NZARES New Zealand Agricultural & Resource Economics Society (Inc.)

Agricultural R&D, Productivity and Global Food Security

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Agricultural R&D, Productivity and Global Food Security

Philip G. Pardey

University of Minnesota and University of Adelaide

NZARES Annual Conference

Tahuna Conference Centre, Nelson

Thursday August 25 ,2011

Department of APPLIED ECONOMICS

UNIVERSITY OF MINNESOTA

INSTEPP INTERNATIONAL SCIENCE & TECHNOLOGY PRACTICE & POLICY

AGMARDT THE AGRICULTURAL AND MARKETING RESEARCH AND DEVELOPMENT TRUST

Global Population

POPULATION

REVIEW

7 Billion and Counting

David E. Bloom

The world is currently in the midst of the greatest demographic upheaval in human history. Dramatic reductions in mortality, followed (but with a lag) by equally marked reductions in fertility, resulted in a doubling of world population between 1960 and 2000. A further increase of 2 to 4.5 billion is projected for the current half-century, with the increase concentrated in the world's least developed countries. Despite alarmist predictions, historical increases in population have not been economically catastrophic. Moreover, changes in population age structure have opened the door to increased prosperity. Demographic changes have had and will continue to have profound repercussions for human well-being and progress, with some possibilities for mediating those repercussions through policy intervention.

U.S. Census Bureau

U.S. & World Population Clocks

You are here: Census.gov › U.S. and World Population Clocks

U.S. 311,959,625

World 6,954,677,857

21:21 UTC (EST+5) Aug 10, 2011

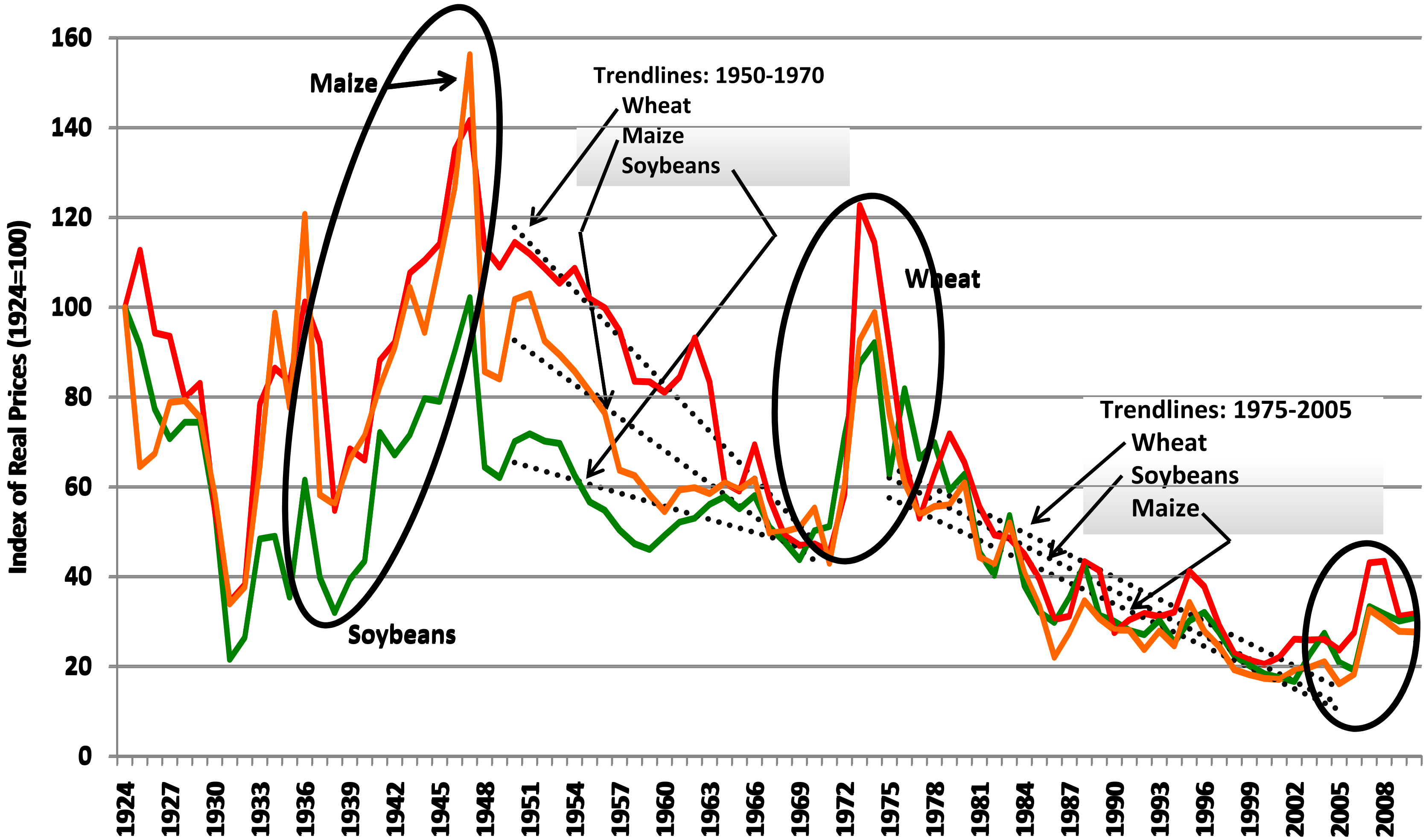
Monthly World population figures:

07/01/11	6,946,043,989
08/01/11	6,952,589,639
09/01/11	6,959,135,290
10/01/11	6,965,469,791
11/01/11	6,972,015,442
12/01/11	6,978,349,943
01/01/12	6,984,895,594
02/01/12	6,991,441,244
03/01/12	6,997,564,595
→ 04/01/12	7,004,110,246
05/01/12	7,010,444,747
06/01/12	7,016,990,398
07/01/12	7,023,324,899

Prices

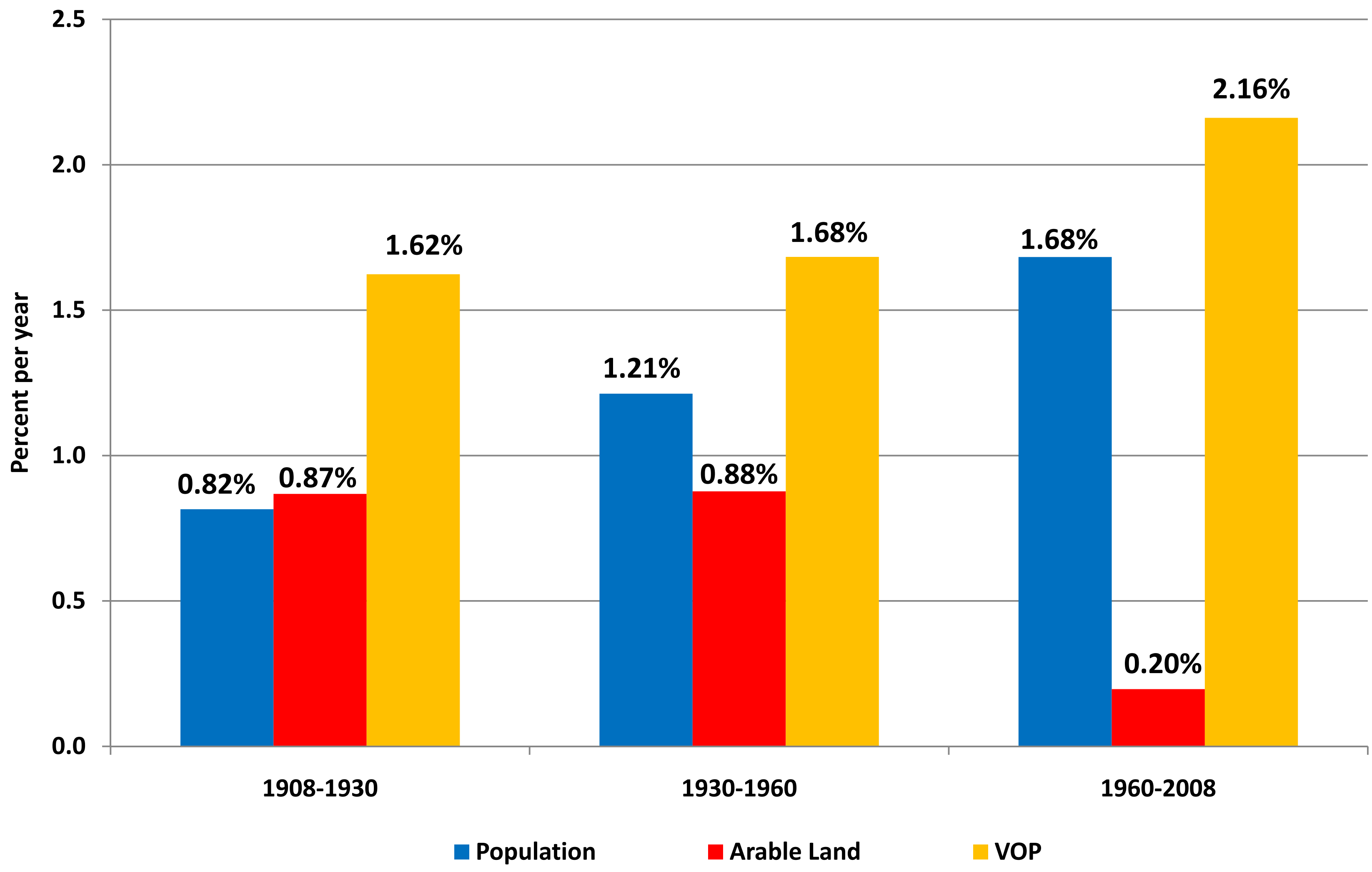

1960s
THE WALL STREET JOURNAL.
APRIL 4, 1967 ~ VOL. 169
The parched plains: wheat lands drought cuts crop, may boost prices of bread, fl
Foreign Agriculture.
June 1, 1964 ~ n.s.:2:22
Western Europe's Rising Food Prices May Affect Farm Import Policies
U.S.News & WORLD REPORT
ember 8, 1969 ~ Vol. 67
Why the high price of food
2010-11
VOANews.com LEARNING ENGLISH
VOA Learning English
Tuesday, 18 January 2011
Special English
Agriculture
World Food Prices Expected to Stay High or Keep Rising
17 January 2011
Food Prices Hit Record High. What
Posted by KRISTA MAHR
The Economist
Food in Mexico
Centéotl's pricier feast
The tortilla-makers cry wolf
Jan 6th 2011 | MEXICO CITY | from PRINT EDITION
GALLONS of blood were spilled by the Aztecs to appease Centéotl, the god of maize. Now someone must have upset him: rising maize prices could force the price of tortillas up by 50%, the makers of the corn pancakes warned last month. That matters: maize
2007
The Christian Science Monitor
Rising food prices curb aid to global poor
Food commodity prices have risen by 21 percent since 2005, which will stretch aid groups' resources.
The Economist
Food prices
The end of cheap food
Rising food prices are a threat to many; they also present the world with enormous opportunity
Dec 6th 2007 | from PRINT EDITION
FOR as long as most people can remember, food has been getting cheaper and farming has been in decline. In 1974-2005 food prices on world markets fell by three-quarters in real terms. Food today is so cheap that the West is battling gluttony even as it scrapes piles of half-eaten leftovers into the bin.
That is why this year's price rise has been so extraordinary. Since the spring, wheat prices have
The Economist $ food index
TIME
The Rising Costs of Food
By JOHN CLOUD Thursday, Jun. 21, 2007
Overabundance at a typical supermarket in Bentonville, Ark., prices are low, but at what cost?
Nina Berman / Redux
All but the wealthiest readers will have noticed by now that food costs have risen this year. In May grocery prices were 4.4% higher than they were the previous May. If 4.4%

Deflated U.S Commodity Prices, 1924-2010 (CPI deflator)



