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The Rise and Fall of U.S. Farm Productivity Growth, 1910-2007

Julian Alston, Matt Andersen & Phil Pardey

Contributed presentation at the 60th AARES Annual Conference,
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The Rise and Fall of U.S. Farm Productivity Growth, 1910-2007

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Background and Context

U.S. farm population

- **1916:** 32.5 million (31.5% of total population)
- **2013:** 4.6 million (1.5% of total population)

20^{th} century transformation of agriculture

- farms much larger and more specialized
- much more produced with less land and much less labor

A particular feature of this process was to move people off farms, a one-time transformation of agriculture that was largely completed by 1980.

Background and Context

Transformation of agriculture was facilitated by development & adoption of new technologies

- various mechanical innovations
- improved crop varieties
- synthetic fertilizers and other chemicals
- information technologies

Farm productivity grew rapidly and food prices fell in real terms

Has the “golden age” of farm productivity growth ended?

Background and Context

Conjectures about a slowdown date back at least 10 years (IAAE 2006), prior to commodity price spikes which revived interest in long-run food security questions

Two groups of researchers have been constructing state-specific and national measures of U.S. agricultural productivity:

- **USDA** – Economic Research Service
- **InSTePP** – University of Minnesota

They disagree on the slowdown

Background and Context

Economists have various views about the existence, nature, extent, and likely duration of a slowdown in U.S agricultural productivity growth

Researchers at USDA ERS reject the slowdown hypothesis:

- Ball, Wang and Nehring (2010, p. 3) reported that "… statistical analysis of the [USDA] data does not provide evidence of a longrun productivity slowdown."

- Wang (2010, p. 6) observed "…statistical analyses of ERS productivity accounts through 2008 did not reveal a corresponding slowdown in long-term rates of [U.S.] agricultural productivity growth."

Background and Context

Economists have various views about the existence, nature, extent, and likely duration of a slowdown in U.S agricultural productivity growth

- Alston et al. (2010) concluded, "There can be little doubt that the data exhibit evidence of a slowdown in multifactor productivity growth in the period 1990–2002 compared with the previous period [1949–1990]."
- Wang, Heisey, Schimmelpfennig and Ball (2015) find "no evidence of a long-run productivity slowdown in the U.S. farm sector."

Background and Context

Economists have various views about the existence, nature, extent, and likely duration of a slowdown in U.S agricultural productivity growth

Why do we care?

- Many uses for productivity measures. Are the measures accurate? Whose do we believe?
- To contribute to an extensive literature about a possible productivity slowdown in various sectors of the economy, including agriculture.
- Looking forward . . . the answers to today's questions about the future of food will depend, as they did in the past, fundamentally on the future path of farm productivity growth.

Data Sources & Data Construction

- National indexes of multifactor productivity *MFP,* land productivity, and labor productivity for the years 1910–2007

- MFP_t – an index of the quantity of aggregate output Q_t divided by an index of the quantity of aggregate input X_t

$$MFP_t = \frac{Q_t}{X_t}$$

- 132 categories of inputs and outputs x 2 (prices and quantities) x 48 states x 59 years (1949–2007) = 747,648 individual price and quantity data points

Data Sources & Data Construction

- Partial-factor Productivity (*PFP*)

Land & **Labor**

Q_t / L_t Q_t / N_t

- Crop yields in pounds per acre for six crops
  (National Agricultural Statistics Service, NASS)

Statistical Analysis

In the paper we report a range of tests using various measures of *PFP* and *MFP*

- Compare average annual growth rates by period
- Zivot-Andrews time-series econometric tests of breakpoints
- Nordhaus-type rolling regressions
- Estimate cubic trend models and inflection points
- State-level analysis

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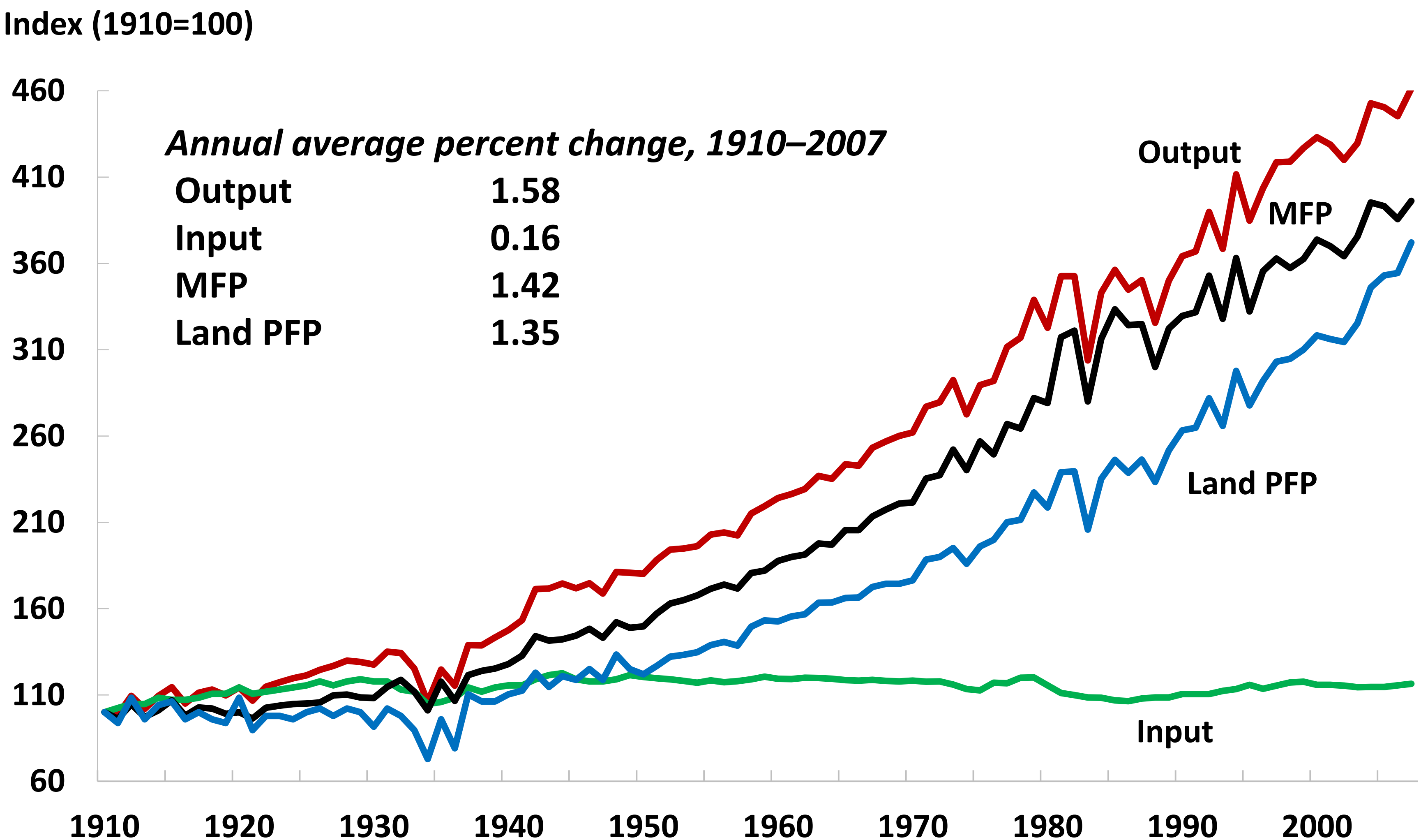
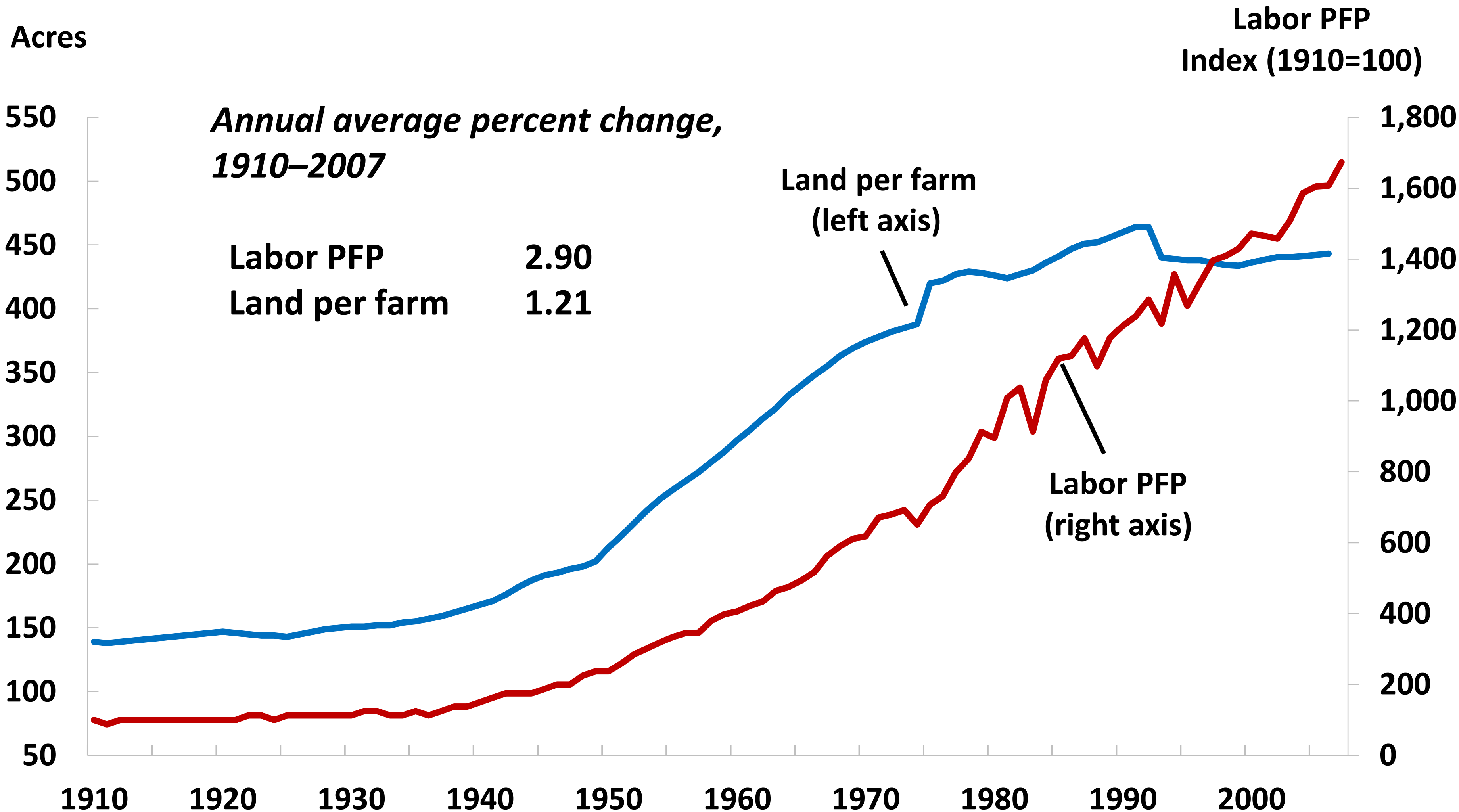
Output, Input, *MFP*, and Land *PFP*, 1910–2007



