demand have been growing at different rates for the different categories of products. Here we are focusing on the supply side. Growth in supply reflects the increased use of some inputs, especially increases in land, water, and chemical inputs (including fuels, fertilizers, and pesticides). This is balanced partly by labor savings in many places, combined with increases in productivity of inputs. Major increases in productivity and changes in input combinations around the world and over time have been associated with changes in technology, along with other changes that contributed to enhanced efficiency of production.

### 3. U.S. AND GLOBAL YIELD TRENDS

Table 3.2 includes growth rates of yields for selected U.S. crops, including corn, wheat, rice, and soybeans for various time periods. The yield growth accelerated in the second half of the twentieth century relative to the first half. But for corn, rice, and wheat (and to a lesser extent for soybeans), average annual rates of yield growth were much lower in 1990-2008 than in 1950-1990. These U.S. yield patterns are consistent with the price patterns discussed previously, but of course prices depend on global supply and demand, not just U.S. yields.<sup>7</sup>

**Table 3.2. Rates of growth (% per year) of yield for selected U.S. crops, 1866-2008**

Period	Crop Yields			
	Corn	Wheat	Rice	Soybeans
1866-2008 <sup>a</sup>	1.30	0.99	1.58	n.a.
1900-2008 <sup>a</sup>	1.57	1.21	1.50	1.52
1900-1950 <sup>a</sup>	0.61	0.60	1.33	2.61
1950-2008	2.40	1.73	1.86	1.04
1950-1990	2.83	2.18	2.12	1.13
1990-2008	1.45	0.71	1.19	0.83

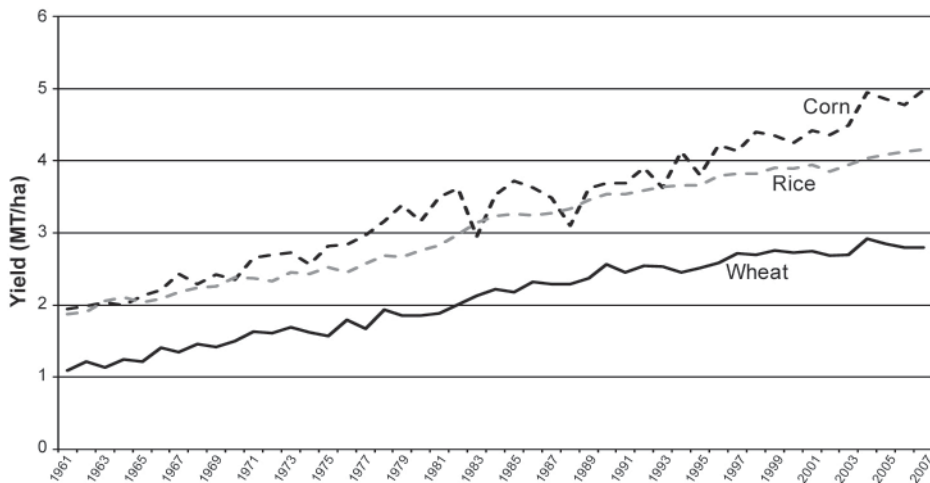
*Sources:* Calculated by the authors based on data reported in Beddow, Hurley, and Pardey 2009 derived from Alston and Pardey 2006 and USDA-FAS unpublished data.

<sup>a</sup> Rice yields start in 1895, soybeans in 1924.

<sup>7</sup>See Chapter 8 in this volume for more detail on U.S. yield growth and developments generally regarding agricultural productivity growth in the United States. Alston et al. (2010, Chapter 5) provide even more detail on U.S. agricultural productivity patterns and examine the slowdown in crop yields in terms of both the absolute and proportional growth in yields.

Figure 3.4 plots average global yields for corn, rice, and wheat (in metric tons per harvested hectare) since 1961 (the earliest year for which global yield estimates are reported by the United Nations' Food and Agriculture Organization [FAO], whence most of these data were drawn). Corn and wheat yields each grew by a factor of 2.6 from 1961 to 2007; over the same period, rice yields increased by a factor of 2.2. Corresponding annual average rates of yield growth are reported in Table 3.3. Separate estimates of average growth rates of yields are reported for North America, Western Europe, and Eastern Europe, for high-, middle- and low-income countries, and for the world as a whole, for two subperiods: 1961-1990 and 1990-2007.<sup>8</sup> The slowdown evident for the global averages (Table 3.3) mirrors the slowdown in U.S. crop yield growth (in Table 3.2), although the low-income countries have seen increasing rates of growth in wheat and rice yields.