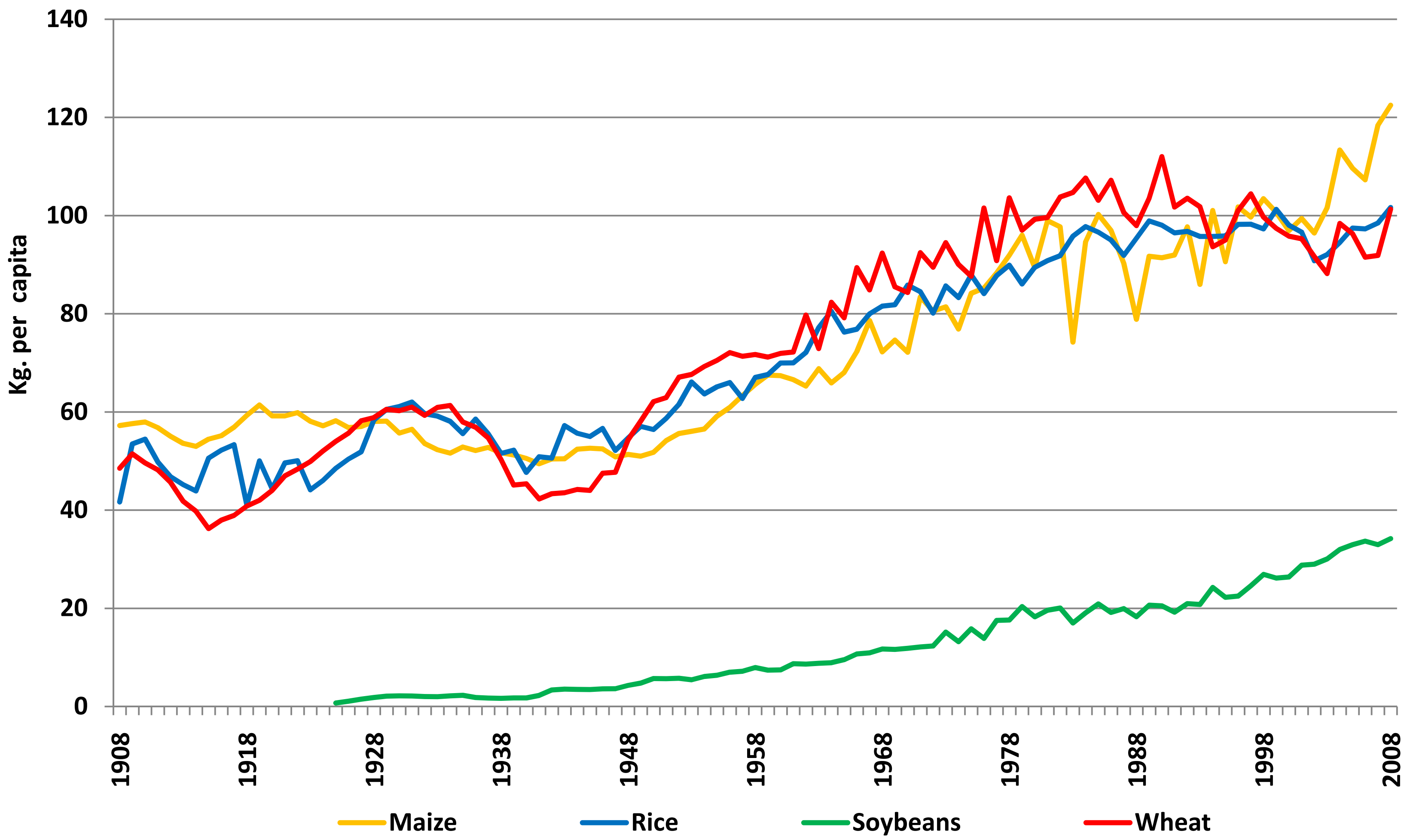
A Century of Global Production

Global Production, Population & Area Growth, 1908-2008



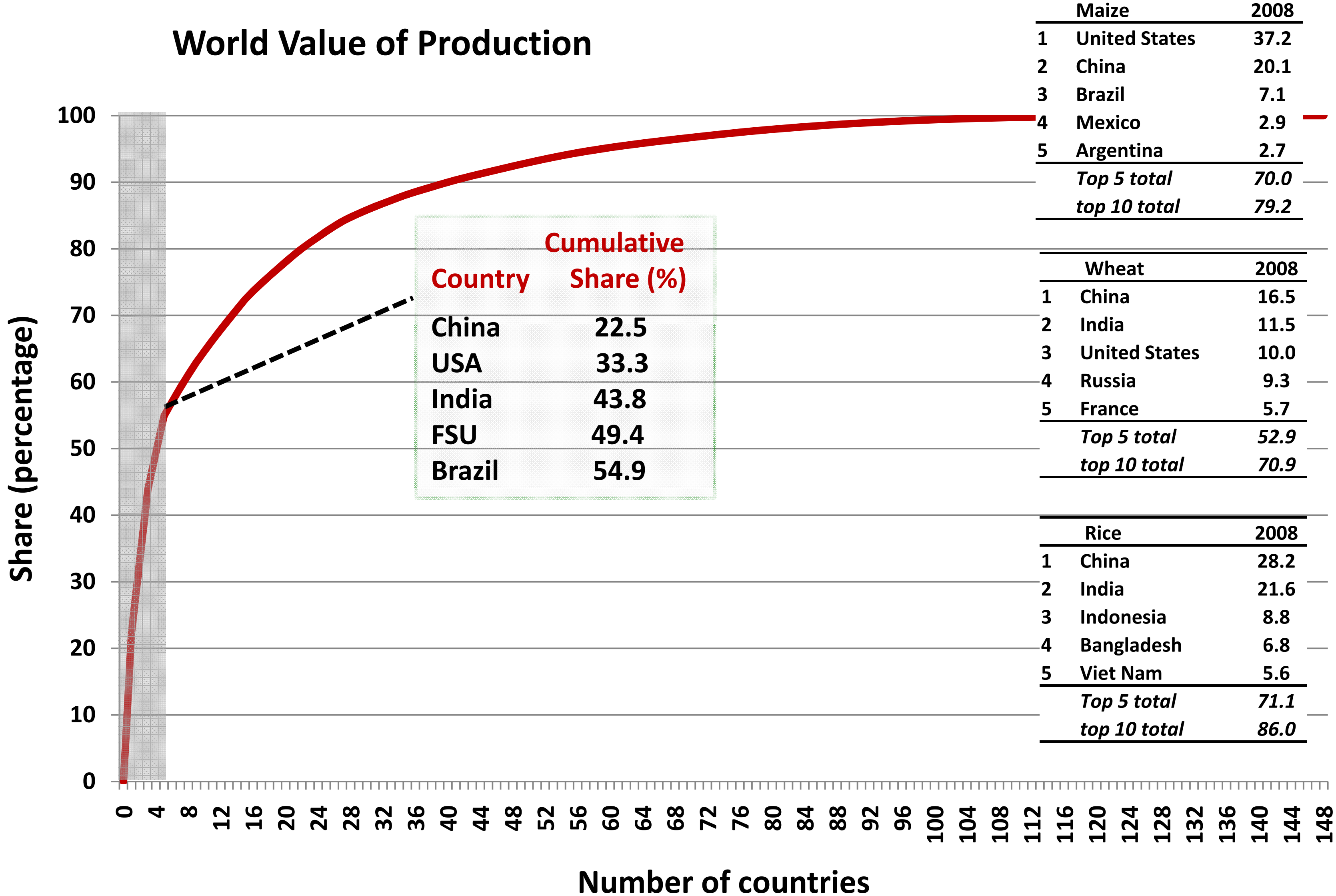
Source: Pardey (2011)

Global Crop Production (per capita), 1908-2008



Source: Pardey (2011)

Spatial Concentration of Global Agricultural Production, 2006-08 average



Country	Cumulative Share (%)
China	22.5
USA	33.3
India	43.8
FSU	49.4
Brazil	54.9

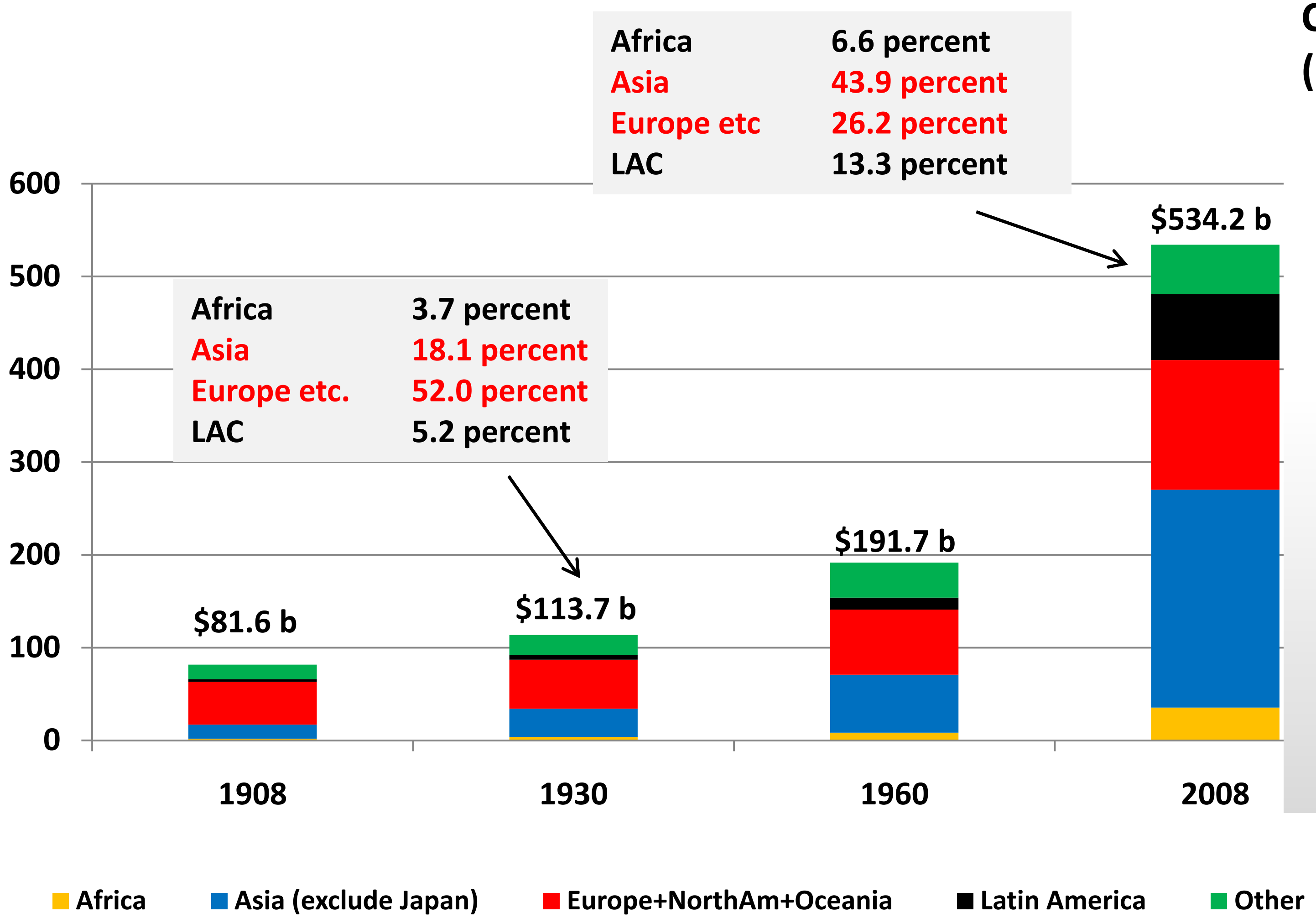
	Maize	2008
1	United States	37.2
2	China	20.1
3	Brazil	7.1
4	Mexico	2.9
5	Argentina	2.7
	Top 5 total	*70.0*
	top 10 total	*79.2*

	Wheat	2008
1	China	16.5
2	India	11.5
3	United States	10.0
4	Russia	9.3
5	France	5.7
	Top 5 total	*52.9*
	top 10 total	*70.9*

	Rice	2008
1	China	28.2
2	India	21.6
3	Indonesia	8.8
4	Bangladesh	6.8
5	Viet Nam	5.6
	Top 5 total	*71.1*
	top 10 total	*86.0*

Source: Pardey (2011)

Global Value of Field Crops Production, 1908-2008



Crops included (15 field crops)

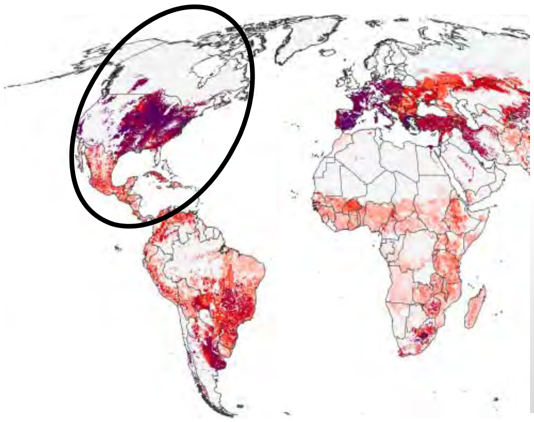
- Barley
- Buckwheat
- Cassava
- Maize
- Millet
- Oats
- Potatoes
- Rice
- Rye
- Sorghum
- Soybean
- Sugarbeet
- Sugarcane
- Sweet potatoes
- Wheat

Source: Pardey (2011)

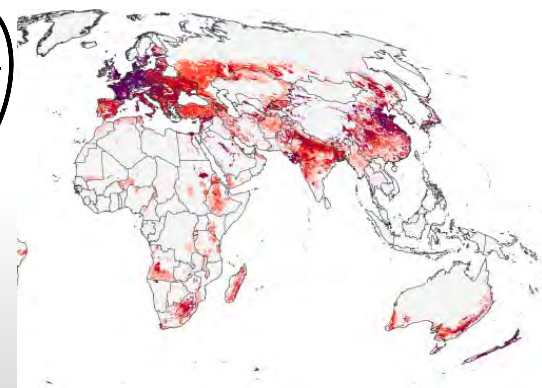
Global Productivity in the Long Run

Spatial Distribution of Crop Yields, 2000 (SPAM ver 3.0)

Panel a: Maize

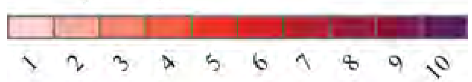


Panel b: Wheat

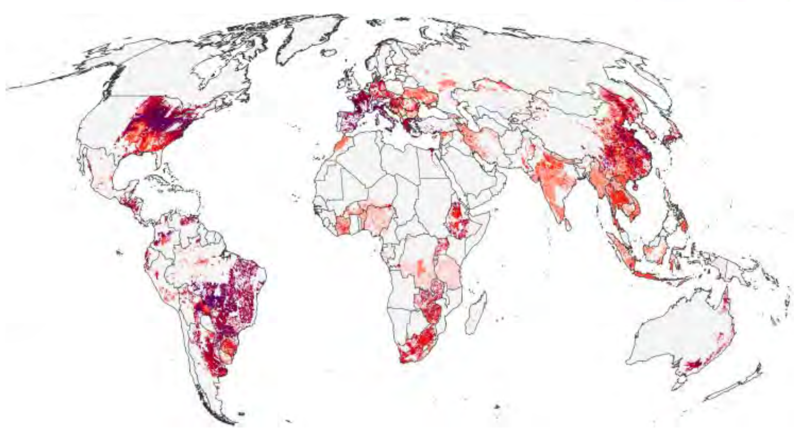


Share of World's High-Yielding Area

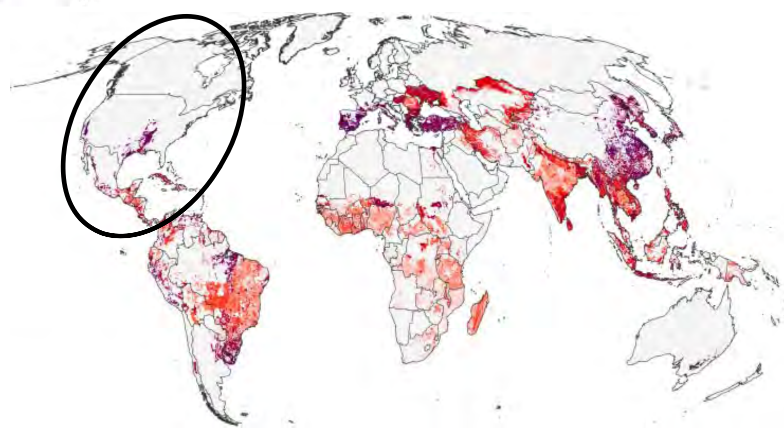
	US	Africa	Australia
		(percent)	
Maize	32	2.5	1.6
Wheat	28	3.6	1.6
Soybean	25	5.6	2.1
Rice	5.3	5.7	1.3