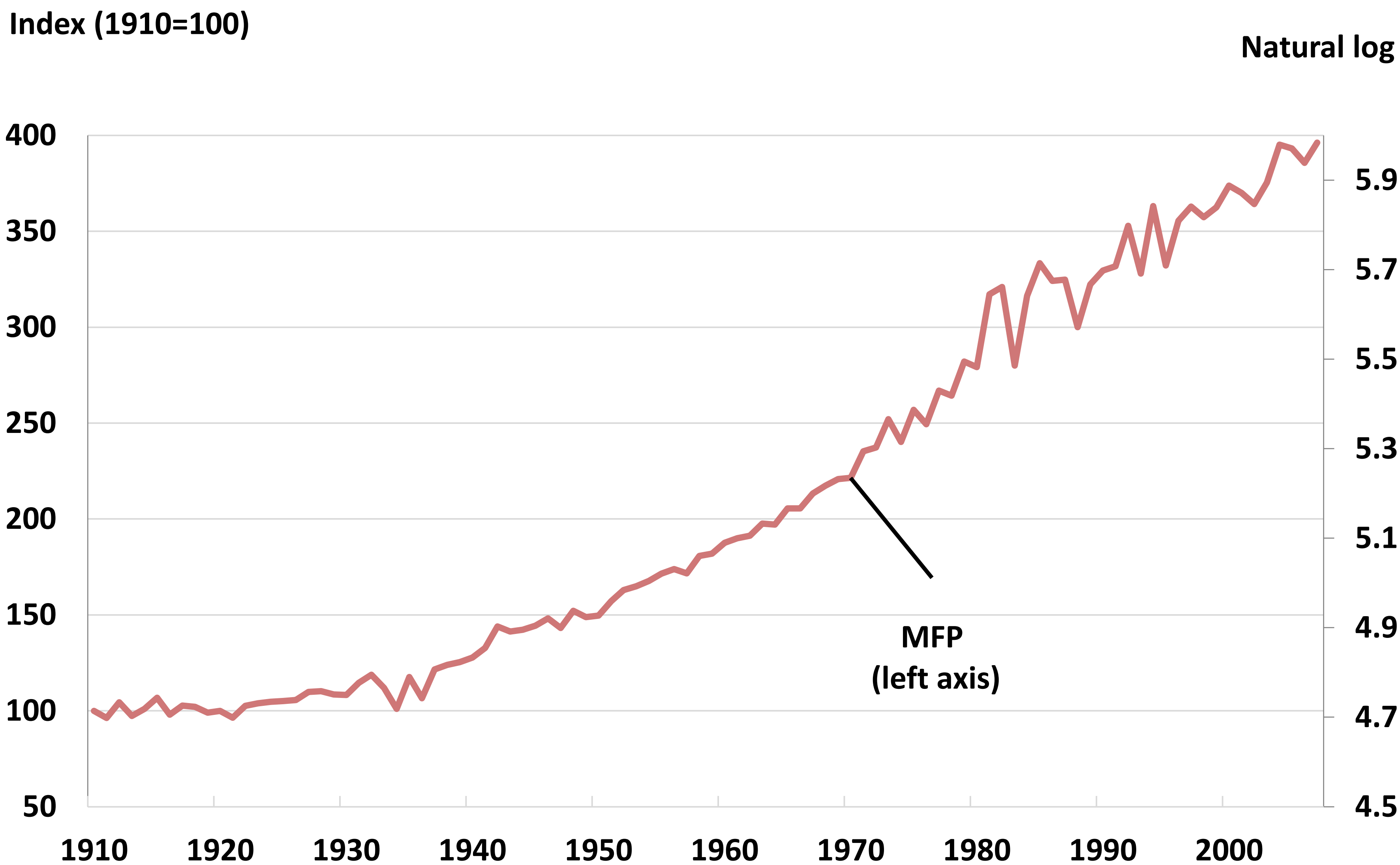
Labor *PFP* and Land per Farm, 1910–2007