For all four commodities, in both high- and middle-income countries, average annual rates of yield growth were lower in 1990-2007 than in 1961-1990. The growth of wheat yields slowed the most and, for the high-income countries as a group, wheat yields barely changed over the 1990-2007 period.



**Figure 3.4. Average global yields for selected crops, 1961-2007**

Source: Compiled by the authors from FAOSTAT Database.

<sup>8</sup>Low-income countries are those with a per capita gross national income (GNI) of \$975 or less, high-income countries are those with a per capita GNI greater than \$11,905, and middle-income countries are those with a per capita GNI that falls between these values (World Development Indicators Database).

Table 3.3. Global yield growth rates (% per year) for selected crops, 1961-2007

Group	Corn		Wheat		Rice		Soybeans	
	1961-1990	1990-2007	1961-1990	1990-2007	1961-1990	1990-2007	1961-1990	1990-2007
World	2.20	1.77	2.95	0.52	2.19	0.96	1.79	1.08
N. America	2.20	1.40	2.23	0.01	1.67	1.54	1.05	0.04
W. Europe	3.30	1.81	3.31	0.63	0.38	0.55	1.64	0.05
E. Europe	1.91	0.97	3.18	-1.69	-0.41	1.07	1.90	2.29
Per capita income								
High	2.34	1.48	2.47	0.06	1.07	0.54	1.14	0.02
Middle	2.41	2.12	3.23	0.85	2.54	0.81	3.21	2.08
Low	1.07	0.65	1.32	2.15	1.46	2.16	2.63	0.00

Sources: Authors' calculations based on FAOSTAT Database and USDA-FAS unpublished data.

Global corn yields grew during 1990-2007 at an average rate of 1.77% per year compared with 2.20% per year for 1961-1990. Likewise, rice yields grew at less than 1.0% per year after 1990, less than half their average growth rate for the period ending 1990. Again, paralleling productivity developments in the United States, the slowdown in crop yields is quite pervasive. In more than half of the countries growing these crops, yields for rice, wheat, corn, and soybeans grew more slowly during 1990-2007 than during 1961-1990 (Table 3.4). More critically, among the most important producers (i.e., the top 10 producing countries worldwide) the slowdown was generally more widespread than among all producing countries.

The interpretation of average global crop yields is problematic for several reasons. For one, countries located in tropical and temperate regions of the world differ considerably in terms of their propensity to plant multiple crops per year, and cropping intensities have changed considerably over time for certain regions of the world.<sup>9</sup> The yield data used here (and by most other observers) report

<sup>9</sup>Wood, Sebastian, and Scherr (2000) developed measures of cropping intensities worldwide that expressed the annual harvested area as a proportion of total crop land (including land in use and fallowed land). Swidden agriculture, for example, relies on maintaining a significant share of production in fallow every year (thus having a cropping intensity of less than one) whereas some irrigated areas in the tropics can produce up to three crops a year from the same physical area (thus having a cropping intensity of three). In 1997, the global average annual cropping intensity was estimated to be about 0.8 (Wood, Sebastian, and Scherr 2000, p. 23). In South Asia, with its extensive use of irrigation, the average intensity was 1.1, whereas in Western Europe and North America the intensities were between 0.6 and 0.7.

**Table 3.4. Percentage (%) of countries with slower yield growth since 1990**

Grouping	Corn	Wheat	Rice	Soybeans
All countries	56	78	56	65
Top 10 producers	60	100	60	78
Top 25 producers	60	88	48	71

Sources: Authors' calculations based on FAOSTAT Database and USDA-FAS unpublished data.

Notes: 155 countries are included for corn, 114 for wheat, 108 for rice, and 55 for soybeans.