Panel c: Soybean

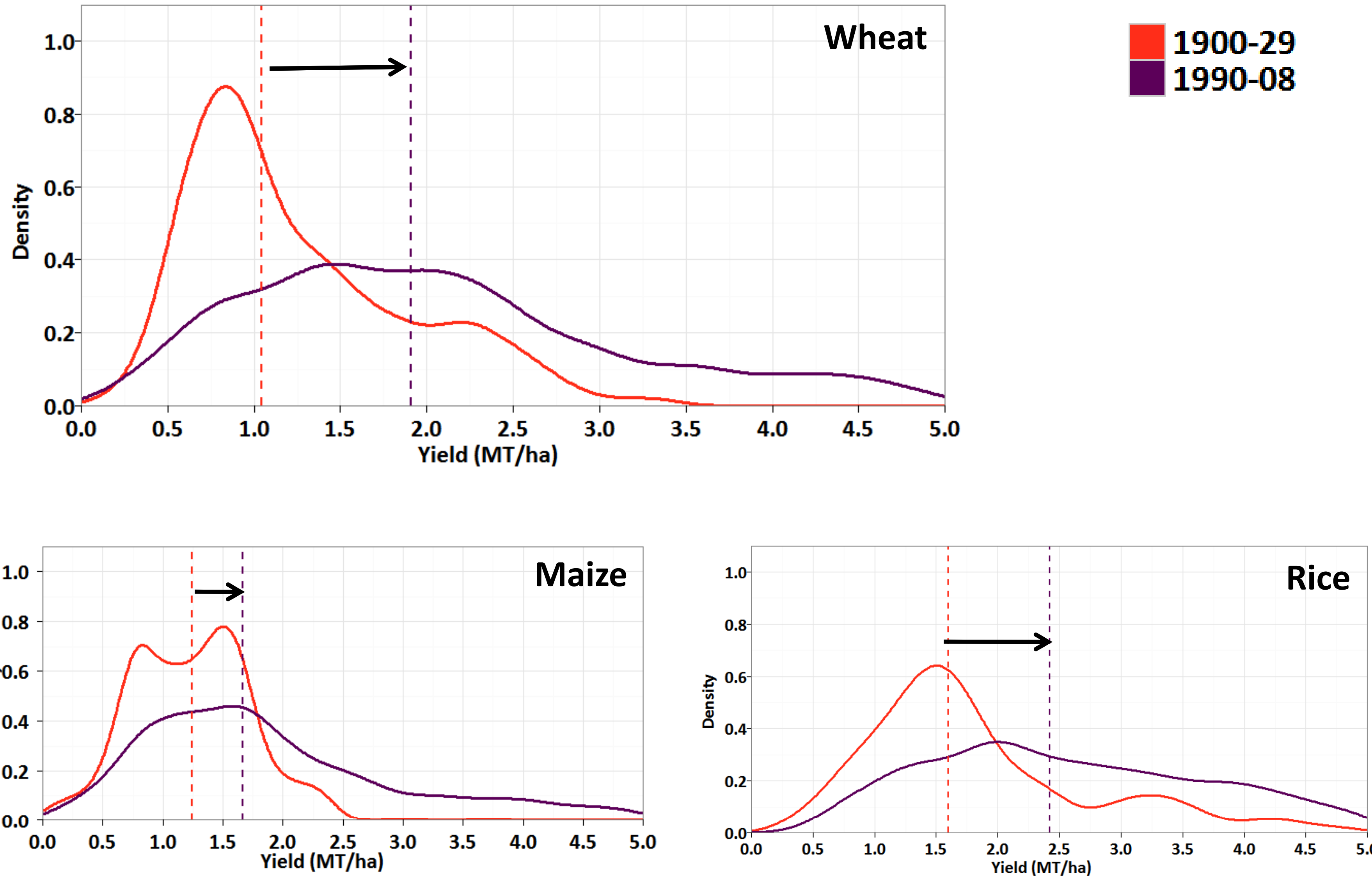


Panel d: Rice



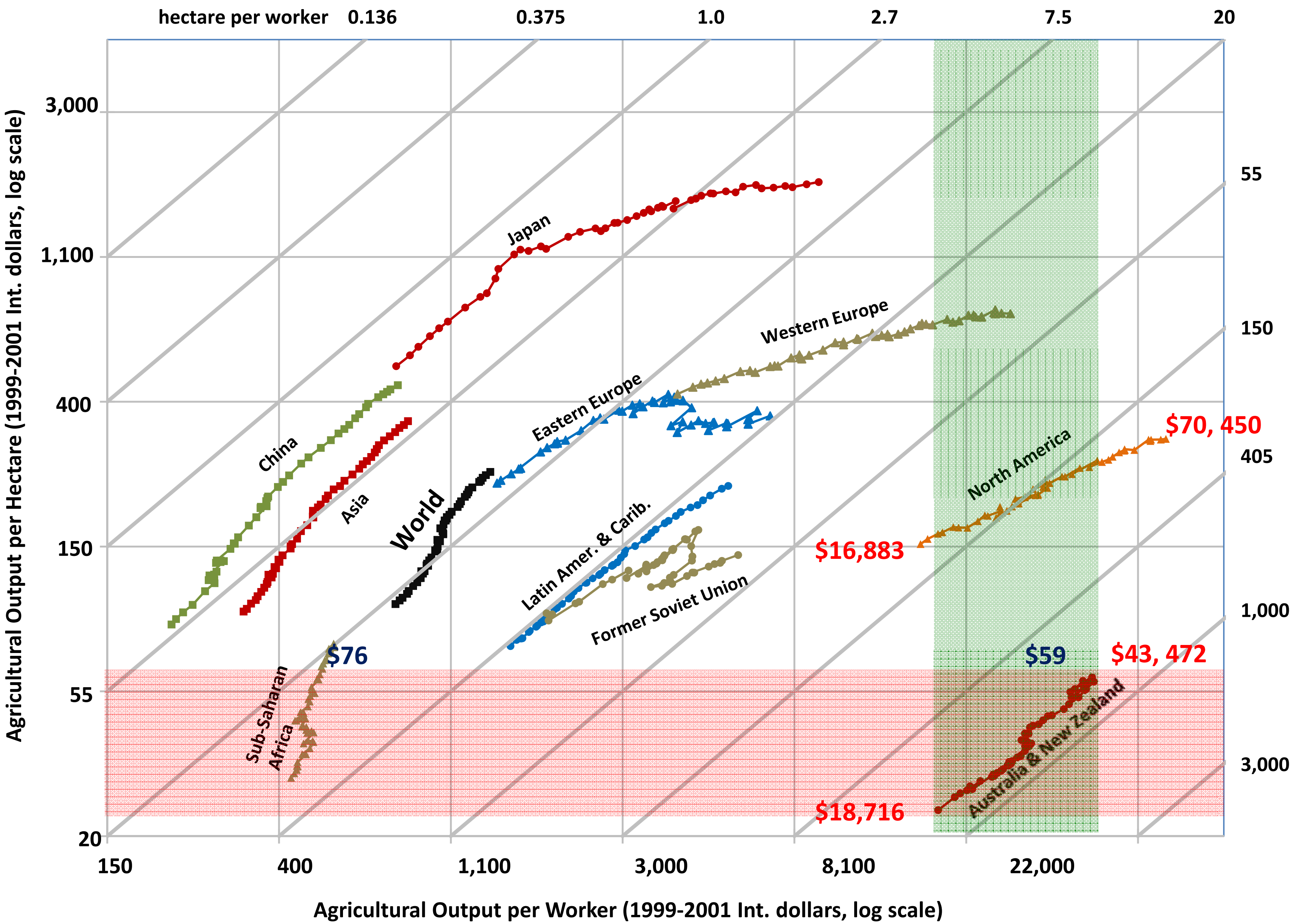
Source: HarvestChoice (2010)

A Century of Global Crop Yield Distributions



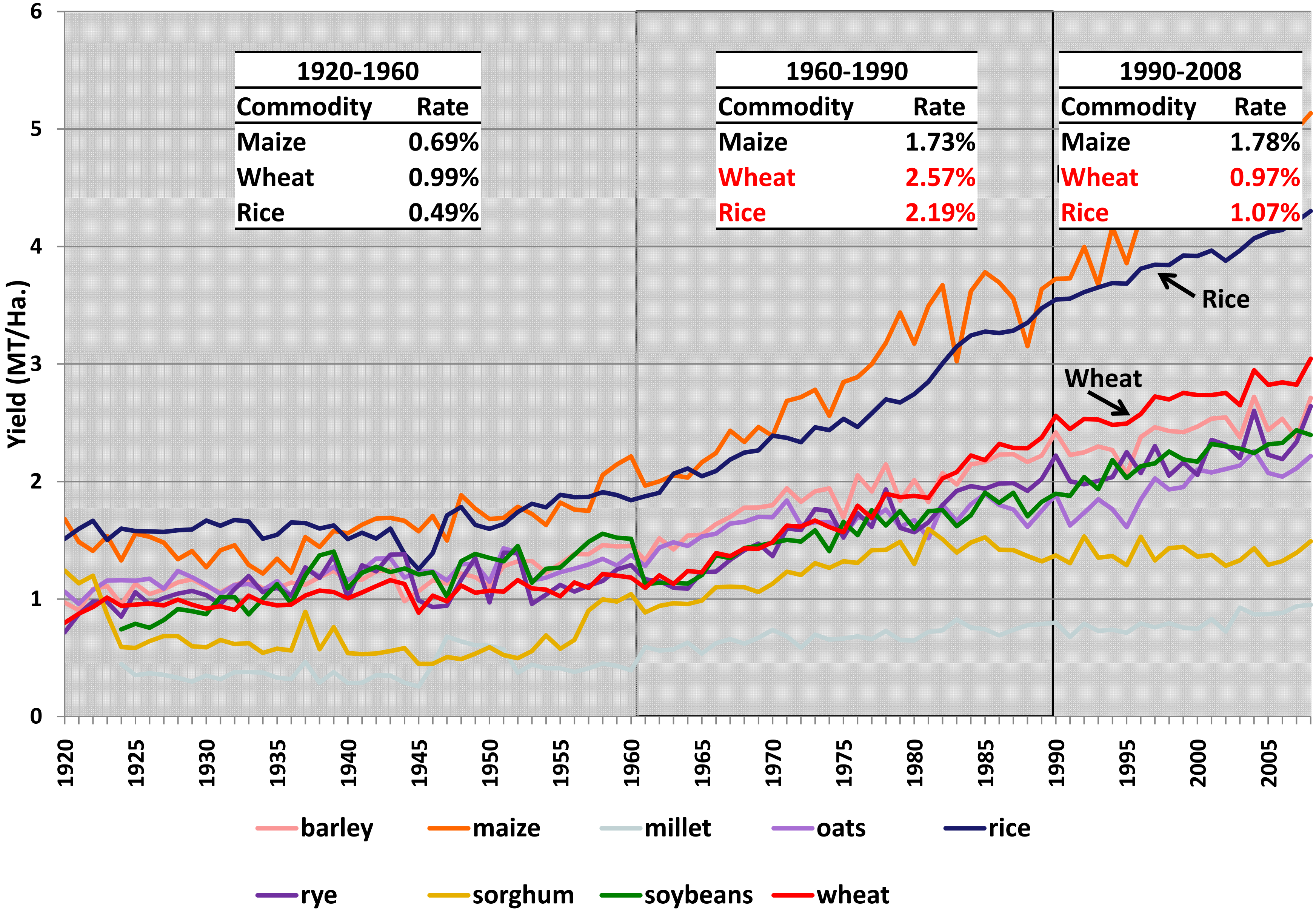
Source: Pardey, Beddow, Rao and Hurley (forthcoming)

Global Land and Labor Productivity Patterns, 1961-2008



Is Agricultural Productivity Growth Slowing?

Global Crop Yields Averages, 1890-2008

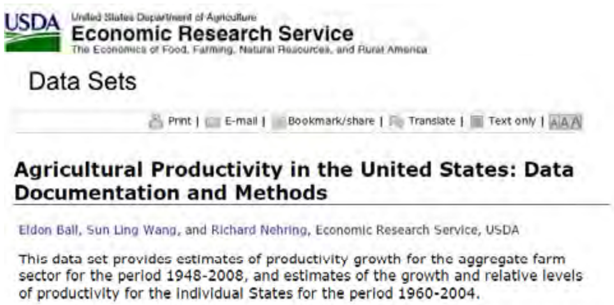


Source: Pardey, Beddow, Xudong and Hurley (forthcoming)

Partial Factor Productivity Growth, 1961-1990 vs 1990-2008

Groupings		Land Productivity				Labor Productivity		
		1961-90	1990-08	Difference		1961-90	1990-08	Difference
		Percent per year						
World (simple av.)		1.78	1.55	-0.23		1.74	1.84	[0.09]
World minus China		1.79	1.53	-0.26		1.09	0.75	-0.35
80% (N = 22)		1.98	2.21	0.23		0.97	1.78	0.82
80% minus China		1.96	1.88	-0.08		2.68	3.06	0.38
< 80% (N= 158)		1.82	1.17	-0.64		1.11	0.24	-0.87

Views on U.S. Agricultural Productivity Growth Rates


USDA United States Department of Agriculture
Economic Research Service
The Economics of Food, Farming, Natural Resources, and Rural America

Data Sets

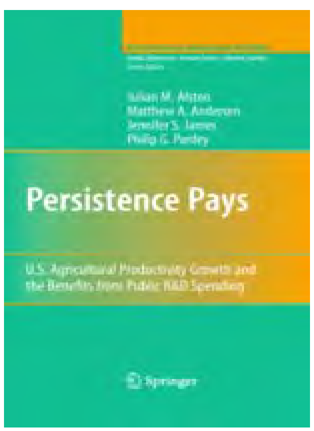
Print | E-mail | Bookmark/share | Translate | Text only | AAA

Agricultural Productivity in the United States: Data Documentation and Methods

Eldon Ball, Sun Ling Wang, and Richard Nehring, Economic Research Service, USDA

This data set provides estimates of productivity growth for the aggregate farm sector for the period 1948-2008, and estimates of the growth and relative levels of productivity for the individual States for the period 1960-2004.

Ball, Wang and Nehring (2010) reported that "… statistical analysis of the [USDA] data does not provide evidence of a longrun productivity slowdown."



Alston, Anderson, James and Pardey (2010a, pp. 120–121) concluded "There can be little doubt that the InSTePP *MFP* data exhibit evidence of a slowdown in multifactor productivity growth in the period 1990–2002 compared with the previous [1949–1990] period."

U.S. Multifactor Productivity, 1910-2007

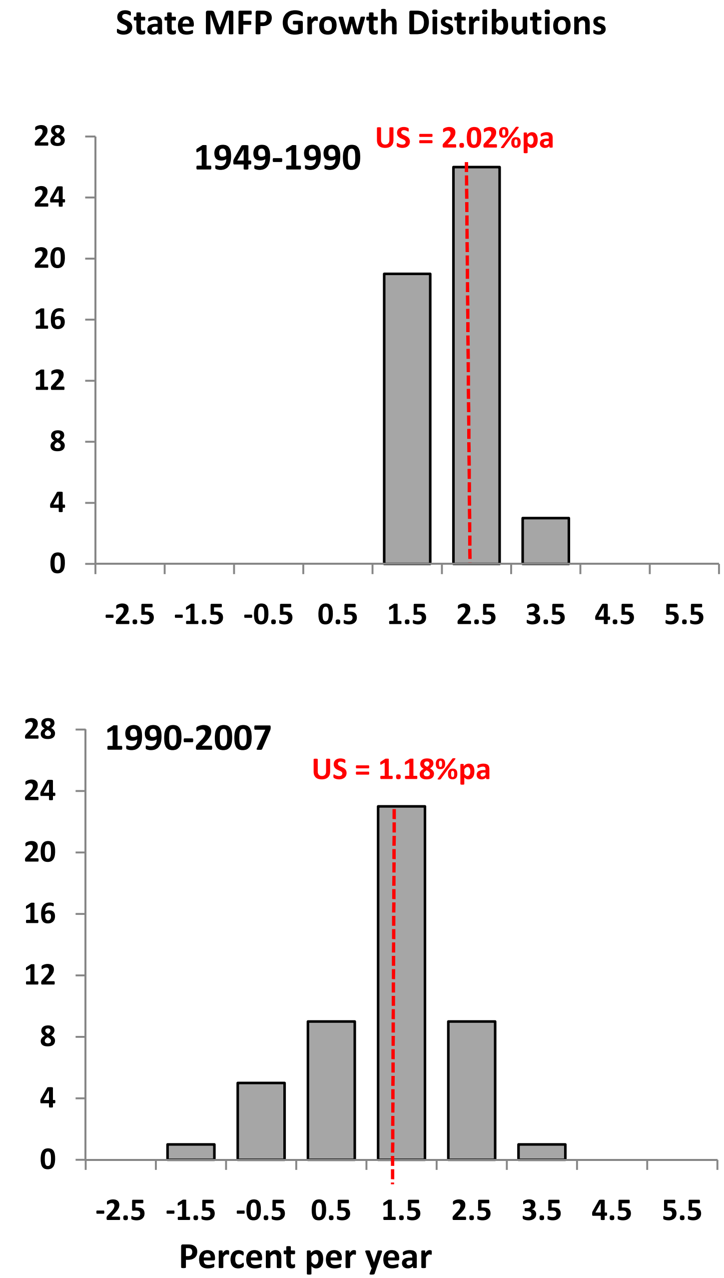
InStePP Production Accounts

Outputs

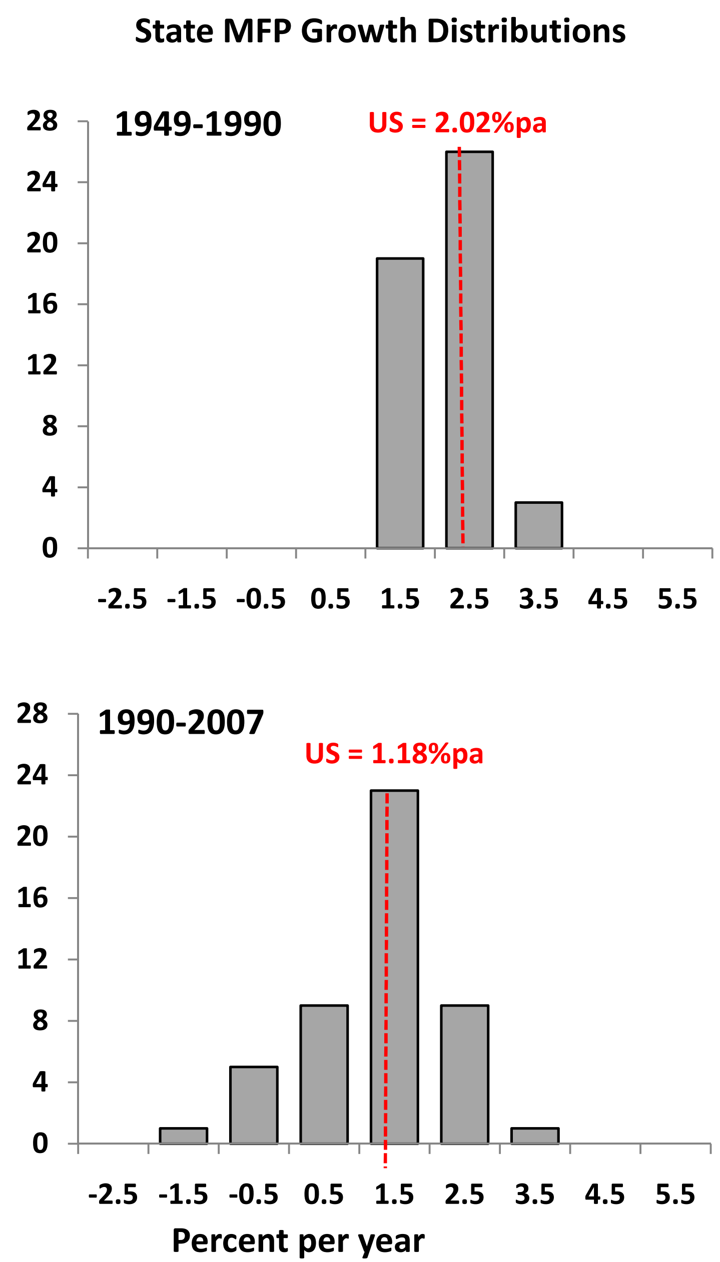
- Crops 61
- Livestock (9)
- Miscellaneous (4)