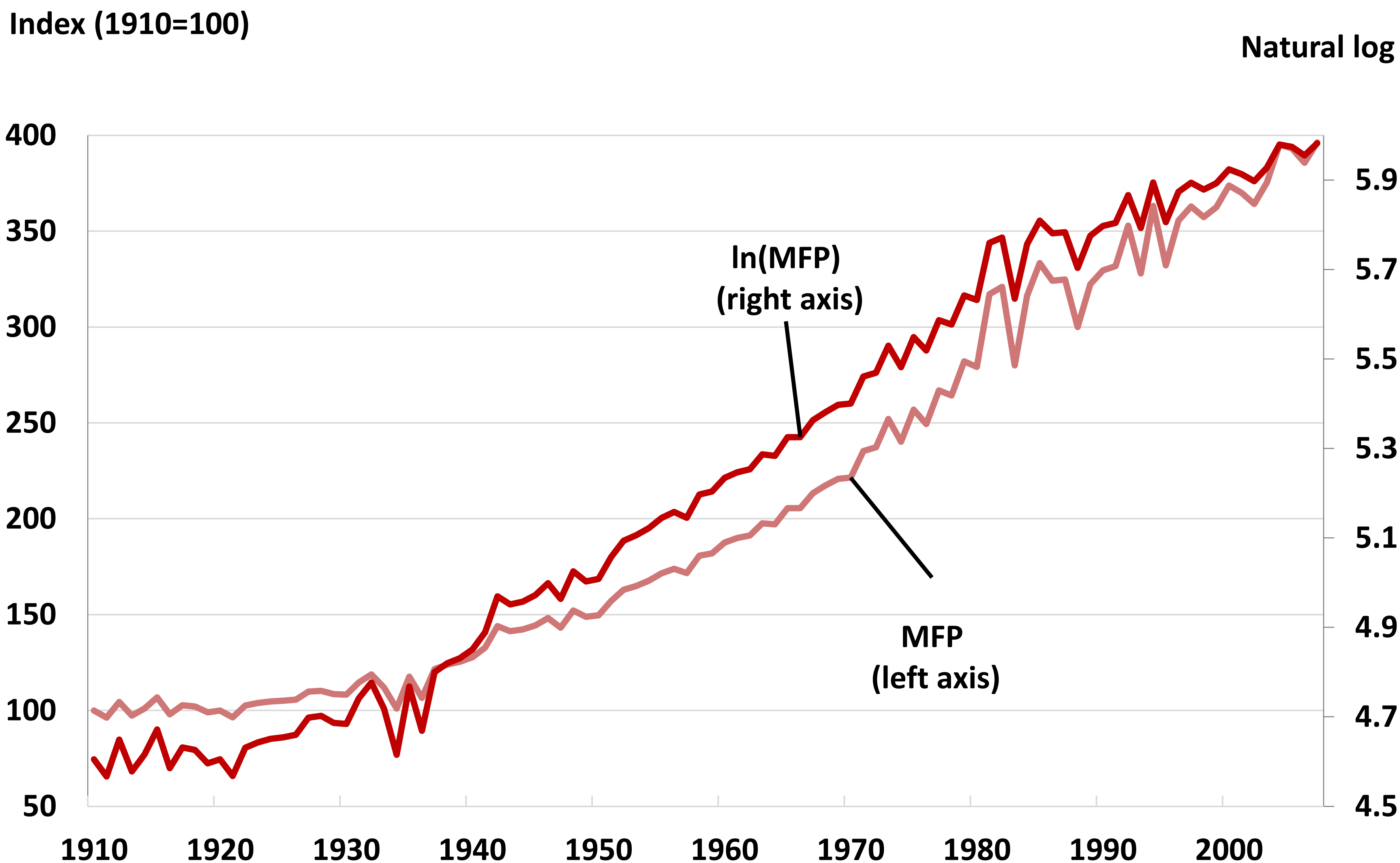
Annual Average Growth Rates in U.S. Farm Output, *MFP* and *PFP*, 1910–2007

		Productivity Indexes		
Period	Output	Multifactor	Labor	Land
		percent per year		
1910 – 2007	**1.58**	**1.42**	**2.90**	**1.35**
1910 – 1950	1.47	1.01	2.16	0.50
1950 – 1990	**1.76**	**1.97**	**4.07**	**1.92**
1990 – 2007	1.39	1.08	1.90	2.04
2000 – 2007	0.90	0.83	1.83	2.23

Index of *MFP* in U.S. Agriculture 1910–2007



Index of *MFP* in U.S. Agriculture 1910–2007



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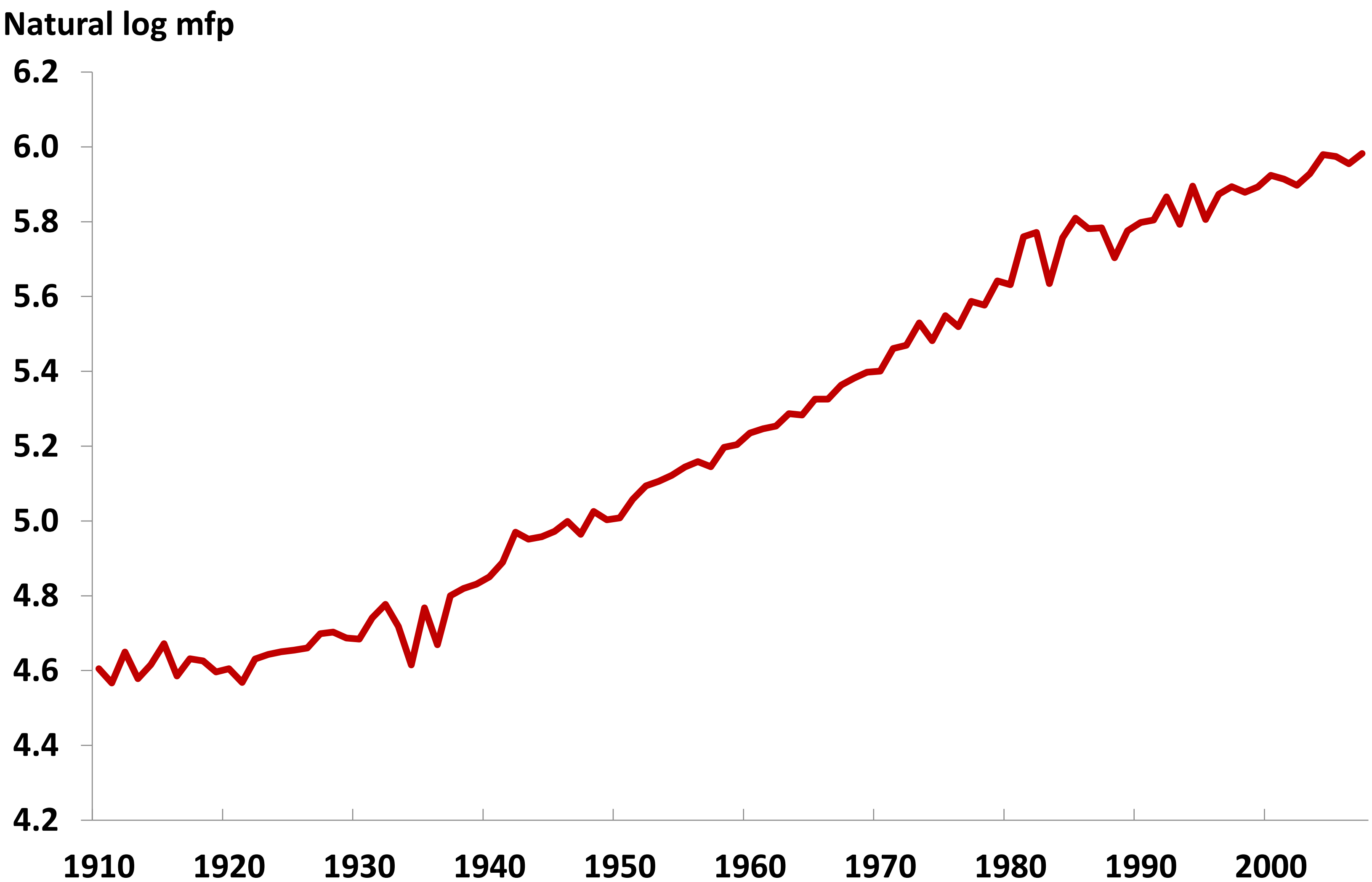
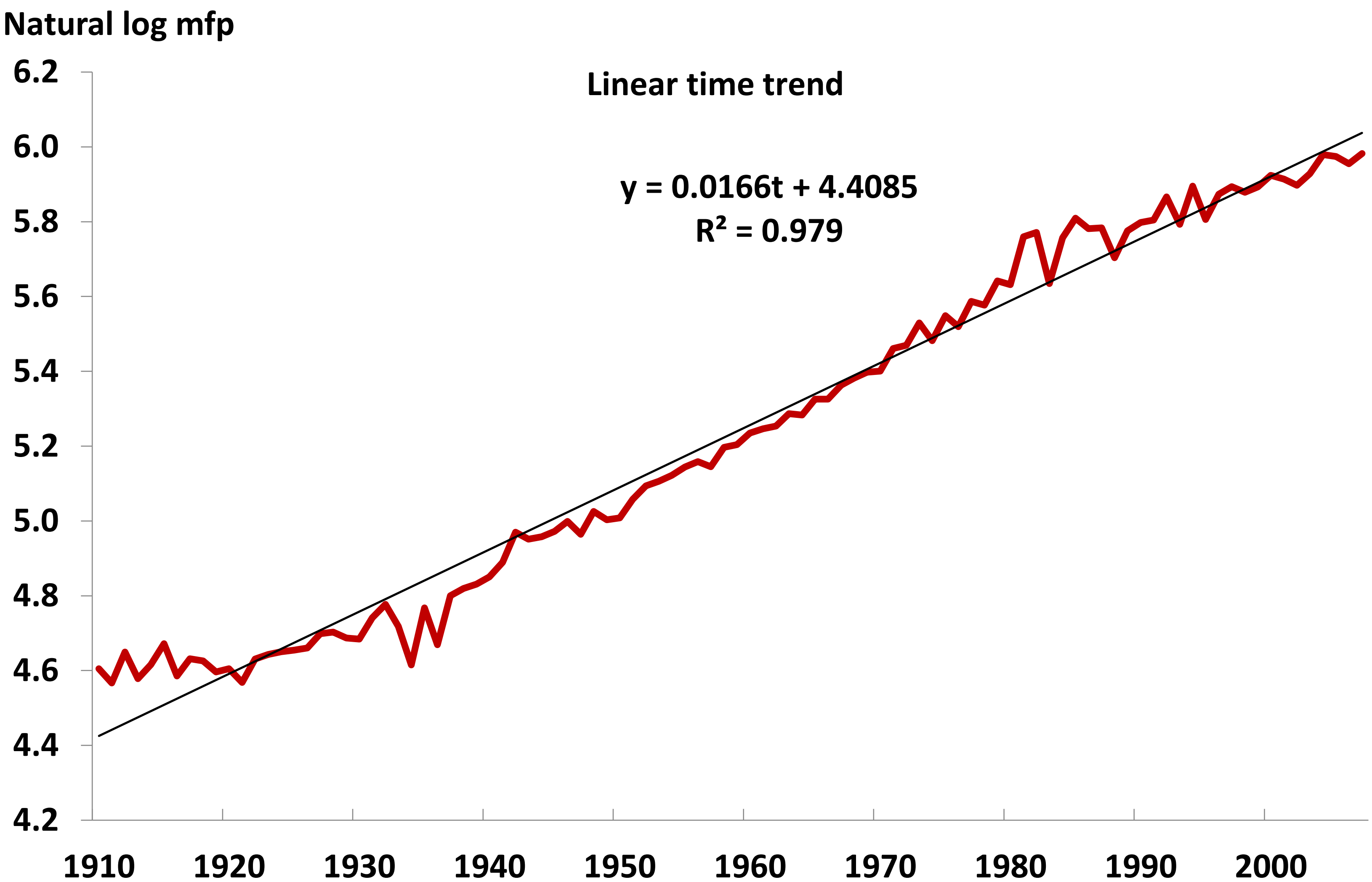
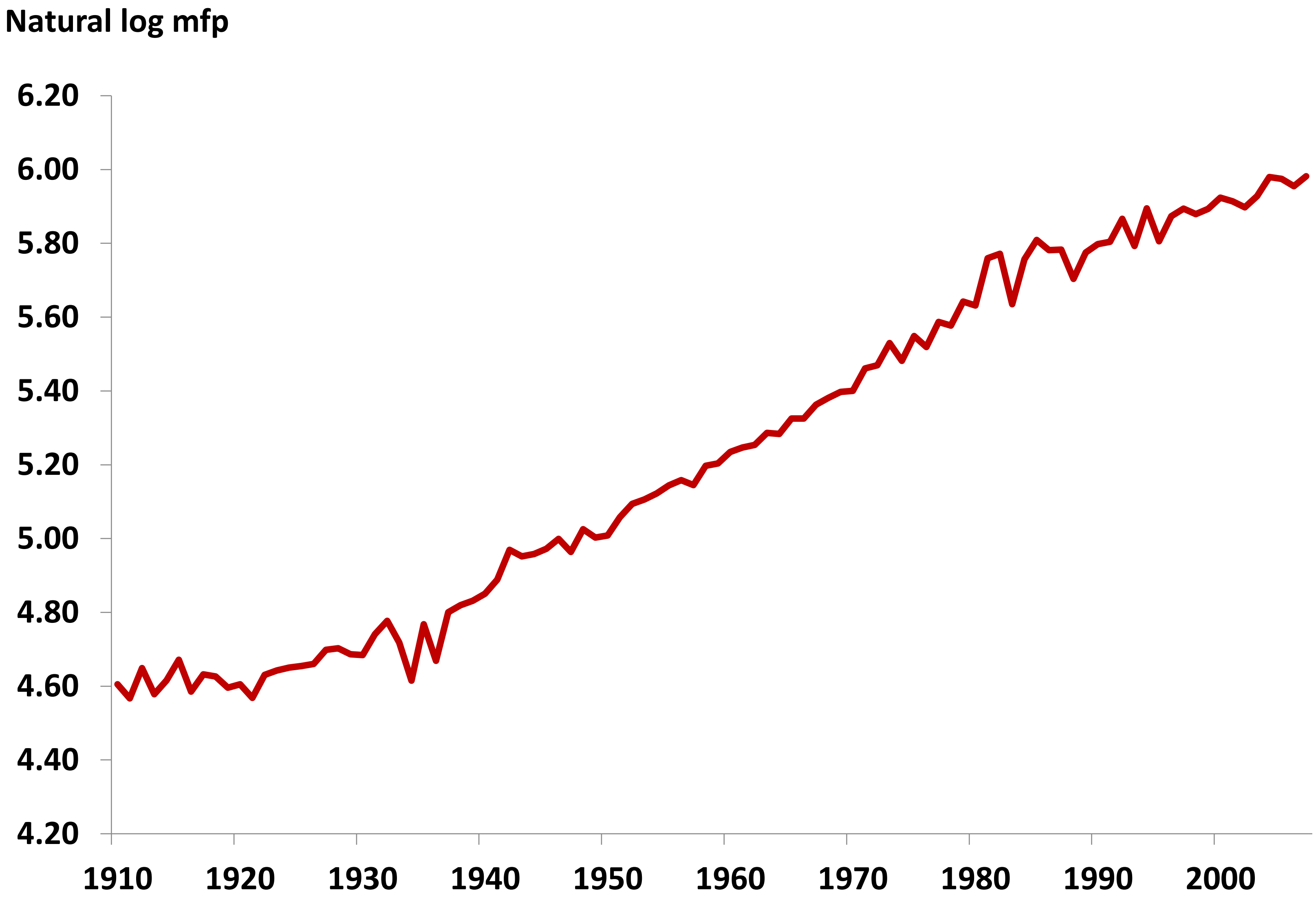