Only countries with area and production data for both periods are included.

yields on the basis of harvested area, which will count the same land twice if it is cropped twice in a given calendar year. An alternative is to report yields on the basis of arable area, which will count the land area only once per year regardless of how often it is cropped. Reporting yields on the basis of harvested area would understate the rate of growth in crop yields compared with crop yields measured on the basis of arable area if the intensity of crop plantings per year had increased over time.<sup>10</sup>

Another confounding factor when interpreting changes in global or regional yield aggregates (as well as national aggregate yields for that matter) is the effects of the changing spatial location of production (see also Chapter 2 of this volume). Table 3.5 illustrates that the location of worldwide wheat production, for example, has moved markedly, even since the early 1960s. During the three-year period 1961-1963, Russia accounted for 15% of the world's wheat production (35.4 million metric tons) and ranked first among wheat producers worldwide. By 2005-2007, Russia had slipped to the world's fourth-ranked wheat producer, accounting for 7.8% (47.4 million metric tons) of world wheat production during those years. The massive increases in production by India and, especially, China are particularly evident in Table 3.5. These changes in location of production imply changes in average productivity (yields) to the extent that different locations have different endowments of soils and climate, different incentives, and different technological opportunities.<sup>11</sup>

<sup>10</sup>For example, if rice yields averaged 2 tons per harvested hectare in 1961 and doubled to 4 tons per harvested hectare by 2007, that would be equivalent to an average annual yield growth of 1.5% per harvested hectare per year. In contrast, if yields per harvested area doubled from 2 to 4 tons per hectare from 1961 to 2007 while the cropping intensity also increased from one to two crops per calendar year, yields reported on the basis of arable area would have grown from 2 to 8 tons per arable hectare, or 3.1% per year.

<sup>11</sup>Olmstead and Rhode (2002) discuss and document this phenomenon in the context of the early development of the U.S. wheat industry.

**Table 3.5. Changing spatial location of global wheat production, 1961-63 and 2005-07**

1961-1963				2005-2007			
Rank	Country	Production (mmt)	Share (%)	Rank	Country	Production (mmt)	Share (%)
1	Russia	35.4	15.0	1	China	103.9	17.0
2	U.S.	31.5	13.4	2	India	71.0	11.6
3	China	16.5	7.0	3	U.S.	53.4	8.7
4	Canada	14.3	6.0	4	Russia	47.4	7.8
5	France	11.3	4.8	5	France	35.2	5.8
Top 5 Total		109.0	46.3	Top 5 Total		310.8	50.9
6	India	11.3	4.8	6	Canada	23.9	3.9
7	Ukraine	10.5	4.5	7	Germany	22.5	3.7
8	Kazakhstan	9.9	4.2	8	Pakistan	22.1	3.6
9	Italy	8.6	3.7	9	Turkey	19.7	3.2
10	Turkey	8.6	3.7	10	Australia	16.3	2.7
Top 10 Total		157.9	67.1	Top 10 Total		415.4	68.0
Top 20 Total		201.8	85.7	Top 20 Total		521.9	85.5

Source: Authors' calculations based on FAOSTAT Database and USDA-FAS unpublished data.

Notes: The country designations used in both periods pertain to 2008 geopolitical boundaries.

For states that were previously part of a statistical or national aggregation, country-specific values were estimated using a decomposition procedure when reliable subnational area and production data were unavailable. Subnational data were obtained for Kazakhstan, Ukraine, and Russia.

Otherwise, data for a number of countries were estimated using the decomposition procedure, including those of the Socialist Federal Republic of Yugoslavia, the People's Democratic Republic of Ethiopia, Czechoslovakia, Serbia and Montenegro, the Belgium-Luxembourg aggregation, and the Former Soviet Union.

#### 4. LAND AND LABOR PRODUCTIVITY

Moving beyond crop yields to more broadly construed productivity measures, global productivity trends show a 2.4-fold increase in aggregate output per harvested area since 1961 (equivalent to annual average growth of 2.0% per year) and a corresponding 1.7-fold increase (or 1.2% per year growth) in aggregate output per agricultural worker. These productivity developments reflect a comparatively faster rate of growth in global agricultural output against

relatively slower growth in the use of agricultural land and labor (0.3% and 1.1% per year, respectively).

In parallel with the foregoing global crop yield evidence, the longer-run growth in land and labor productivity masks a widespread slowdown in the rate of growth of both productivity measures during the post-1989 period compared with the previous three decades. Among the world's top 20 producers (according to their 2005 value of agricultural output), land and labor productivity growth in the period 1990-2005 was significantly slower than in 1961-1990, once the large, and in many respects exceptional, case of China is set aside (Table 3.6). Across the rest of the world (i.e., after setting aside the top 20 producing countries), on average, the slowdown is even more pronounced.