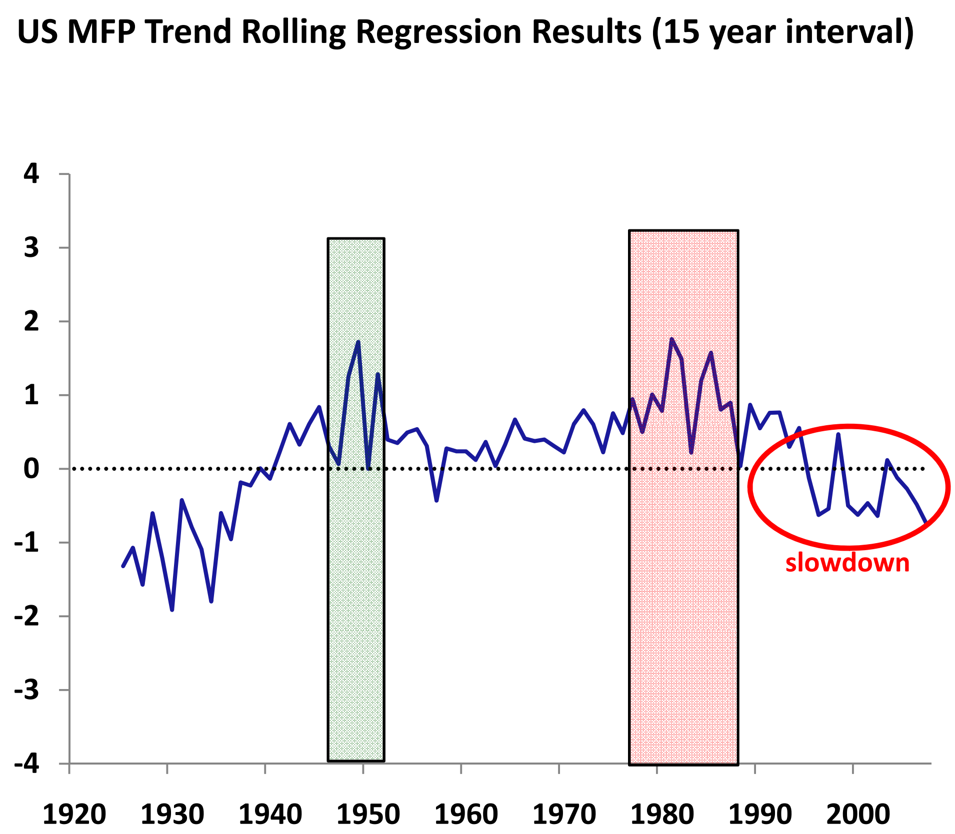
Inputs

- Land (3)
  - Cropland, irrigated cropland, pasture and grassland
- Labor (32)
  - Family labor
  - Hired labor
  - Operator labor (30)
    - Education: 0–7 years, 8 years, 1–3 years of high school, 4 years of high school, 1–3 years of college, 4 years or more of college
    - Age: 25–34, 35–44, 45–54, 55–64, or 65 or more years of age
- Capital (12)
  - Machinery (6)
    - Automobiles, combines, mowers and conditioners, pickers and balers, tractors, trucks
  - Biological capital (5)
    - Breeding cows, chickens, ewes, milking cows, sows
  - Buildings
- Materials (11)
  - Electricity, purchased feed, fuel, hired machines, pesticides, nitrogen, phosphorous, potash, repairs, seeds, miscellaneous purchases



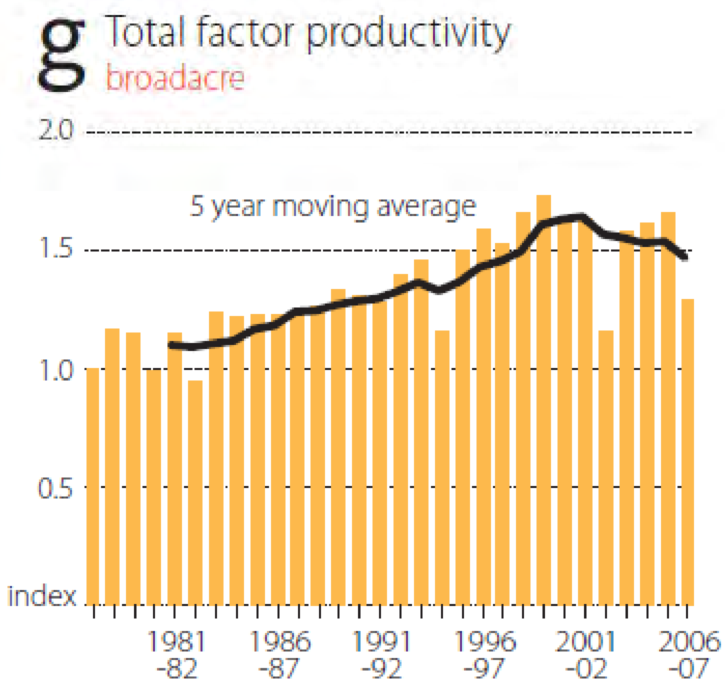
U.S. Multifactor Productivity, 1910-2007

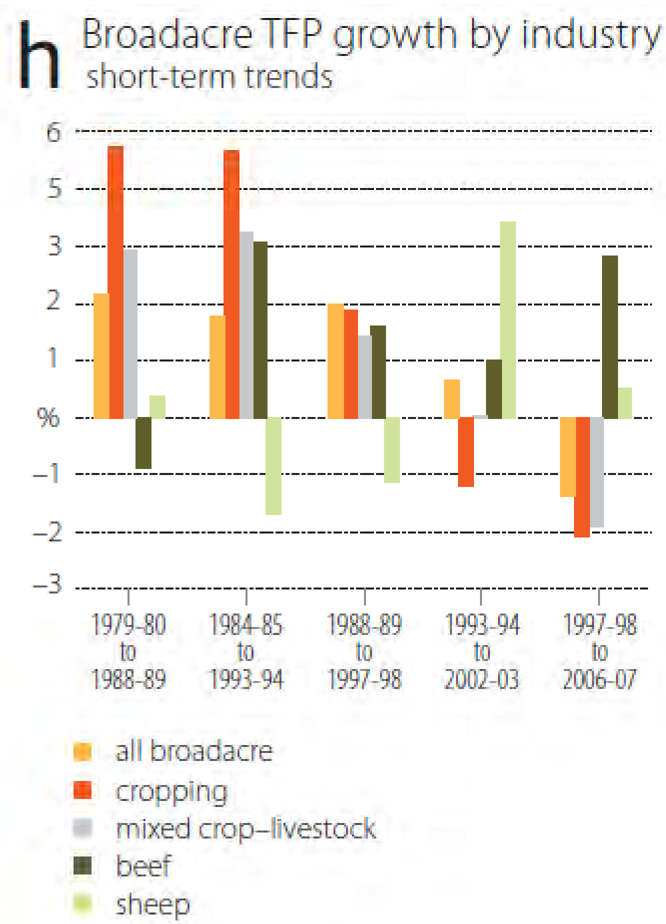




Source: Alston, Anderson, James and Pardey (2011 forthcoming)

Australian Broadacre Agricultural Productivity Performance, 1978-2007





Source: Nossal et al. (2009)

On the Desirability of Zero Productivity Growth!

"Since we know little about the causes of productivity increase, the indicated importance of this element may be taken to be some sort of measure of our ignorance about the causes of economic growth in the United States."

Abramovitz (AER 1956, pp. 5-23)

In an idea he attributed to Zvi Griliches, Schultz argued that the economically ideal output-to-input ratio would stay at or close to one, the notion being that "… the closer we come to a one-to-one relationship in our formulation, the more complete would be our (economic) explanation [of the sources of output growth]."

Schultz (1956, p.758)

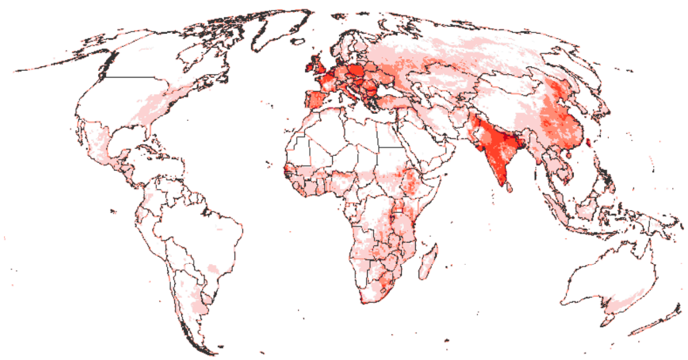
“Sources” of *Measured* Productivity Growth

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

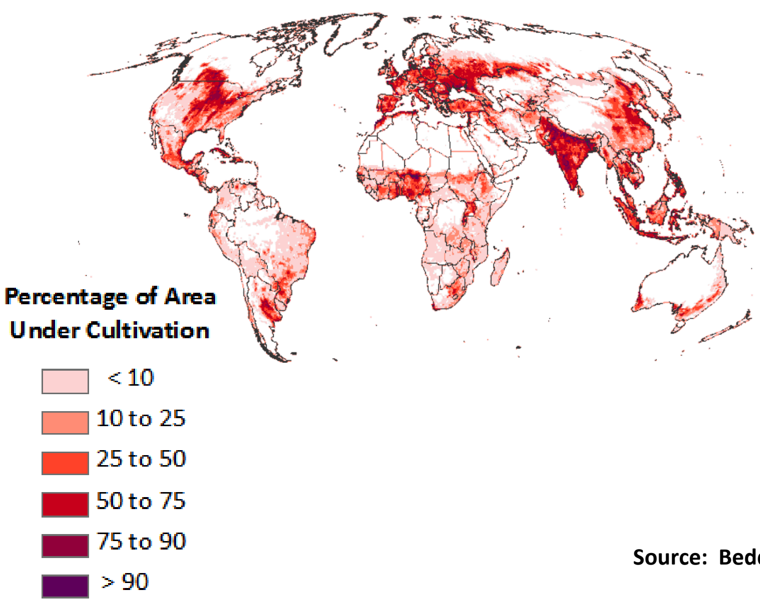
- Technical change (attributable to R&D)
- Scale effects (gains from specialization and integration)
- Mismeasured input growth (e.g., labor quality, land quality)
- Omitted input
  - Biological inputs
  - Energy, chemicals etc. in LDCs
  - Natural inputs
    - Weather (rainfall, temperature, day length, wind, incl. timing)
    - Soil attributes
    - Pests and diseases (exputs)