Index of *MFP* in U.S. Agriculture 1910–2007



Index of *MFP* in U.S. Agriculture 1910–2007



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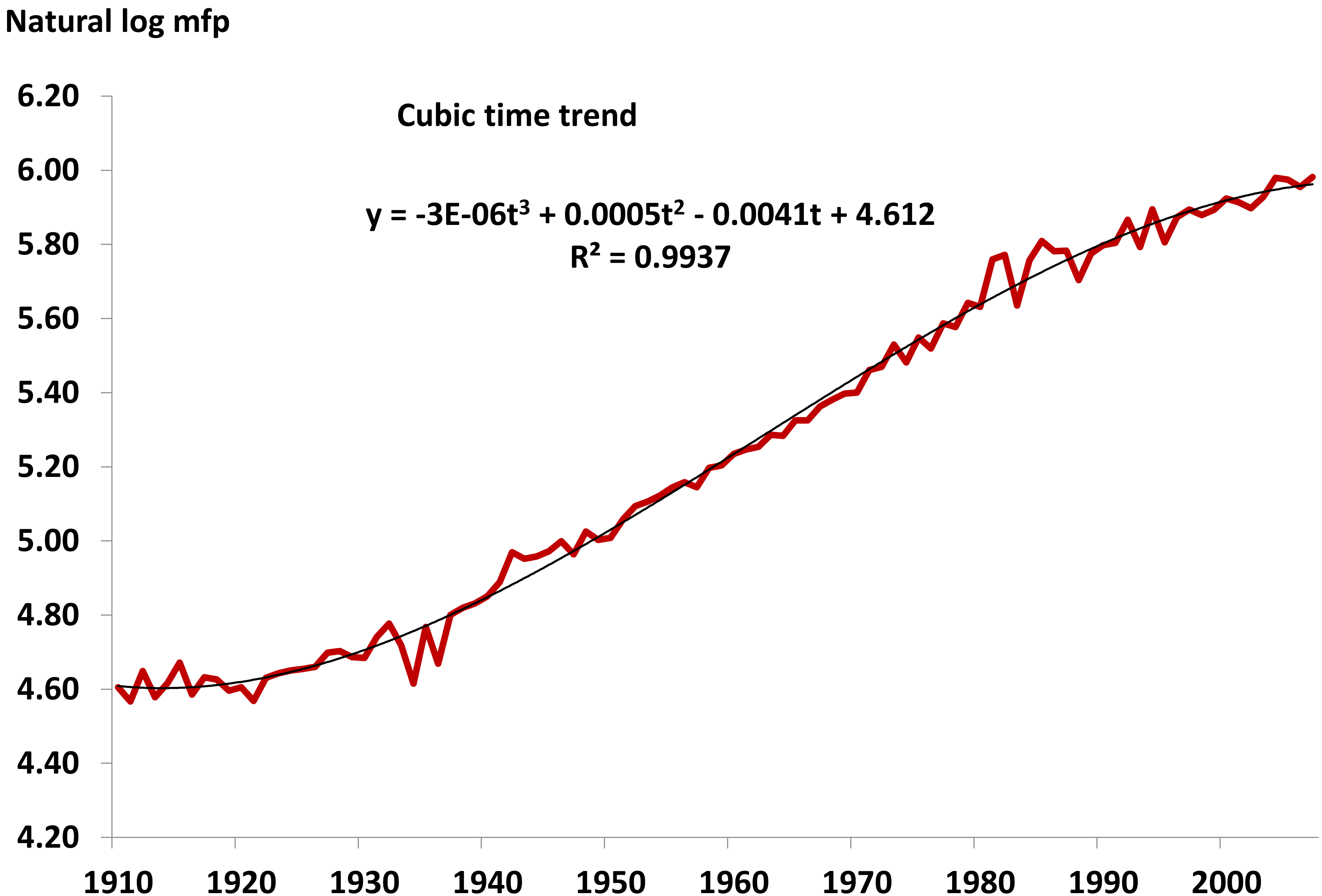