**Table 3.6. Growth in agricultural land and labor productivity worldwide, 1961-2005**

Group	Land Productivity		Labor Productivity	
	1961-90	1990-05	1961-90	1990-05
World	2.03	1.82	1.12	1.36
Excl. China	1.90	1.19	1.21	0.42
Excl. China & FSU	1.91	1.57	1.13	0.73
Latin America	2.17	2.83	2.15	3.53
Asia	2.56	3.01	1.83	2.72
Excl. China	2.45	1.83	1.69	1.24
China	2.81	4.50	2.29	4.45
Africa	2.18	2.21	0.68	0.90
Low-Income Countries	2.00	2.39	0.46	1.03
Middle-Income Countries	2.35	2.30	1.51	2.02
Excl. China	2.18	1.37	0.39	0.81
High-Income Countries	1.61	0.72	4.26	4.18
Top 20 Producers	2.11	2.16	1.17	1.77
Excl. China	1.98	1.38	1.33	0.63
Other Producers	1.74	0.88	1.00	0.07

*Sources:* Authors' calculations based on FAOSTAT Database and USDA-FAS unpublished data.

*Notes:* Labor is measured as economically active workers in agriculture. Land is the sum of area harvested and permanently pastured areas. Output is a value of production measure developed by the authors by weighting a time series of country-specific commodity quantities (spanning 155 crop-related and 30 livestock-related commodities) with an unpublished 1999-2001 global average of commodity-specific international prices developed by FAO.

For this group of countries land productivity grew by 1.83% per year during the period 1961-1990 but by only 0.88% per year thereafter; labor productivity grew by 1.08% per year prior to 1990, but barely budged during the period 1990-2005.

Worldwide, land productivity grew at a slower pace in the period 1990-2005 (1.82% per year) than during earlier decades (2.03% per year), whereas labor productivity increased at a faster rate for the period 1990-2005 than for 1961-1990 (1.37% versus 1.12% per year). Once again these world totals are distorted by the significant and exceptional case of China. Netting out China, global land and labor productivity growth has been slower in the period 1990-2005 than during the prior three decades. The same period relativities prevail if the former Soviet Union (FSU) is also netted out, although the magnitude of the global (net of China and FSU) productivity slowdown is less pronounced because both partial productivity measures for the FSU actually shrank during the period 1990-2005.<sup>12</sup>

Figure 3.5 draws on the FAOSTAT database to report land and labor productivity measures for 212 countries (some of which no longer exist) grouped into various aggregates according to regions and per capita income. Here we use the graphical technique developed by Hayami and Ruttan (1971), where the horizontal axis measures labor productivity (in logarithms) and the vertical axis measures land productivity (in logarithms). The productivity loci were formed by taking ratios of the value of aggregate output to the quantity of land input and to the quantity of labor input. Output is an estimate of the total value of agricultural output (spanning 155 plant commodities and 30 animal commodities) expressed in 1999-2001 average purchasing power parity agricultural prices obtained from FAO. Land is a measure of harvested and permanently pastured area, and labor is a head count of the economically active workers in agriculture. These ratios were then scaled by the corresponding value ratios of output and input in the base year 1961, and the natural logarithms of the scaled index ratios were then taken. Since both axes are mea-

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<sup>12</sup>While notable in their own right and of significance in terms of global totals, developments in the FSU and China are exceptional, with unique, essentially one-off attributes. The impacts on agricultural productivity growth and downsizing of agriculture in the FSU economies following the break-up of the Soviet Union are documented and discussed by Mathijs and Swinnen (1998), Macours and Swinnen (2002), and Brooks and Gardner (2004) among others. The massive institutional changes in China (notably the introduction of the household responsibility system into Chinese agriculture in the late 1970s) also had a sizable, one-shot, albeit enduring, effect on productivity developments in that country (see for example, Lin 1992 and Fan and Pardey 1997).