Changing Location of Agriculture

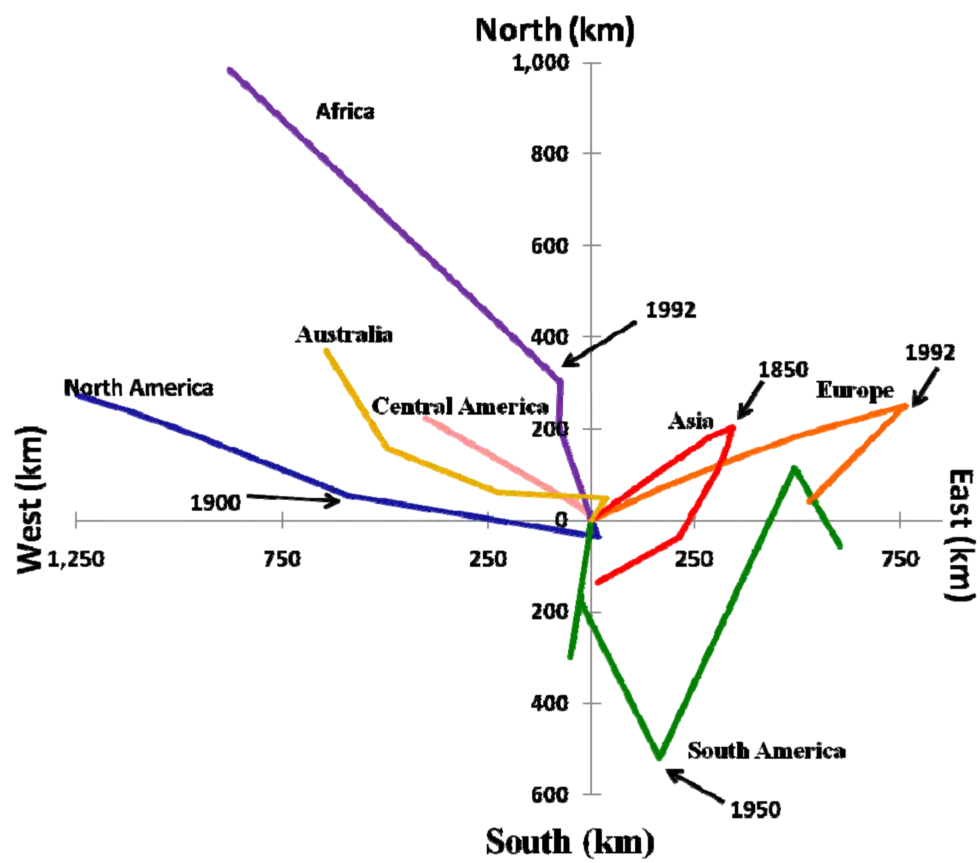
Panel a: Cropland Extent, 1700



Panel b: Cropland Extent, 2000

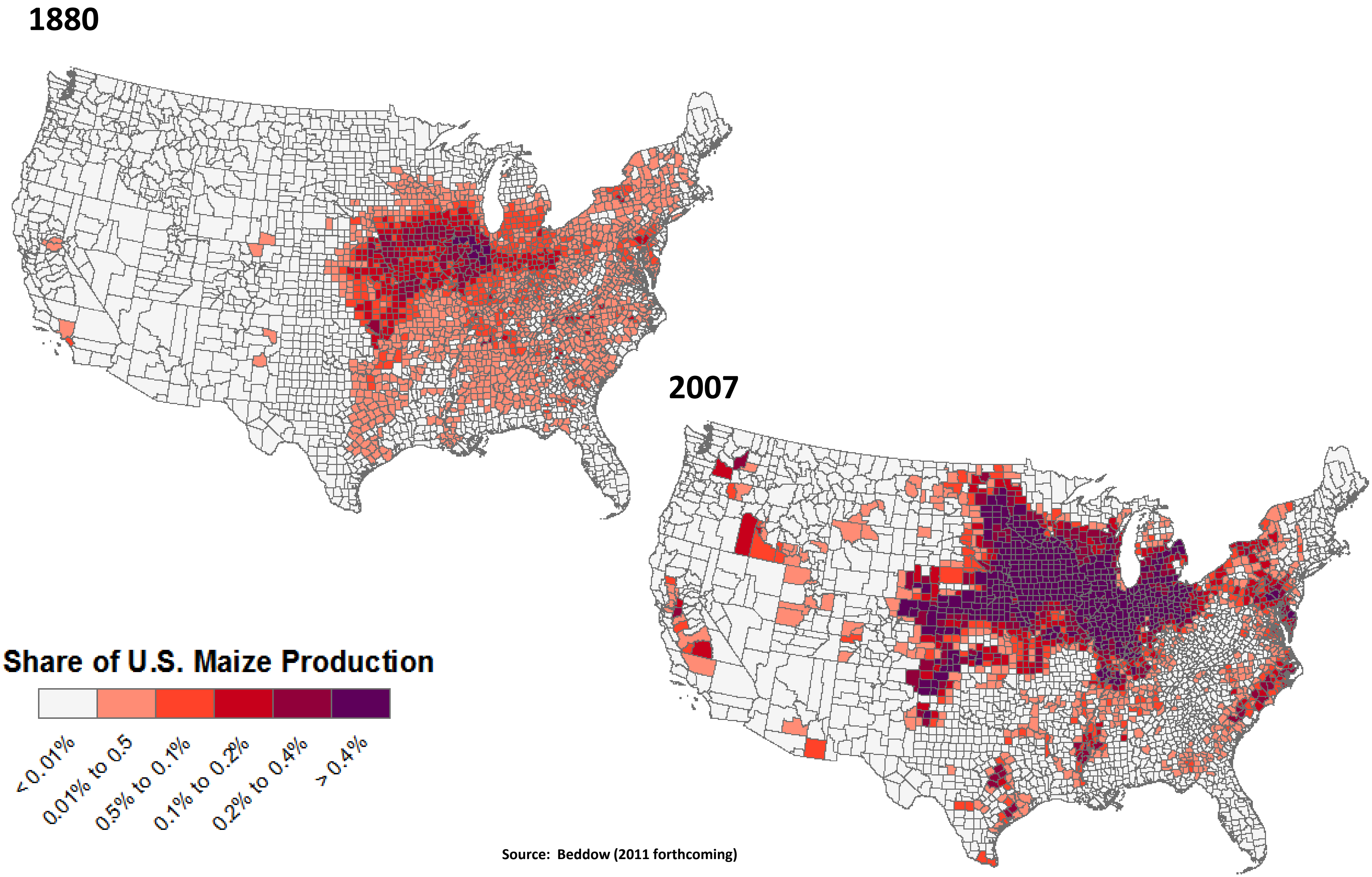


Panel c: Movement of Regional Cropland Centroids, 1700 – 2000



Source: Beddow, Pardey, Koo and Wood (2010)

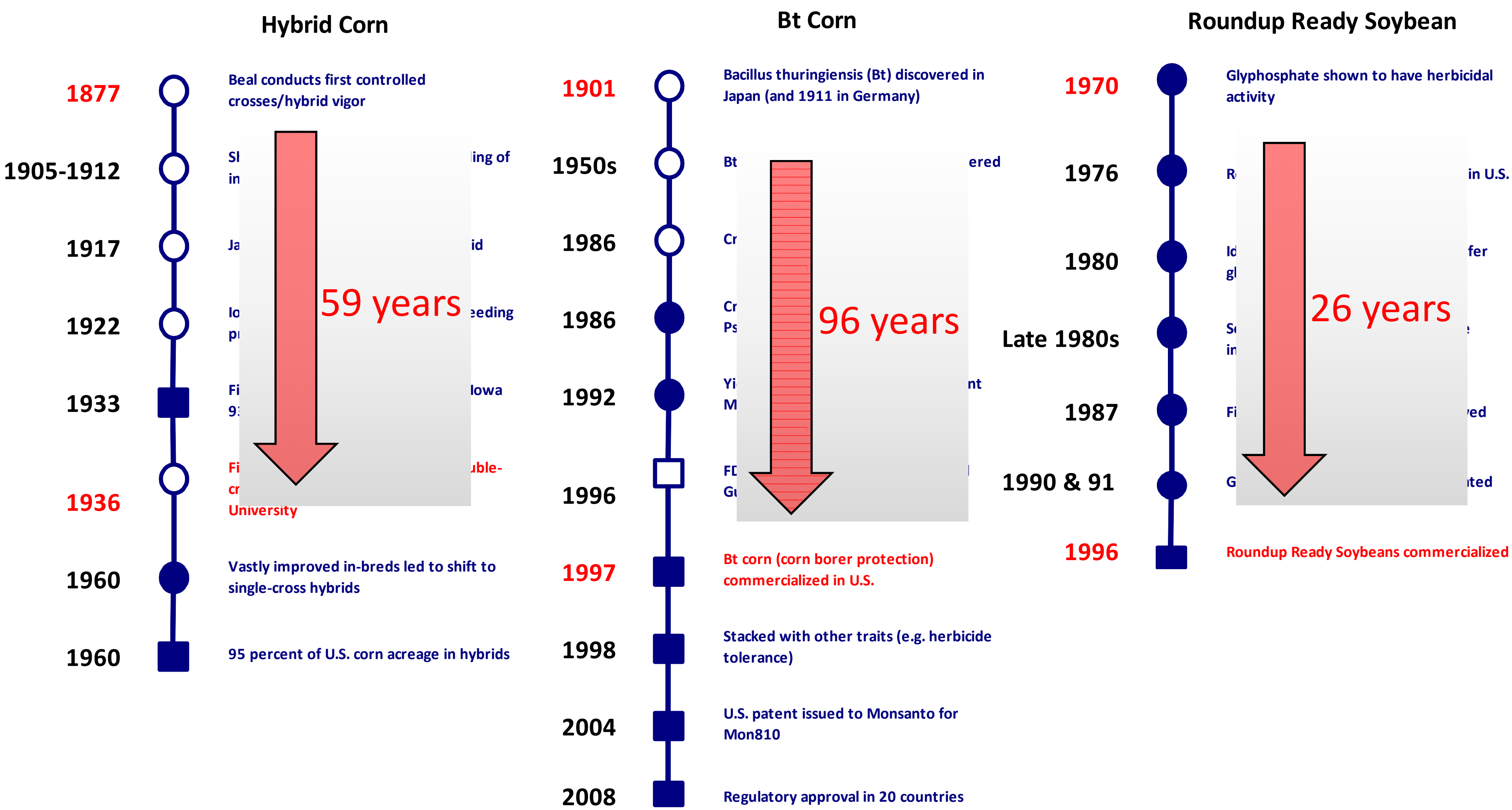
U.S. Maize Production, 1880 and 2007



Source: Beddow (2011 forthcoming)

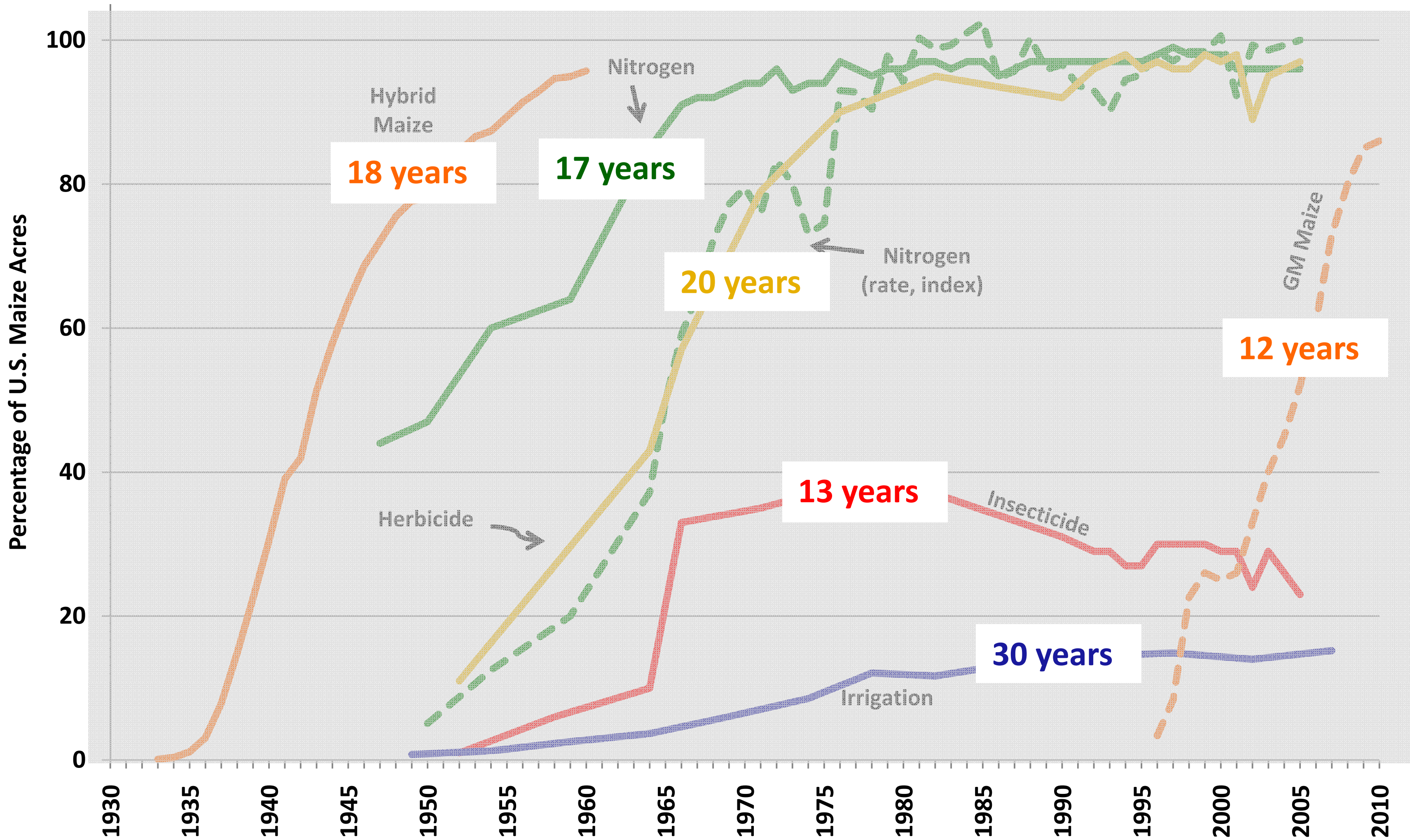
R&D-Productivity Relationships

Illustrative Technology Development Lags



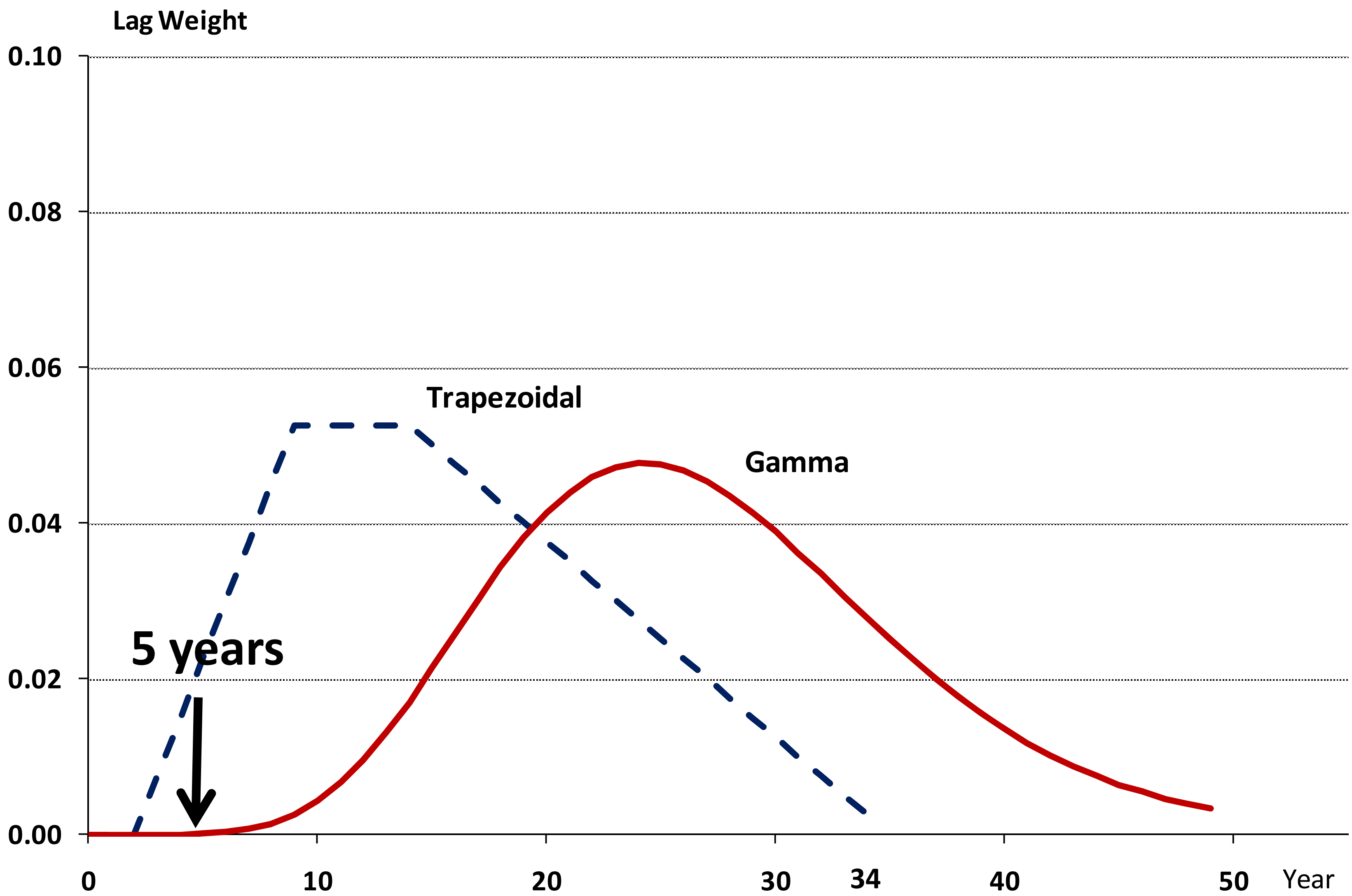
Source: Alston, Pardey and Ruttan (2008) and Alston et al. (2010)

U.S. Maize Technology Adoption Lags



Source: Beddow (2011 forthcoming)

Aggregate R&D-Productivity Lag

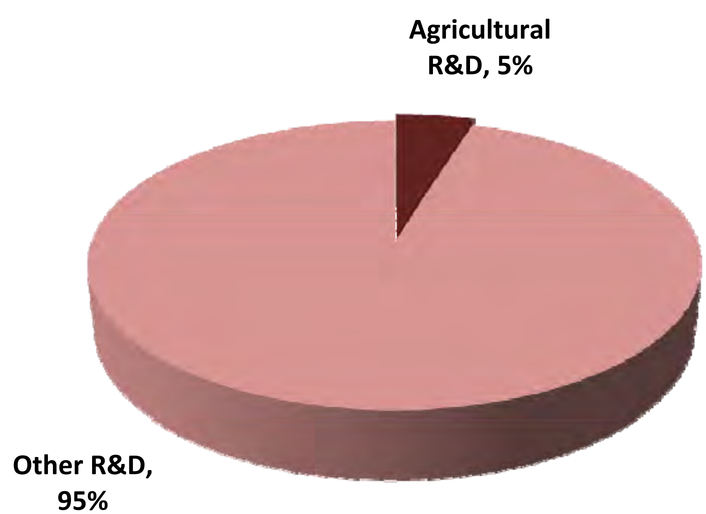


Source: Alston, Pardey and Ruttan (2008) and Alston et al. (2010)

What's Been Happening to Food and Agricultural R&D Investments Globally?