Cubic Trend Models: Inflection Point Analysis

A cubic trend model of the natural log of *y*:

$$\ln y_t = b_0 + b_1 T_t + b_2 T_t^2 + b_3 T_t^3 + e_t$$

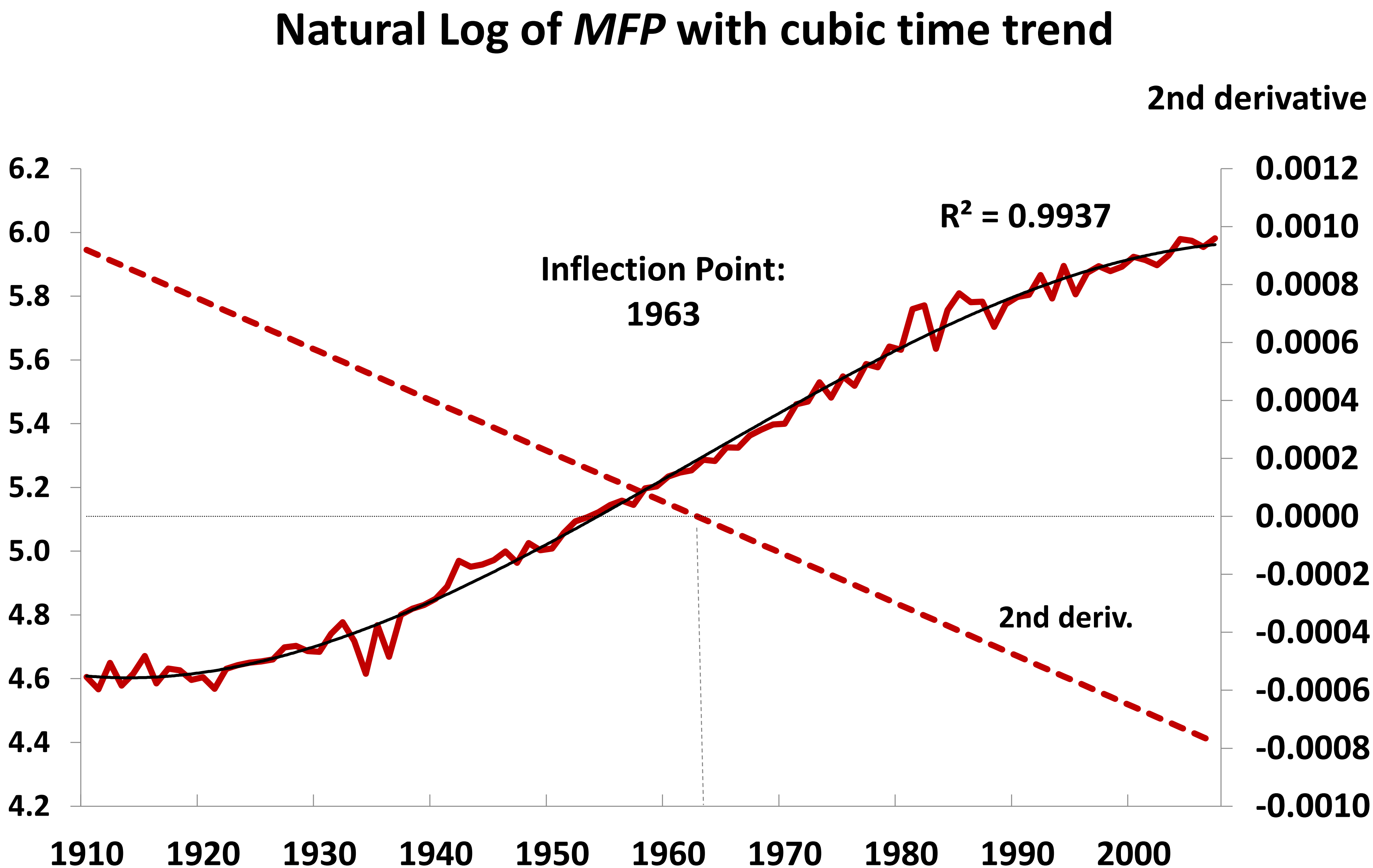
The second-order partial derivative is a linear function:

$$\frac{\partial \ln^2 y_t}{d \ln T_t^2} = 2b_2 + 6b_3 T_t$$

Setting this equal to zero and solving yields the inflection point, T_{IP}:

$$T_{IP} = -\frac{b_2}{3b_3}$$

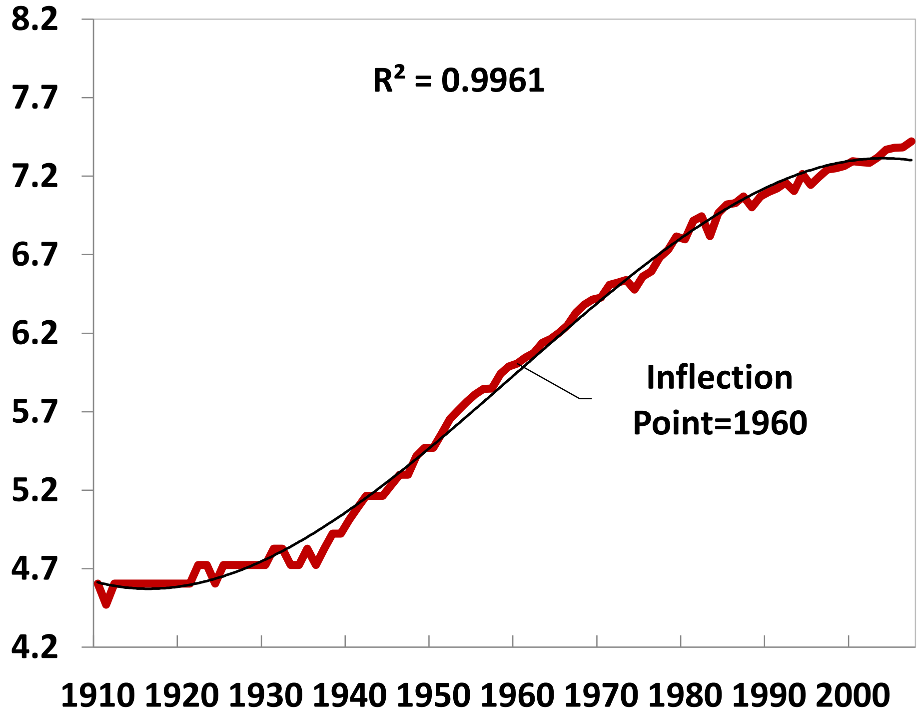
Cubic Trend Models: Inflection Point Analysis