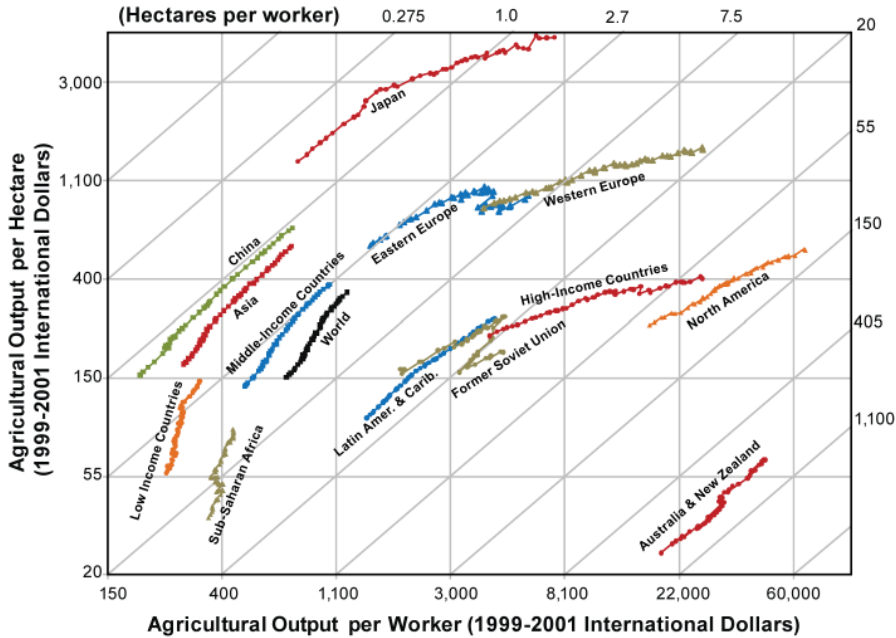


Figure 3.5. Land and labor productivity by region, 1961-2005

Sources: Authors' calculations based on FAOSTAT Database and USDA-FAS unpublished data.

Notes: The land-labor ratio is constant along each grey diagonal line, and values for those ratios are given at the terminus of the respective diagonal line on the top and right axes. Notably, any arbitrary 45 degree line represents a constant land-labor ratio, so regional plots with slopes greater than 45 degrees (e.g., Sub-Saharan Africa and the middle-income countries) indicates increased land use relative to labor use while the opposite is true for regions with plots that have a slope of less than 45 degrees (e.g., North America and Western Europe).

sured in natural logarithms, a unit increase in either direction is interpreted as a proportional increase in land or labor productivity, and the length of the productivity locus is an indication of the average annual rate of change in productivity. All of the productivity paths move generally (but not uniformly) in a northeasterly direction, starting in 1961 and ending in 2005, indicating productivity growth.

The diagonals indicate constant land-to-labor ratios. As the productivity locus for a particular country or region crosses a diagonal from left to right, it indicates a decrease in the number of economically active workers in agriculture per harvested hectare in that region. Substantive but gradually changing differences can be seen in the land-labor ratios among countries and regions. In Japan's case, land-labor ratios rose from 0.6 hectares per worker in 1961 to 1.6 in 2005. Land-labor ratios in Australia and New Zealand have changed little, whereas they have



risen by some 83% in North America. They also rose, albeit very slowly, for the Latin America and Caribbean region, consistent with the region's labor productivity growing slightly faster than its land productivity. Sub-Saharan Africa has become much more labor-intensive so its land-labor ratios have declined. In 1961 the region averaged 10.0 hectares per agricultural worker, but by 2005 the land-labor ratio had halved to 5.0 hectares per worker.

The relative positions of the productivity loci are revealing as well. In the terminal year of the data series, 2005, low-income countries as a group averaged just \$331 of output per agricultural worker, compared with \$1,032 per worker for middle-income countries and \$26,975 per worker for high-income countries when taken as a group. The land productivity relativities are less clearly tied to per capita incomes. For example, middle-income countries as a group had similar output per hectare in 2005 (\$381) as the high-income countries (\$405 per hectare). According to these data, in 2005 the average land productivity in sub-Saharan Africa (\$88 per hectare) exceeded that of Australia and New Zealand (\$64 per hectare). Clearly, broad, regional productivity trends mask significant local variation caused by a host of agro-ecological, market-related, and policy-related factors.