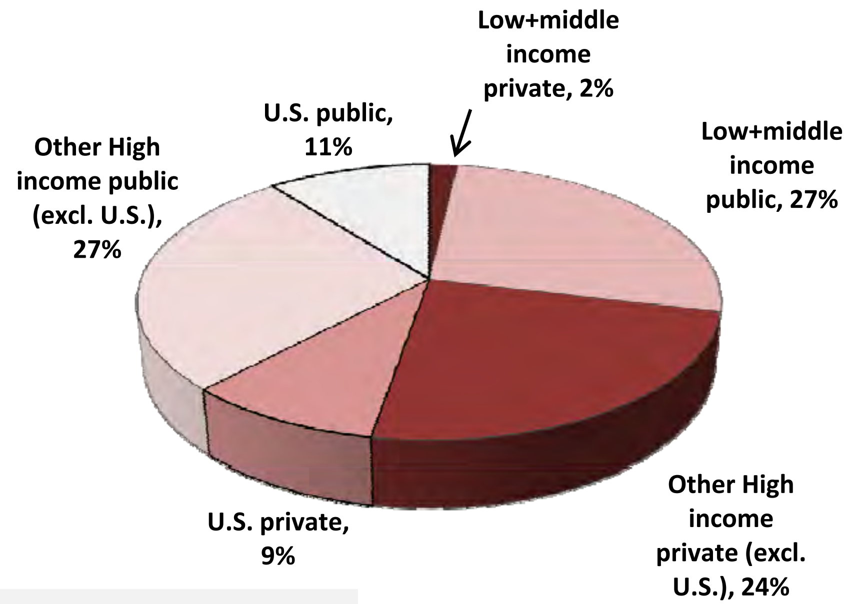
Global Science Spending Landscape, 2000

Total Science



$782.7 billion

Food & Agricultural R&D



$37.8 billion

2007 OECD Total = $30.7 billion

New Zealand share

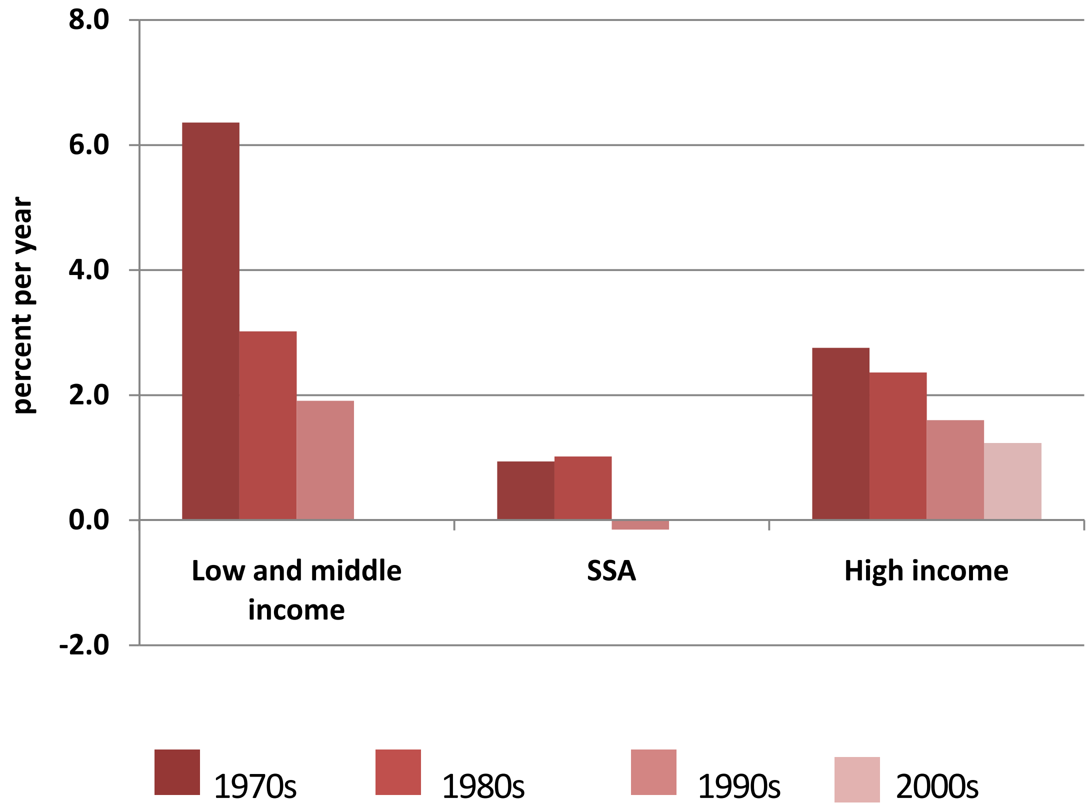
Public	1.4%
Private	0.7%
Total	1.1%

Note: Spending in 2005 prices

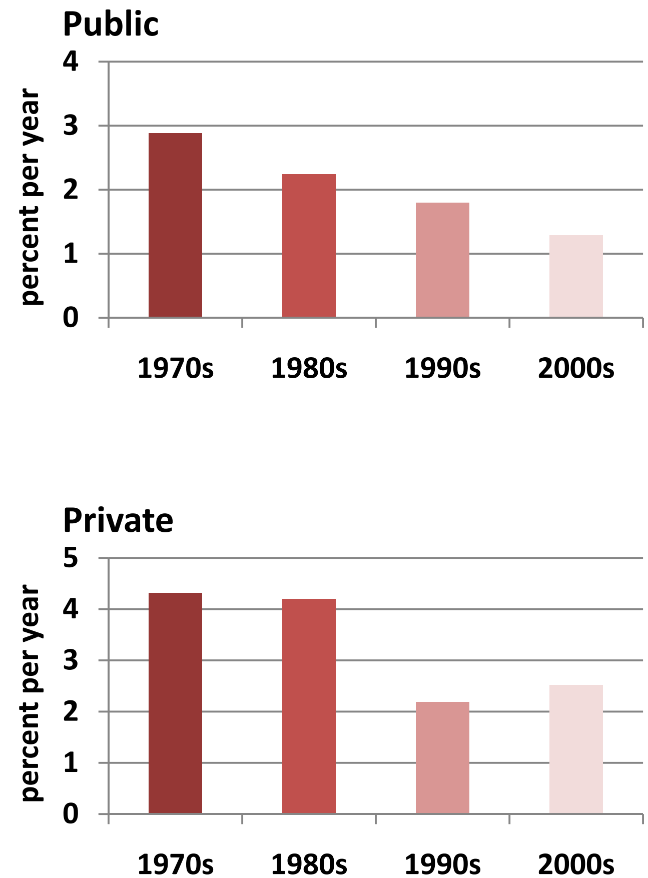
Source: Pardey and Chan-Kang (2011, beta version) and Dehmer and Pardey (2011)

Growth in Food and Agricultural R&D Expenditures

"Global" Public Spending



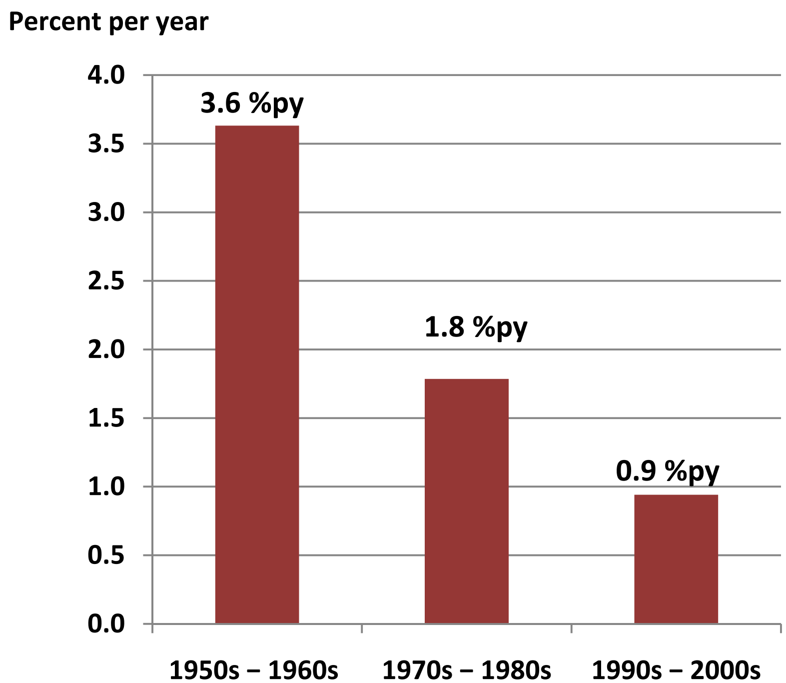
OECD Countries



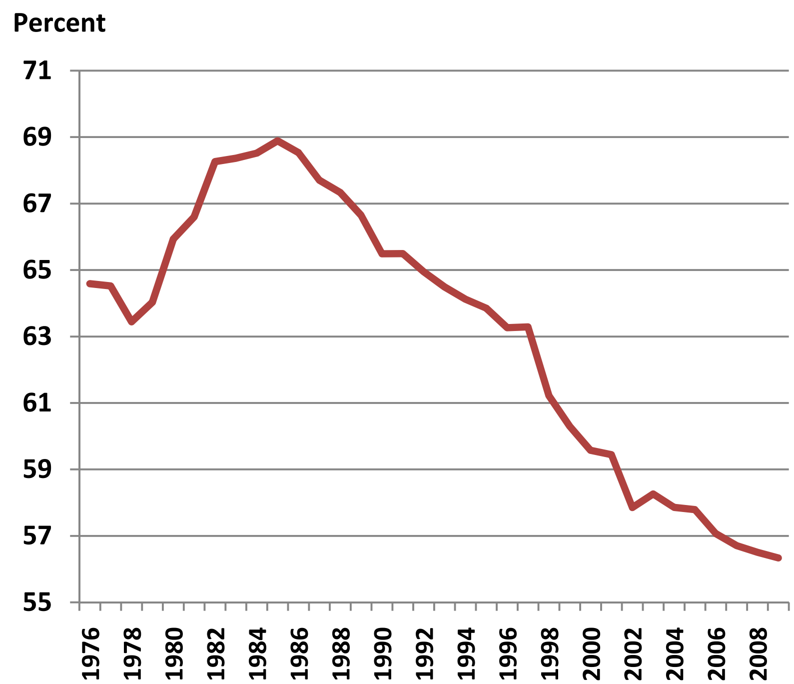
Source: Pardey and Chan-Kang (2011, beta version)

U.S. Agricultural Research Developments, 1950-2009

Slowing Growth in Spending

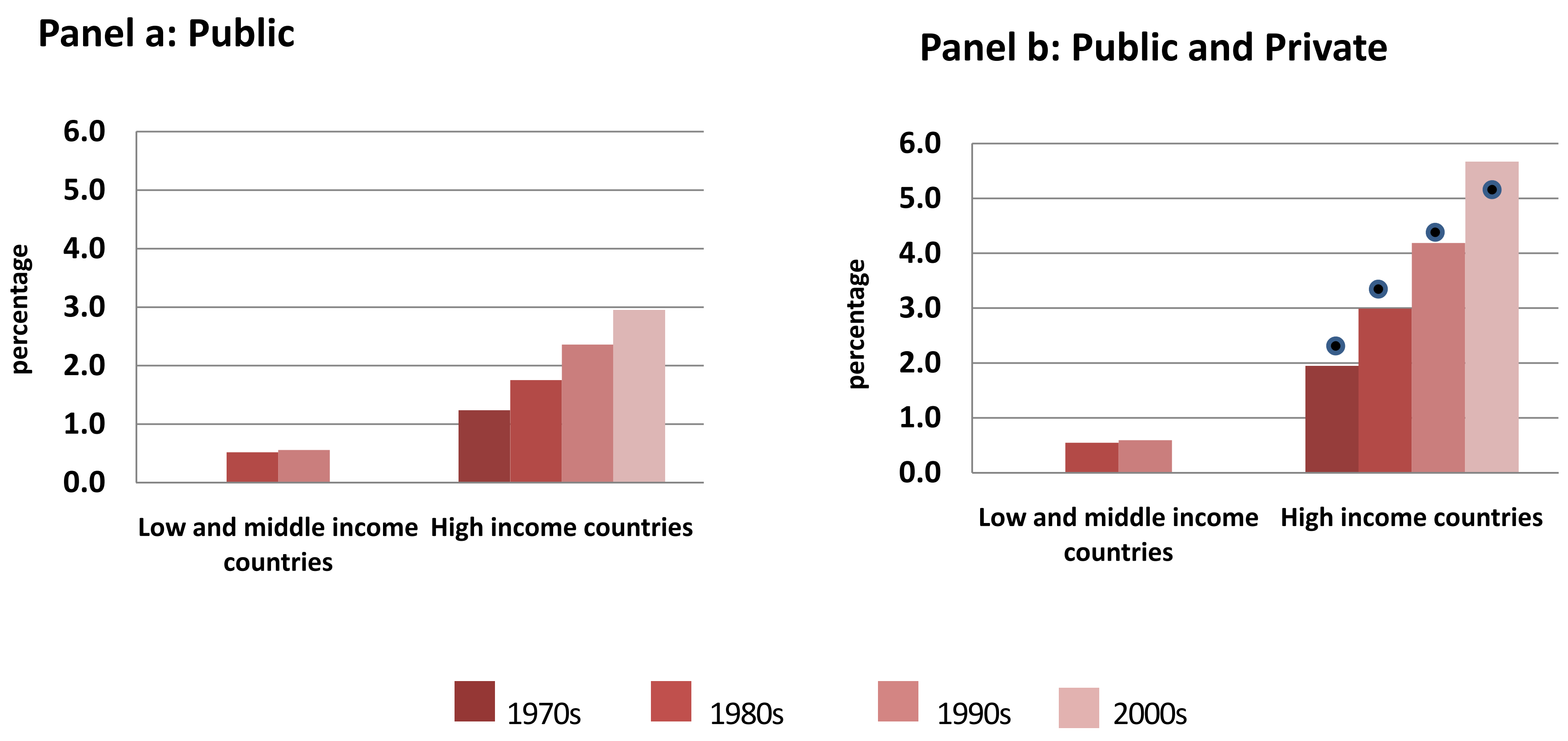


Declining Emphasis on Farm Productivity



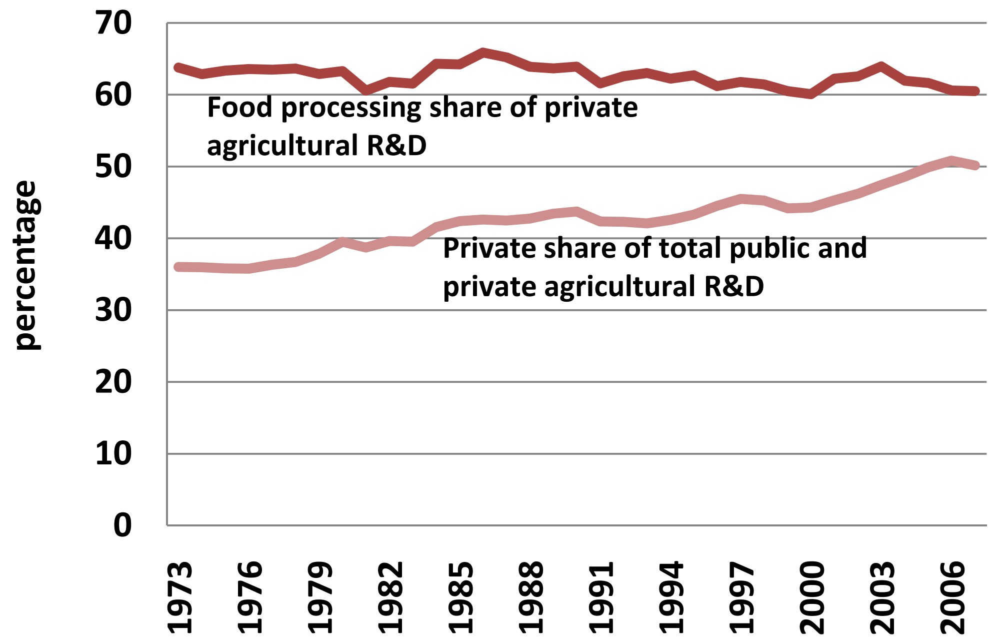
Source: Pardey and Chan-Kang (2011)