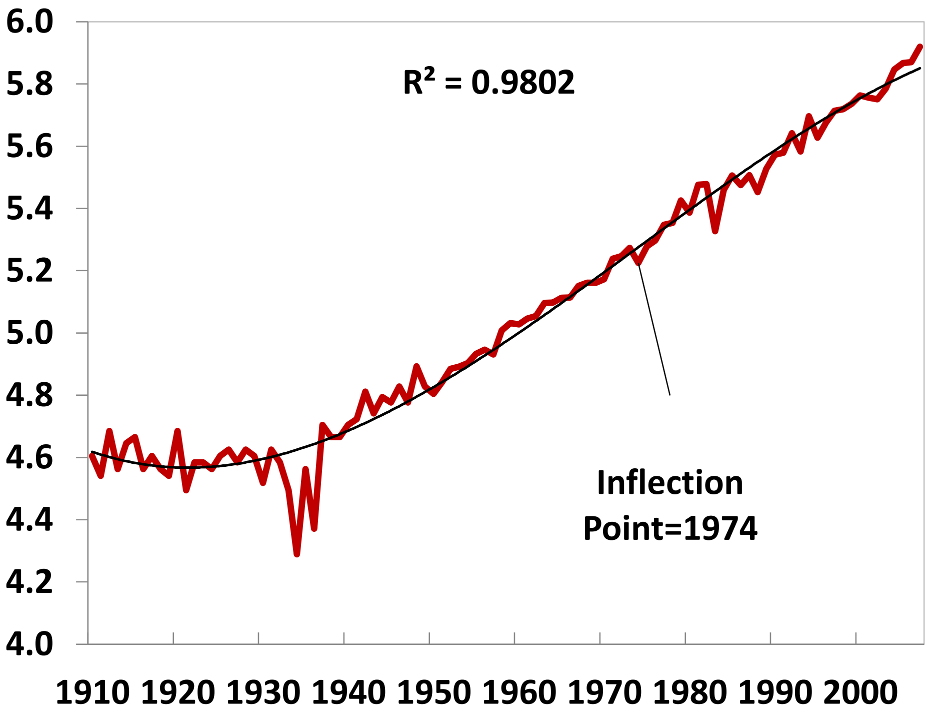
Cubic Trend Models: Inflection Point Analysis

Natural Log of *PFP* with cubic time trend

Labor

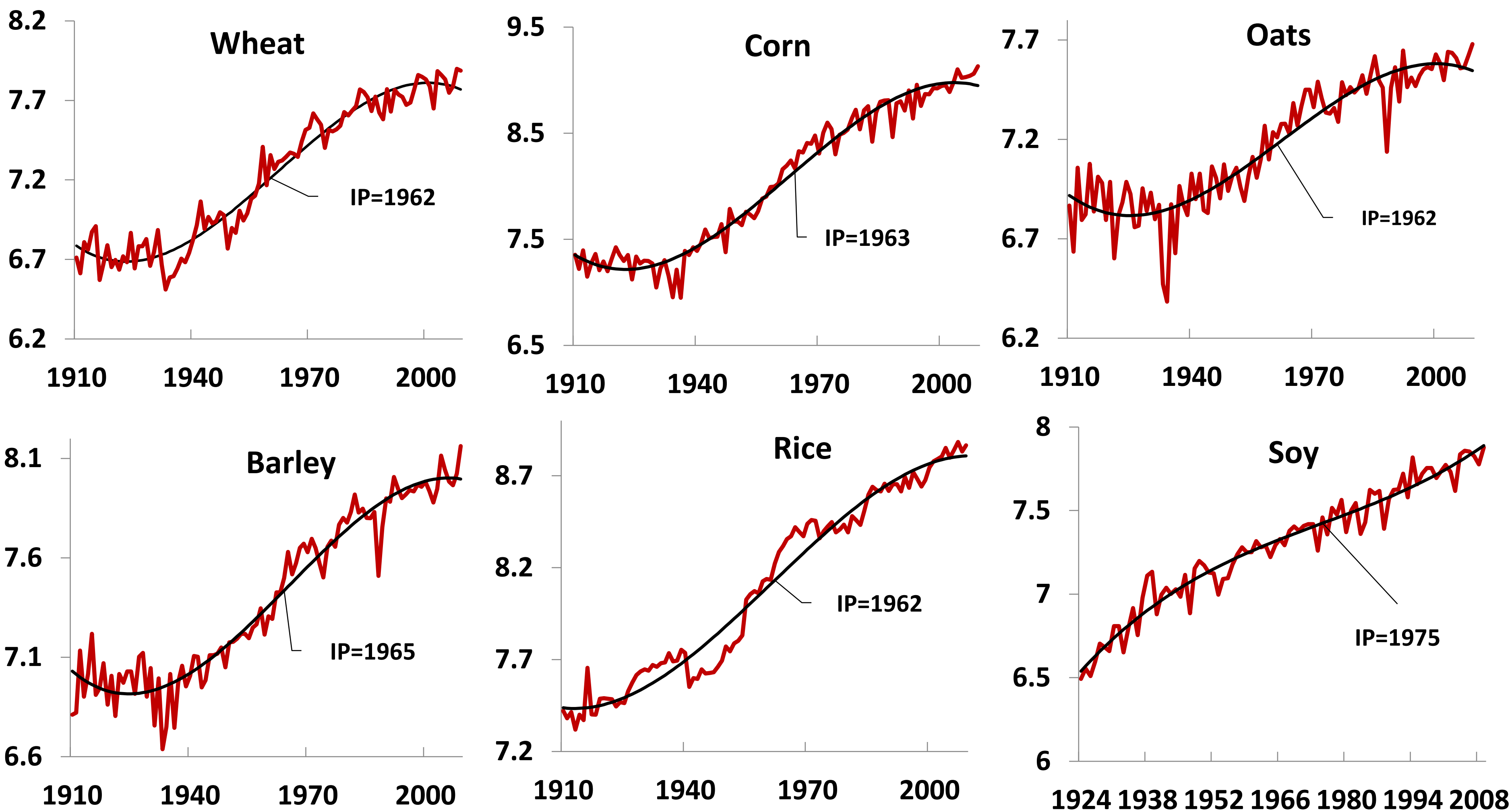


Land



Cubic Trend Lines for Crop Yields, 1910–2007

Natural Log of crop yield with cubic time trend



Inflection Dates for Productivity Measures

Productivity Measure	Data Period	Year of Inflection (Maximum Growth Rate)		
		Point Estimates	95 Percent Confidence Interval	
			Lower Bound	Upper Bound
Crop yields				
Wheat	1910–2009	1962	1960	1964
Corn	1910–2009	1963	1961	1964
Barley	1910–2009	1965	1962	1968
Oats	1910–2009	1962	1959	1966
Rice	1910–2009	1962	1959	1964
Soybeans†	1924–2009	1975	1969	1981
Productivity indexes				
MFP	1910–2007	1962	1961	1964
Labor	1910–2007	1960	1959	1961
Land	1910–2007	1974	1969	1979

Statistical Tests for a Slowdown in MFP Growth

Time Period	During Period	After Period	Difference	P-value
		annual average percent change		
Using differences in logarithms				
1949–1960	2.04	1.55	0.48	0.002
1949–1970	2.01	1.44	0.58	0
1949–1980	2.01	1.23	0.78	0
1949–1990	2.02	0.73	1.29	0
1949–2000	1.79	0.58	1.21	0
1949–2007	1.65	–	–	–
Using regression of logarithms				
1949–1960	2.04	1.60	0.43	0.007
1949–1970	1.88	1.33	0.55	0
1949–1980	1.96	0.85	1.12	0
1949–1990	2.04	0.68	1.37	0
1949–2000	1.87	0.98	0.89	0.011
1949–2007	1.72	–	–	–

State-specific data, 1949-2007, including 2,832 observations.

A rise and fall of agricultural MFP growth in the 20th century could reflect

Theory #1

A decades prior slowdown in agricultural R&D investments or a change in the effectiveness of those investments:

- diminishing returns to R&D over time
- coevolving pests and diseases
- changes in climate
- reallocation of R&D resources to non-productivity purposes.

A rise and fall of agricultural MFP growth in the 20th century could reflect

Theory #2

- A “big wave” surge in farm productivity reflecting “great clusters” of inventions:
  - mechanical
  - biological
  - chemical
  - Information

A series of interlinked, mostly one-time events, not to be repeated

Akin to and possibly linked to Gordon’s “big wave” surge in U.S. productivity – the “glorious half century” between WWI and the early 1970s

A Slowdown in Investment in R&D?

	Public agricultural R&D spending	Public and private agricultural R&D spending
	percent per year	
1889–2009	3.9	3.8
1950–1980	3.4	2.7
1980–2009	0.7	1.2

One "Big Wave" of Productivity Driven by Innovations?