## 5. INTERPRETATION AND INFERENCES

Much of the dramatic transformation of global agriculture over the past 100 years, as well as before that, can be traced to the adoption of new technologies that allowed more to be produced with less. The increases in agricultural productivity have been impressive and enormously valuable. It can be difficult to partition the past productivity growth accurately between elements associated with new technology and elements attributable to other sources (including weather and infrastructure), but technological change has surely been the main source. Technological change itself can come from multiple sources, but organized research undertaken by governments and industry has played a central role, especially over the past 150 years.

In this chapter we have presented a range of different measures of productivity across many countries, and the counterpart patterns of commodity prices. This evidence consistently indicates that the long-term downward trends in real prices of food and feed commodities, like their counterpart measures of partial and multifactor productivity, accelerated in the 1970s and 1980s and then slowed in the 1990s and the first half-decade of the twenty-first century. Such

patterns are difficult to discern precisely given the effects of temporary fluctuations associated with year-to-year variations in weather, and more-enduring but still temporary departures from trend, such as the price spike in the early 1970s. Additionally, measured growth rates are sensitive to the choices of starting and ending dates, and more so when the intervals are shorter.

The compilation of country-specific studies reported in Alston et al. (2000) reveals a strong association between lagged research and development (R&D) spending and agricultural productivity improvements. We suspect that a substantial share of past agricultural productivity growth resulted from agricultural R&D. Consistent with that view, and the fact that research affects agricultural productivity with a long lag, we also suspect that the reduced growth in productivity observed during the past decade or two may be attributable in significant part to a slowdown in the rate of growth in spending on agricultural R&D a decade or two previously.<sup>13</sup>

An implication of our analysis is that a restoration of the growth in spending on agricultural R&D may be necessary to prevent a longer-term food price crisis of a more enduring nature. This message may be discounted or dismissed on the grounds that, if necessary, science can solve this problem, as it did in the 1970s, proving false the prophecy of the doomsayers of the time such as the “Club of Rome.”<sup>14</sup> Optimism about the potential for science to contribute to solving our problems may well be justified, but an appropriate investment in science and the translation of that scientific know-how into technological changes on farms is required to realize that potential—it should not be forgotten that the 1960s and 1970s witnessed a very rapid growth in spending on agricultural science around the world, including the creation of the Consultative Group on International

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<sup>13</sup>See also von Braun 2007 and Trostle 2008.

<sup>14</sup>For example, in *The Population Bomb*, published in 1968, the eminent ecologist Paul Ehrlich predicted that in the 1970s “the world will undergo famines—hundreds of millions of people are going to starve to death in spite of any crash programs embarked upon now. At this late date nothing can prevent a substantial increase in the world death rate....” (p. 11). William and Paul Paddock’s 1967 *Famine 1975! America’s Decision: Who Will Survive?* had a similar message. They advocated a triage approach to foreign aid, in which countries in need of food aid should be divided into three groups, as are soldiers injured in battle. The “can’t be saved” group, which should receive no aid, included India and the Philippines, both of which have since had years of food surplus from their own harvests. Biologist Garrett Hardin, famous for coining the phrase “The Tragedy of the Commons” to describe the very real problems that can arise when there is open access to exploitation of a natural resource, published *The Limits of Altruism* in 1977 in support of a “tough-minded” approach that recognized that countries like India had exceeded their “carrying” capacity.

Agricultural Research, which played an instrumental role in the green revolution (Alston, Dehmer, and Pardey 2006).