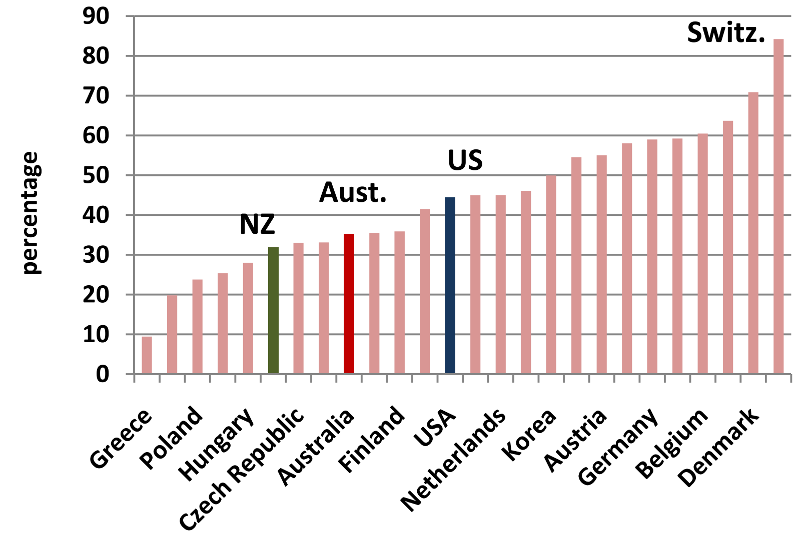
Food and Agricultural Research Intensity Ratios

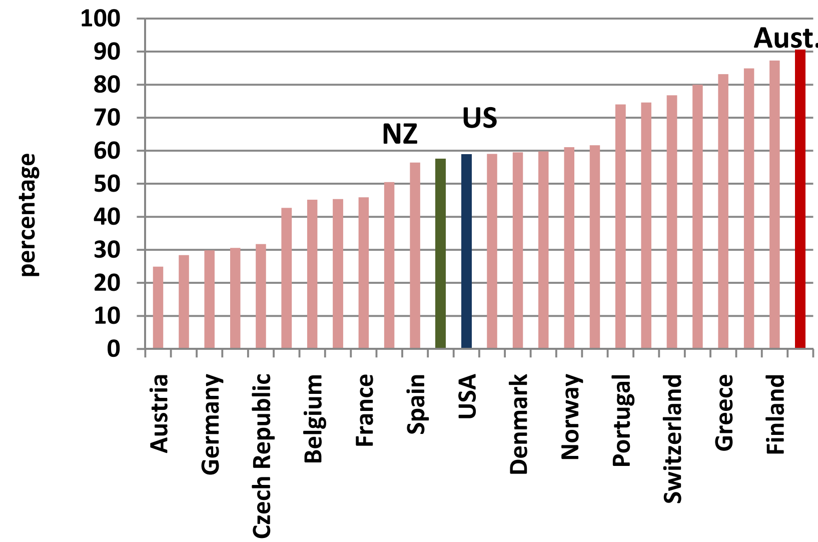


Source: Pardey and Chan-Kang (2011, beta version)

R&D Shares, 1973-2007 (high-income countries)







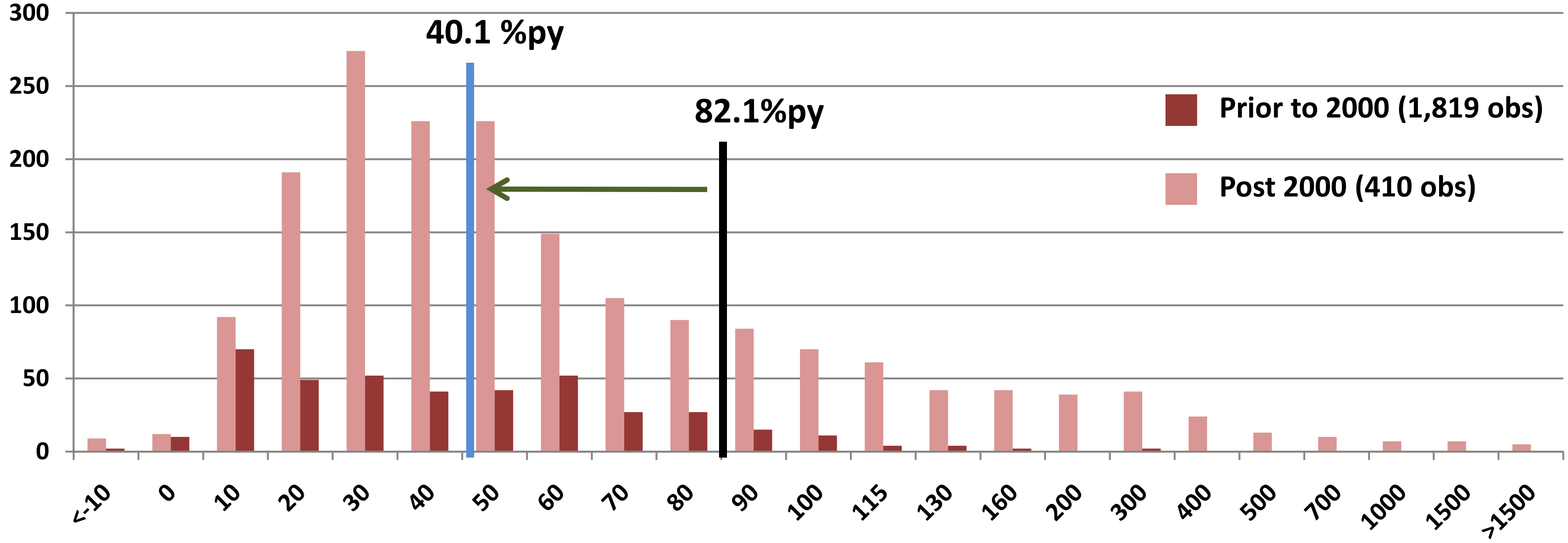
Source: Pardey and Chan-Kang (2011, beta version)

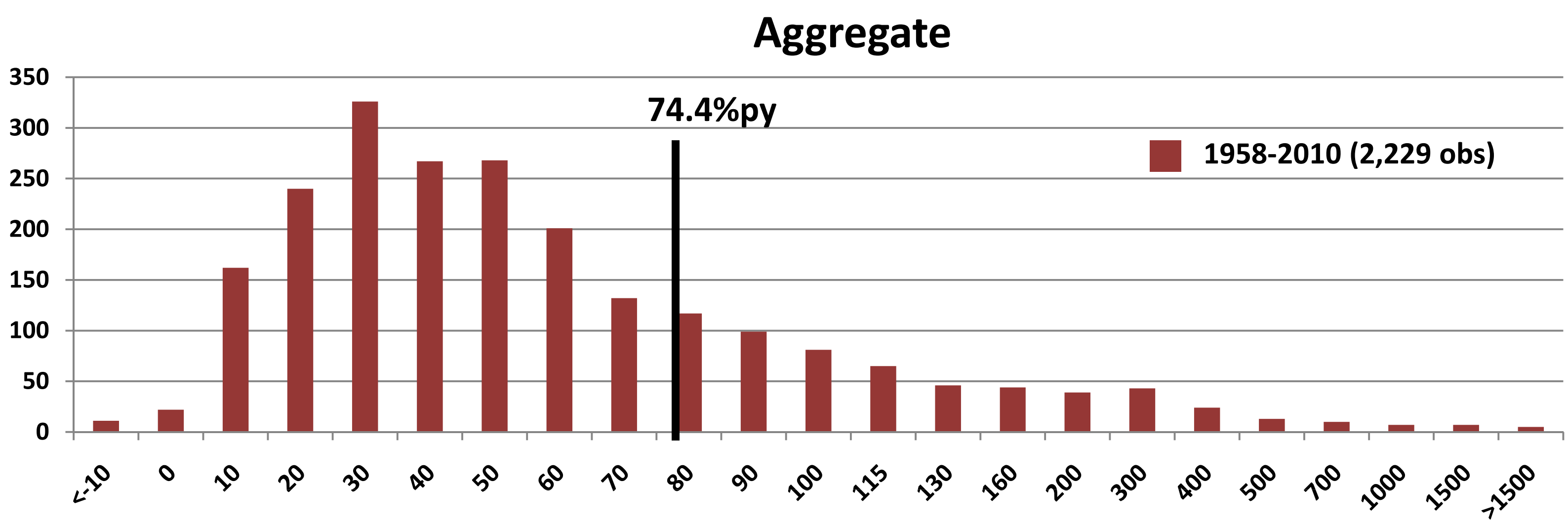
New Evidence on the Payoffs to Investing in Agricultural R&D

What are the estimated rates?

"Gilding the Lily" – Are they believable?

Meta Evidence on the Returns to Agricultural Research





Source: Pardey, Xudong, and Hurley (2011) and Alston et al (2000)

US Evidence on Rates of Return to Research


CAST Commentary
QTA2011-1 March 2011

Investing in a Better Future through Public Agricultural Research

Authors: **Wallace Huffman (Chair)**, Iowa State University, Ames; **George Norton**, Virginia Tech, Blacksburg; **Luther G. Tweeten**, The Ohio State University, Columbus

Reviewers: **Allen S. Levine**, University of Minnesota, St. Paul; **Marty D. Matlock**, University of Arkansas, Fayetteville; **John C. Owens**, University of Nebraska, Lincoln; **John F. Soper**, Pioneer Hi-Bred, Johnston, Iowa

CAST Liaison: **Phillip Stahlman**, Kansas State University, Hays

Introduction

"Focusing on the contribution of productivity-oriented agricultural research undertaken by the main U.S. public agricultural research institutions—SAESs, VMCs, ARS, and ERS—to agricultural productivity in the 48 contiguous states, including spillover effects to other states in the same geoclimatic region, during 1970–2004, the marginal real rate of return is approximately 50% (Huffman 2010: Huffman and Evenson 2006a,b)."

Huffman, Norton and Tweeten (March 2011)

If 50% per Year Was the Right Answer

Terminal value of a dollar invested for

- **35 years is $1.5 billion**
- **50 years is $637.6 billion**

Terminal value of $4 billion invested in 2005

- **35 years (year 2040) is $5,824 trillion**

>100 times the projected size of the US economy ($42 trillion)*

>10 times projected global GDP ($307 trillion)*

* Fogel (2007)

Benefit-Cost vs Real Internal Rates of Return, New Evidence

	Benefit-Cost Ratio (3% real discount rate)		Conventional Real Internal Rate of Return	
Returns to	Own-State	National	Own-State	National
	ratio		*percent per year*	
State R&E				
48-State Average	**21**	**32.1**	**18.9**	**22.7**
48-State Minimum	2.4	9.9	7.4	15.3
48-State Maximum	57.8	69.2	27.6	29.1
USDA Research		**17.5**		**18.7**

Benefit cost ratios seem very big . . . but the implied IRRs are comparatively modest compared with prior estimates, reflecting the very long lags and other modeling details (improvements)

Recalibrating the Rates of Return

- **Conventional internal rates of return implicitly assume that the flow of benefits can be reinvested by the beneficiaries (say farmers or food consumers) at the same rate as the investment being evaluated**

- **A modified internal rate of return assumes the stream of benefits is reinvested by the beneficiaries at some external rate of return, *r*, which could be different from the rate for the project being evaluated**

	Internal Rate of Return	
	Conventional	Modified
	percent per year	
State Average	18.9	8.8
National	22.7	9.9

Key Points from Meta-Analyses and Other Recent Work

Challenge

- Which research, conducted by whom, and when was responsible for observed productivity growth?

Attribution Issues

- Long time lags in knowledge creation and adoption
- Spatial spillovers within and among countries
- What is the relevant counterfactual alternative?

Estimation Issues

- Errors in (implicit) assumptions about reinvestment rates

Bottom Line

Studies have tended to overstate rates of return as a result of attribution biases and estimation problems . . . but true returns are still very large

The Tyranny of the Red Queen

- **Productivity effects of (many) agricultural innovations confounded by**
  - **Changing location of production => adaptive research**
  - **Co-evolving pests and diseases and climate change effects => maintenance research**

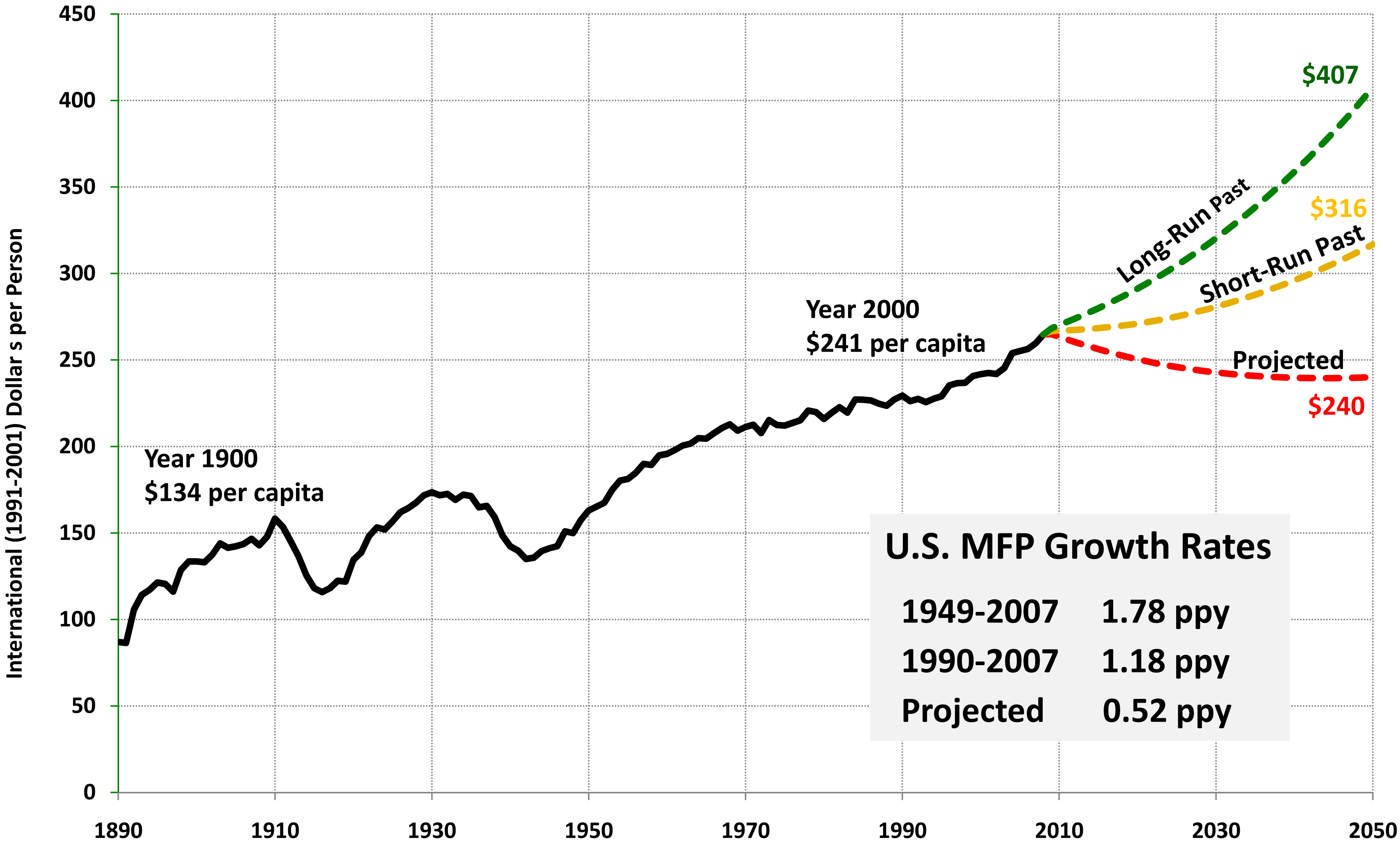
- **The "Red Queen" effect**

"Well, in our country," said Alice, still panting a little, "you'd generally get to somewhere else — if you run very fast for a long time, as we've been doing."