Earlier gains

1. Primarily Mechanical
    a) Tractors & mechanical reapers
    b) Pulled and self-propelled combines
    c) Bulk handling equipment

2. Improved technology for long distance transportation of farm output
    a) Refrigeration and preservation
    b) Public infrastructure (roads and railroads)

3. Rural electrification, telephone service, and irrigation projects

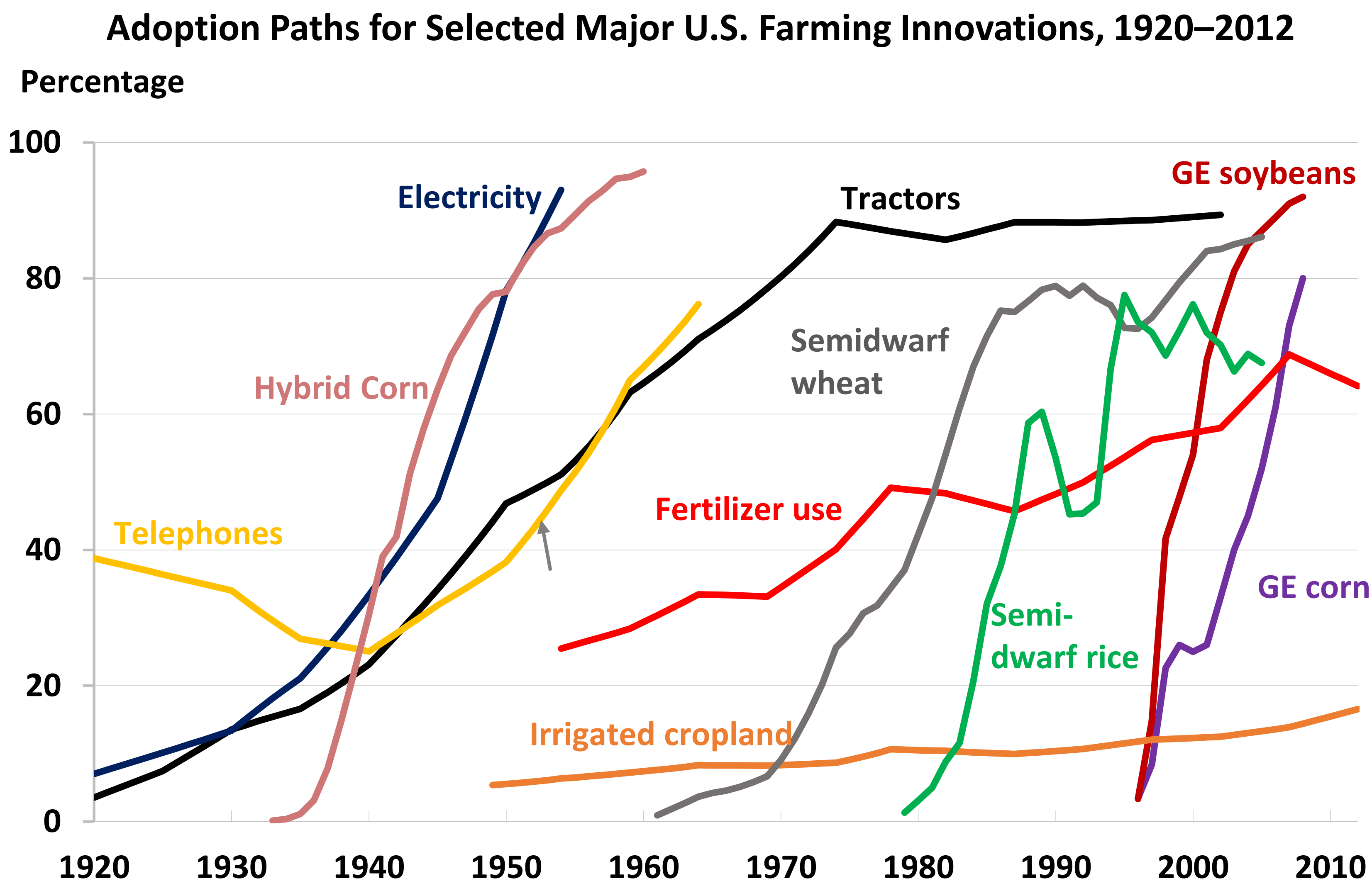
Later gains

1. Biological innovations
    a) Improved crop varieties
    b) GE crop varieties

1. Agricultural chemicals
    a) fertilizers
    b) pesticides & herbicides
    c) antibiotics & hormones

2. Information & computer technology
    a) GIS & precision prod. systems
    b) Satellites & remote sensing

One "Big Wave" of Productivity Driven by Innovations?



Conclusion

Can the rapid *MFP* growth of the of the middle of the 20th Century be recaptured in coming decades?

The statistical analysis suggests that the rapid *MFP* growth during the period 1950–1990 could be an aberration

One interpretation emphasizes the transformation of agriculture to shed much of its labor, and replace horses, mules, and people with machines and other inputs bought off-farm

=> many fewer farms, much less labor, and much more land per farm

Conclusion

Another interpretation of this evidence emphasizes agricultural science and public policy and a slowdown in the rate of funding of agricultural R&D starting in the late 1970s

On the first interpretation it is less clear if the rapid productivity growth of the 1950–1990 period can be restored, even with an acceleration in R&D spending

On the second interpretation it seems possible to restore productivity growth through a sustained acceleration in spending on farm productivity-enhancing R&D

Thanks!

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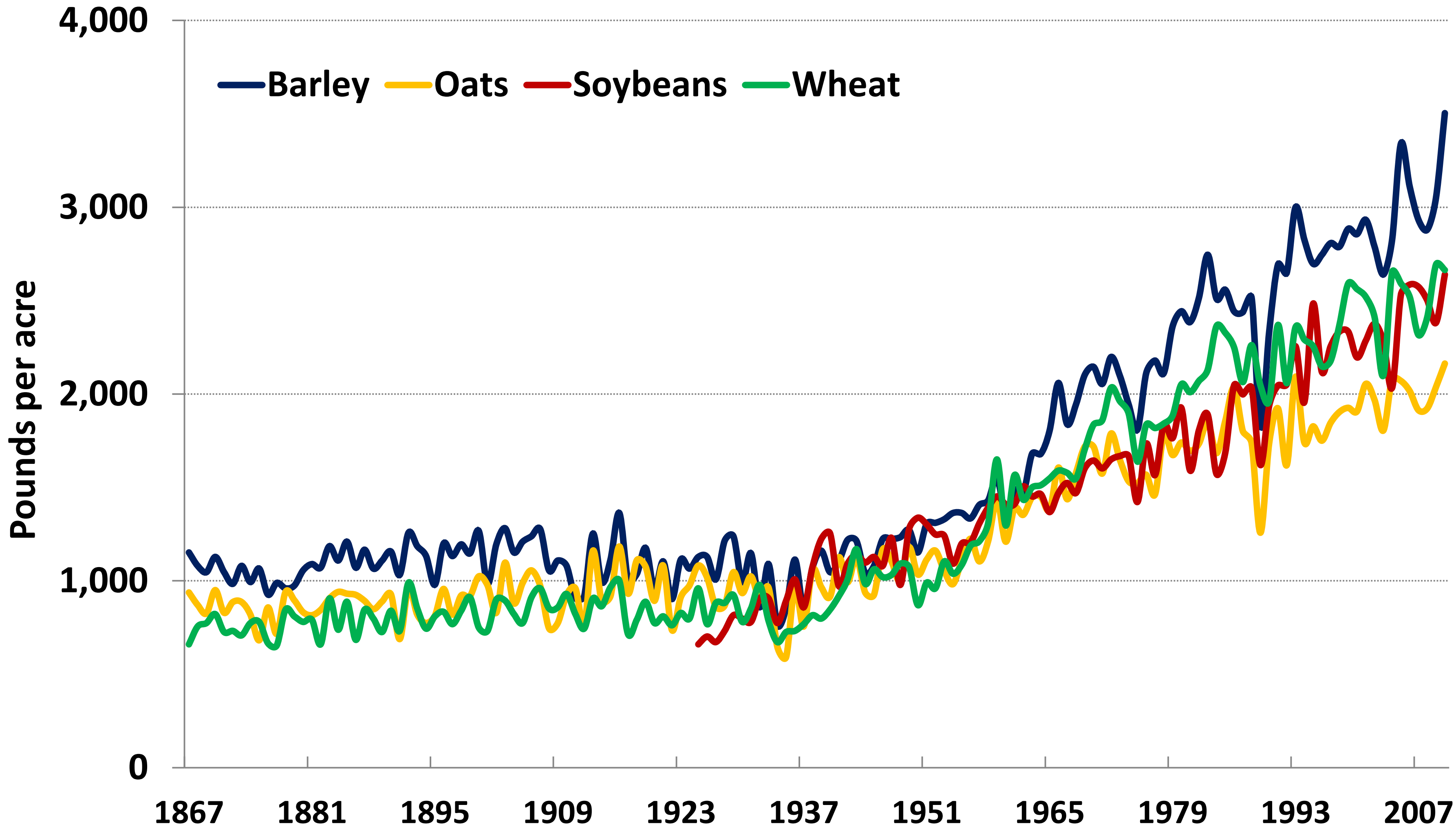
Crop Yields in Pounds per Acre, 1867–2007