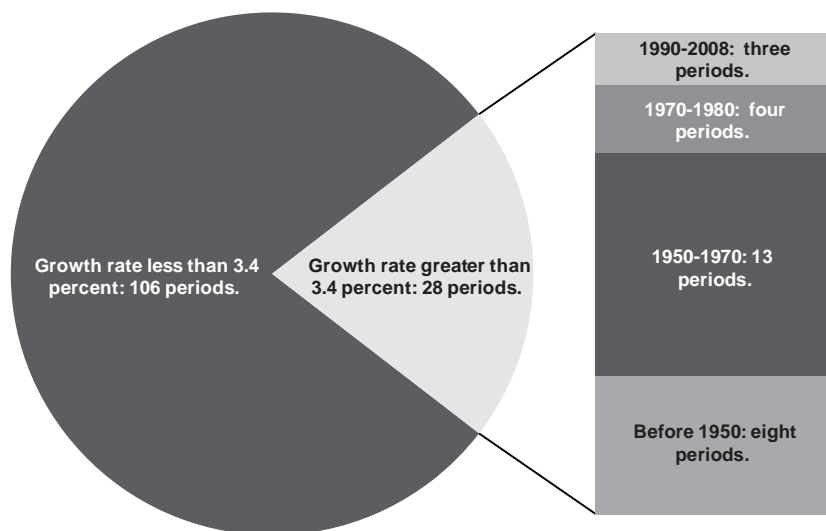
Some may suggest that we can count on the private sector to solve the problem. Indeed, seed and biotech firms have a range of technologies in prospect if not already in the pipeline. For instance, speaking at the U.S. Department of Agriculture's Agricultural Outlook Forum in February 2008, DuPont Vice President and General Manager and Pioneer Hi-Bred President Paul Schickler said, "We expect the traits and technologies in our product pipeline to help meet that demand by doubling the rate of genetic gain—targeting a 40% yield increase in our corn and soybean products over the next 10 years." More recently, in an article in the *New York Times* in June 2008, Andrew Pollack reported that "Monsanto, the leader in agricultural biotechnology, pledged Wednesday to develop seeds that would double the yields of corn, soybeans, and cotton by 2030 and would require 30% less water, land, and energy to grow."<sup>15</sup>

Such prospects might provide grounds for optimism about the potential of agricultural supply to more than keep pace with demand. But even if the technology possibilities can be realized (and adopted in some parts of the world), there are big differences between what is possible in the laboratory and what happens in farmers' fields. We have to remember that the regulatory approval process is long and expensive and getting longer and more expensive for new biotech crop varieties, so the rates of innovation will be slower in farmers' fields than in the laboratories. And it is still the case that much of the world has not begun to adopt biotech varieties because of perceived market resistance or other political barriers, so the benefits from any rapid yield gains in biotech crop varieties will accrue only on a fraction of farmers' fields around the world.

Relative to past performance, the claims by Monsanto and DuPont about potential yield gains seem very optimistic. The rates of yield gain realized in farmers' fields would have to match the highest ever, as recorded in the 1960s and 1970s, and recent yield growth rates have not been nearly so fast. Both claims imply a sustained compound growth rate of about 3.4% per year, a rarity in recent history. Figure 3.6 identifies the number of years for which corn yield growth averaged 3.4% per year over the previous decade. This occurred

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<sup>15</sup>The Schickler quote is available at <http://www.pioneer.com/web/site/portal/menuitem.d4f86eb536a8ca24c5892701d10093a0/> and the Pollack article is at <http://www.nytimes.com/2008/06/05/business/worldbusiness/05crop.html?pagewanted=print>.



**Figure 3.6. Number of 10-year periods since 1875 when growth in corn yields exceeded 3.4% per year**

*Sources:* Authors' calculations based on data reported in Beddow, Hurley and Pardey 2009, derived from Alston and Pardey 2006 and QuickStats: Agricultural Statistics Database.

*Note:* Values are attributed to the end of each 10-year period. For example, the 1950-1970 category includes all 10-year periods ending between 1950 and 1969 (thus starting between 1941 and 1960).

in only 28 instances during the past 133 years, and about half of those instances were for 10-year periods ending in the 1950s and 1960s. In contrast, only one-sixth of the years during the 1990s and since 2000 had corn yield growth rates in excess of 3.4% per year over the preceding 10 years. While it is feasible to sustain (global) growth rates that would achieve the Monsanto and Du Pont targets, it seems improbable, especially given recent trends in crop yields.<sup>16</sup> To do so would mean the future must be substantially different from the more recent past.

<sup>16</sup>The more-recent evidence further lengthens the odds of achieving a 3.4%-per-year worldwide growth rate of crop yields. World average yield growth rates exceeded that target for corn for only two decade periods ending after 1961 (i.e., the decades ending in 1973 and 1979); wheat for seven decade periods (four of which terminated in years during the 1970s); and soybeans only once. Rice yields never sustained that average rate of growth for a 10-year period. Moreover, average growth in crop yields for all four crops never exceeded the 3.4%-per-year threshold for any decade period ending after 1990. Further, the Monsanto claim suggests that yield growth rates in excess of 3.4% per year can be sustained over a period of two decades, which, historically, even in the United States has not occurred since the decade ending in 1960.

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