"A slow sort of country!" said the Queen. "Now, here, you see, **it takes all the running you can do, to keep in the same place**. If you want to get somewhere else, you must run at least twice as fast as that!"

– ***Through the Looking Glass***

Per Capita Agricultural Output—Past, Present and Future?



Thanks!

Selected Sources

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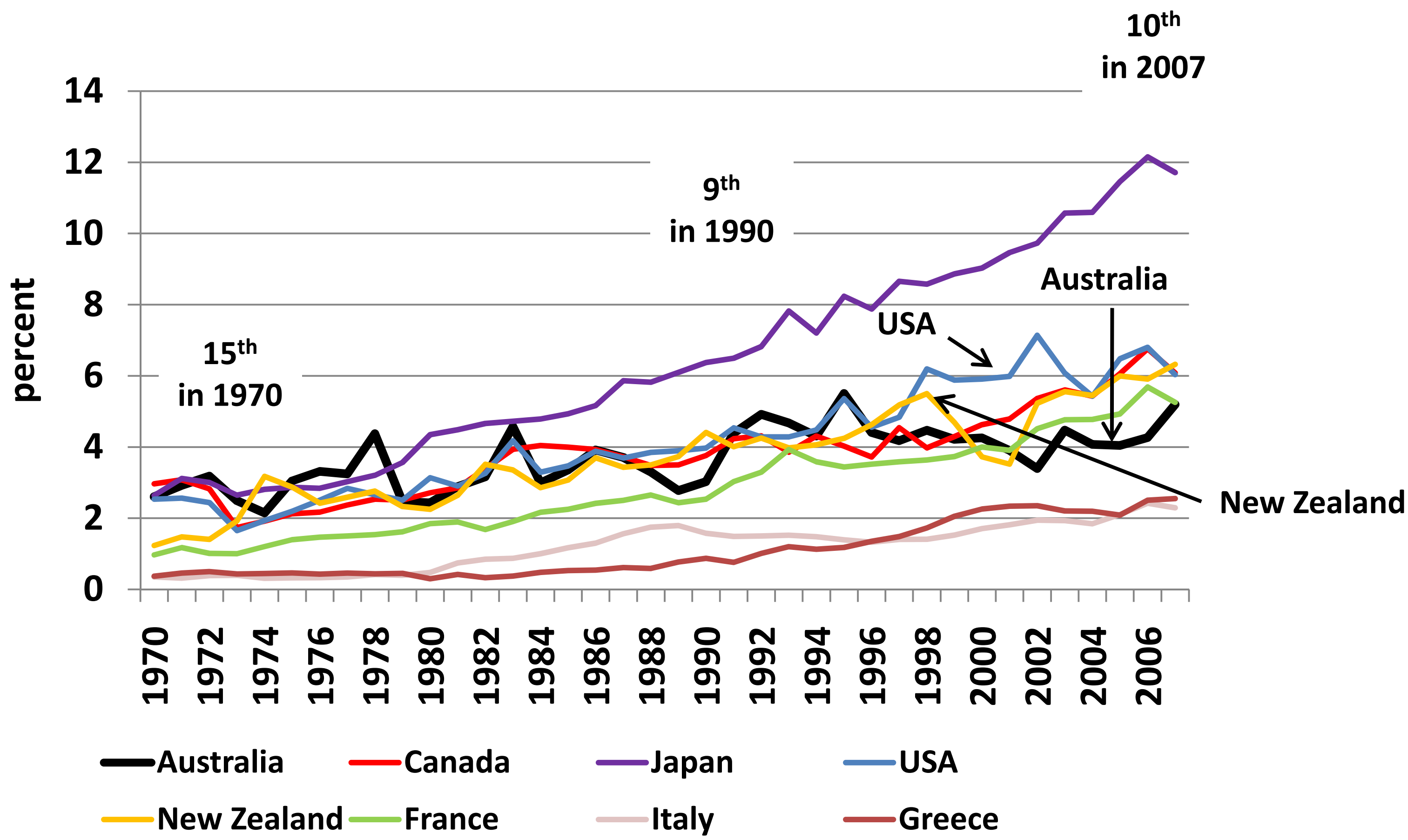
Food and Agricultural Research Intensity Ratios, 1970-2007

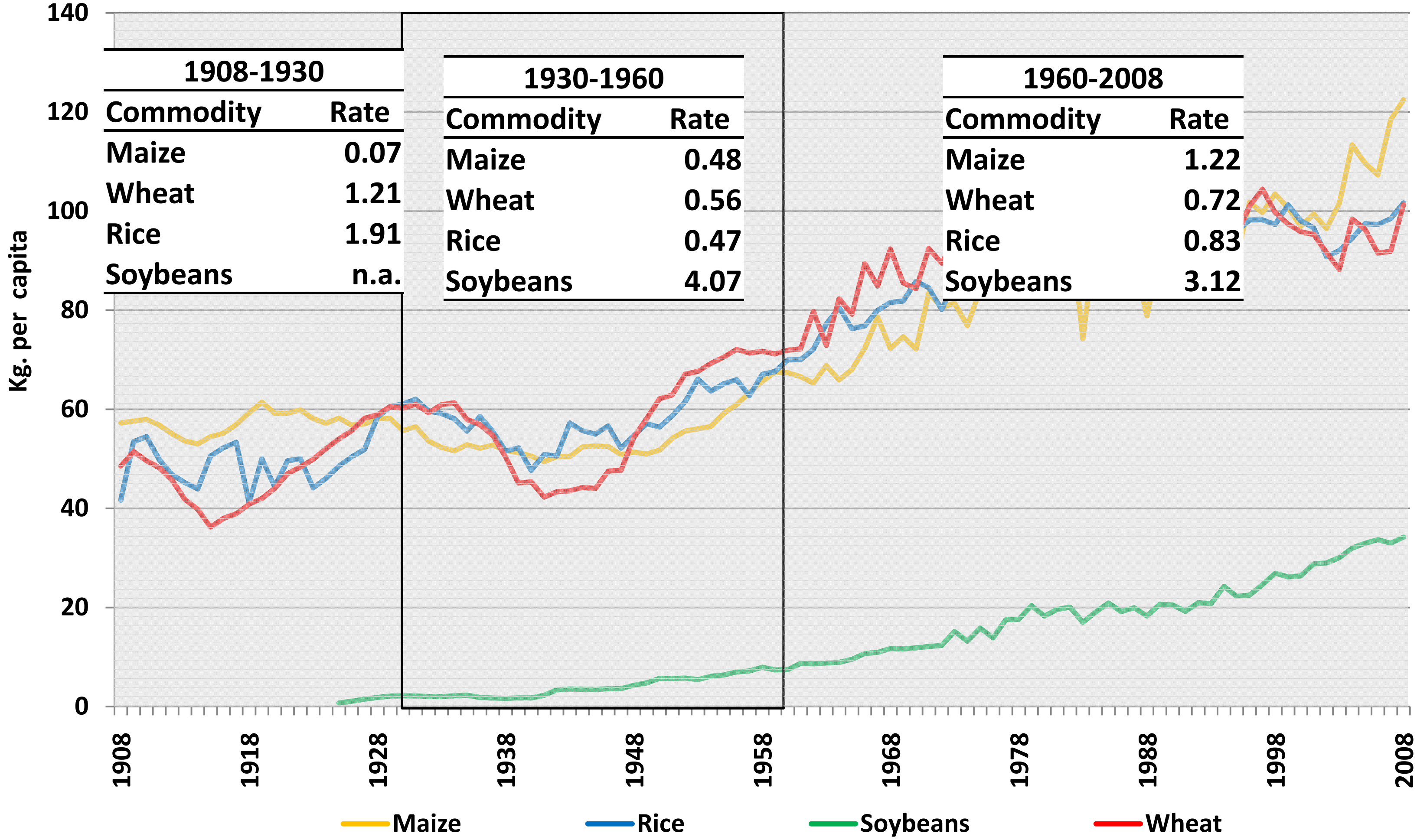


Source: Pardey and Chan-Kang (2011, beta version)

Final Remarks

1. **High rates of return to agricultural R&D**
   - Implies persistent underinvestment
2. **Shifting patterns of public support for R&D**
   - High-income countries
     - Slowdown in spending growth
     - Diminishing share for on-farm productivity enhancement
   - A different pattern in China, for example
3. **Shifting productivity patterns**
   - Productivity slowdown in high-income countries
   - A different pattern in China
4. **Implications—institutional reform required?**
   - Enhance rates of research investment, restore productivity growth, reduce pressure on natural resource stocks

Global Crop Production (per capita), 1908-2008



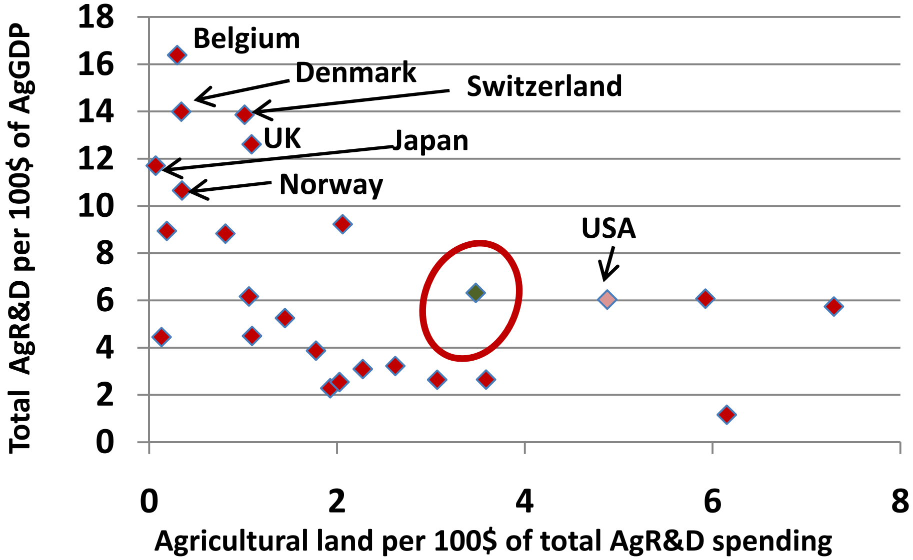
1908-1930	
Commodity	Rate
Maize	0.07
Wheat	1.21
Rice	1.91
Soybeans	n.a.

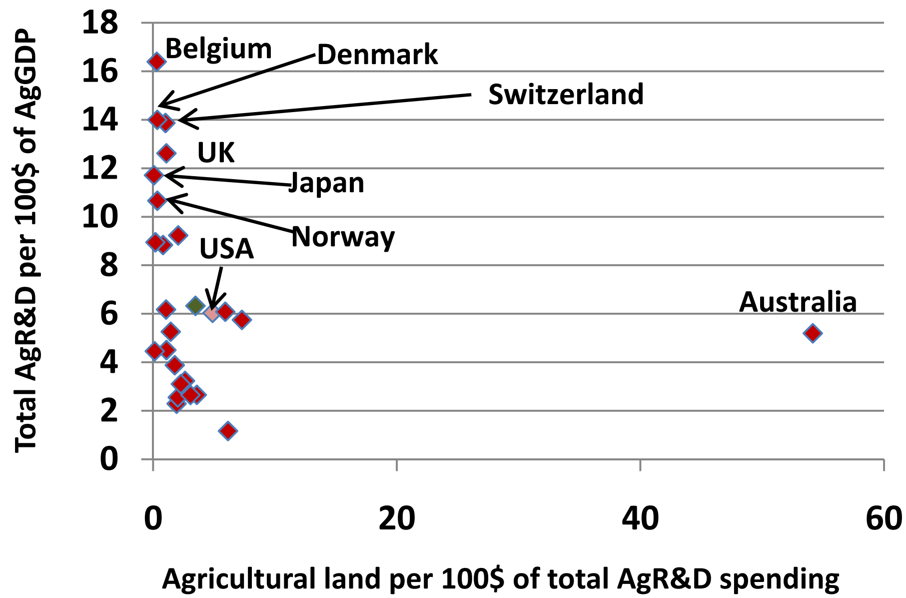
1930-1960	
Commodity	Rate
Maize	0.48
Wheat	0.56
Rice	0.47
Soybeans	4.07

1960-2008	
Commodity	Rate
Maize	1.22
Wheat	0.72
Rice	0.83
Soybeans	3.12

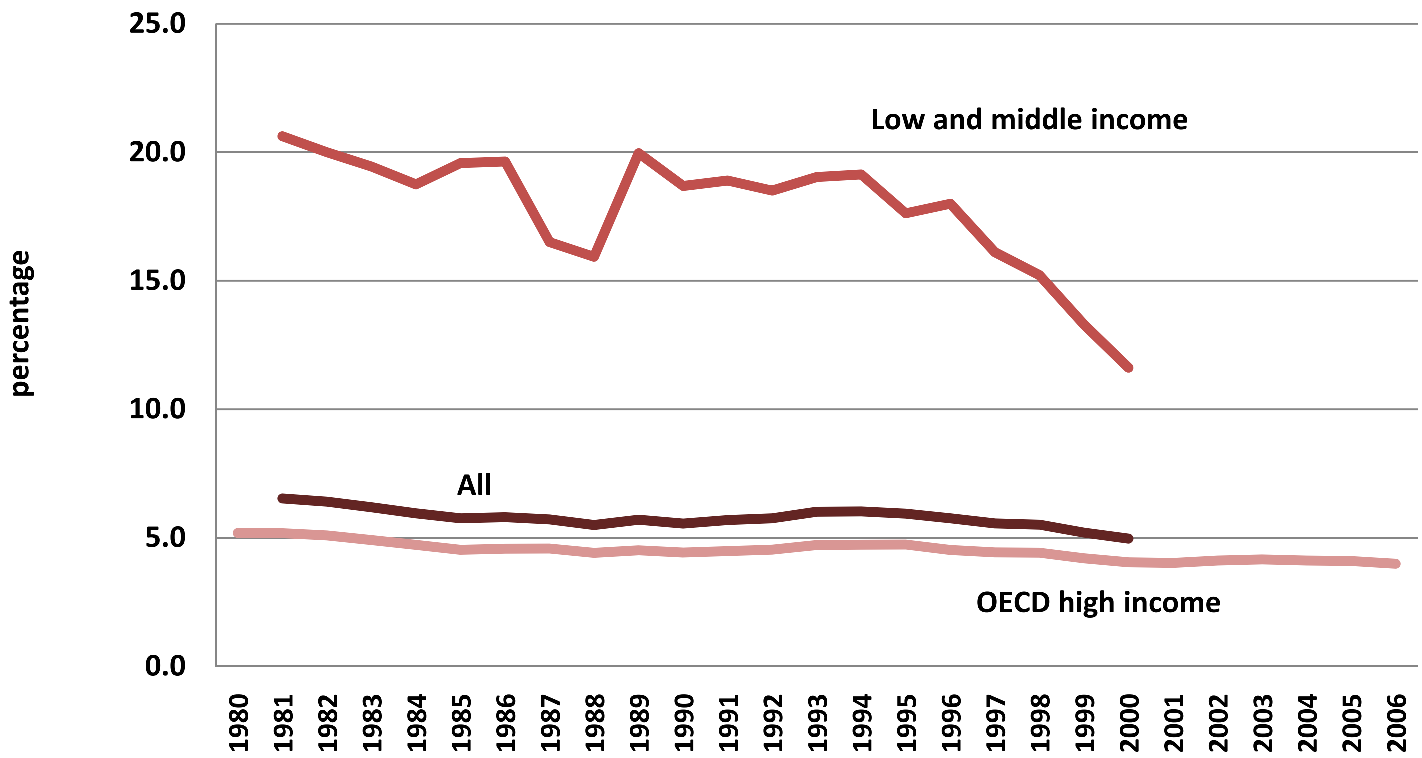
Source: Pardey (2011)

Agricultural R&D Intensities vs Agricultural Area Extent, 2007





Food and Agricultural R&D Share in Total R&D



Note: Low and middle income group excludes Eastern Europe and countries that were part of the former USSR

Source: Pardey and Chan-Kang (2011, beta version)