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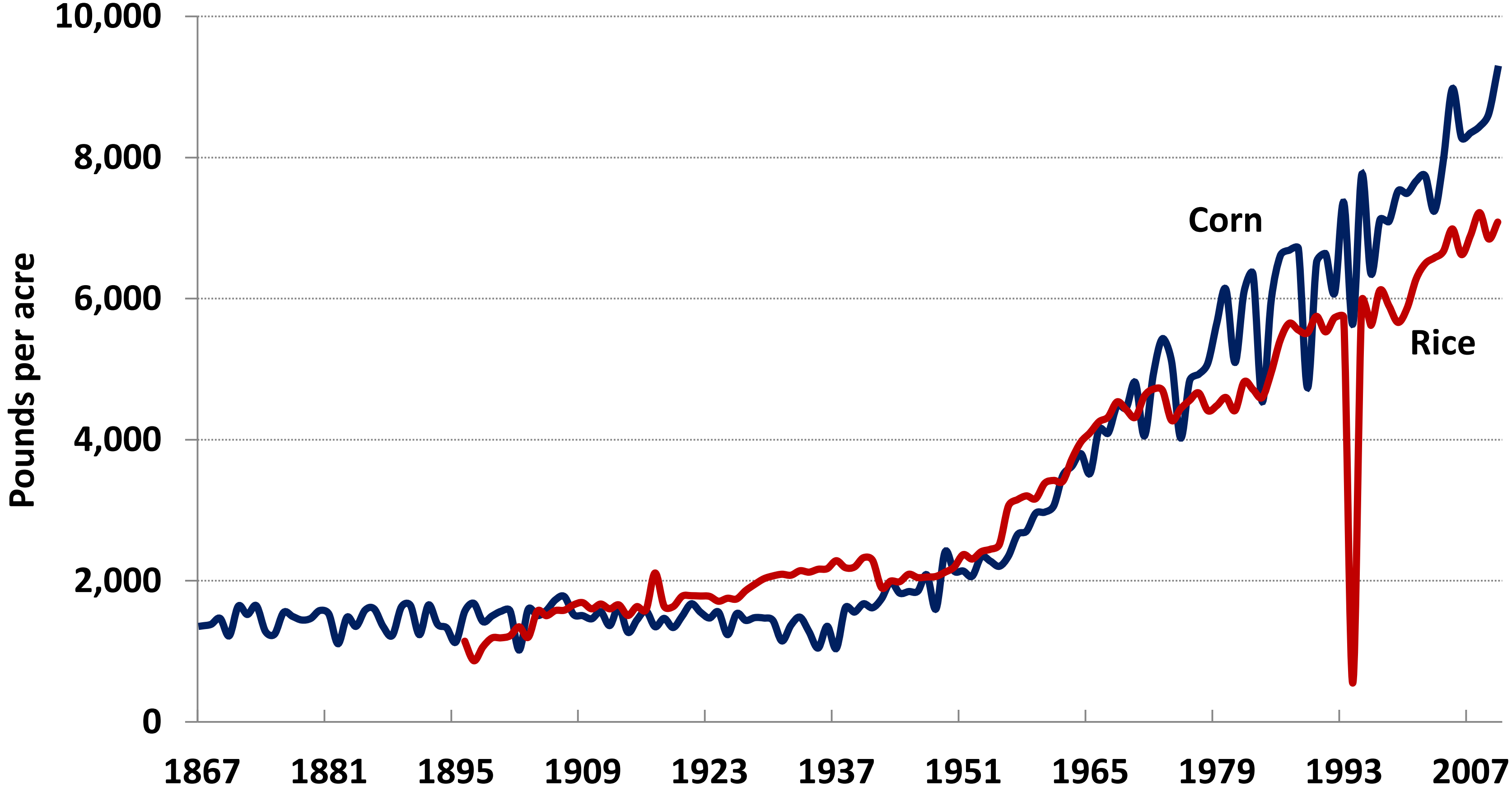


Rolling Regressions

Used by Nordhaus (2004) to detect a productivity slowdown in the U.S. economy during the 1970s and 1980s

Simple regression of productivity growth ($\Delta \ln MFP_t$) on an intercept and a dummy variable:

$$D\ln MFP_t = a_0 + a_1 D_t + e_t$$

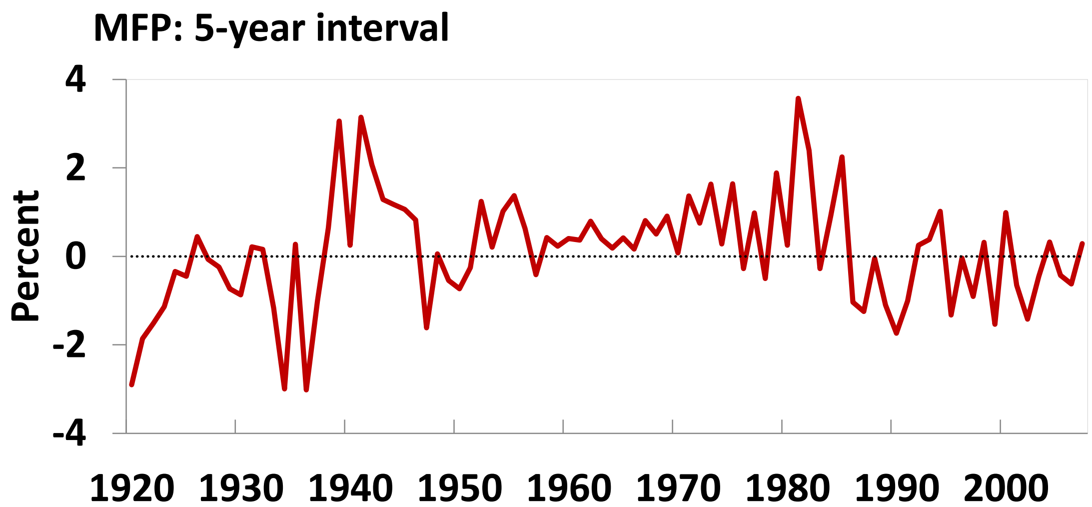
D_t = 1 inside the window and D_t = 0 outside the window

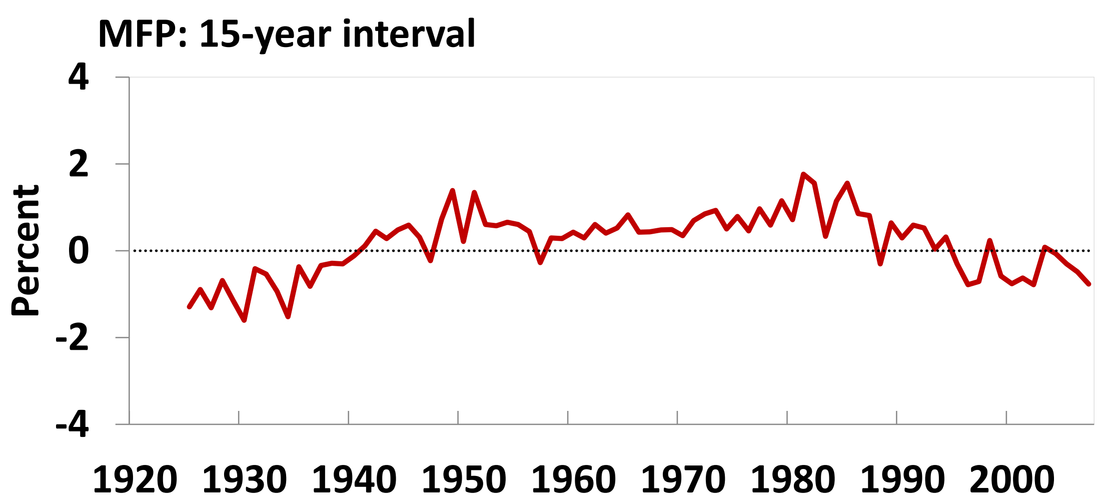
5-year and 15-year windows, roll through the sample.

α_1= average $\Delta \ln MFP_{IW}$ – average $\Delta \ln MFP_{OW}$

Rolling Regressions

The figures indicate the difference between the average *MFP* growth rate for the interval ending in the year shown, and for all other years in the sample.





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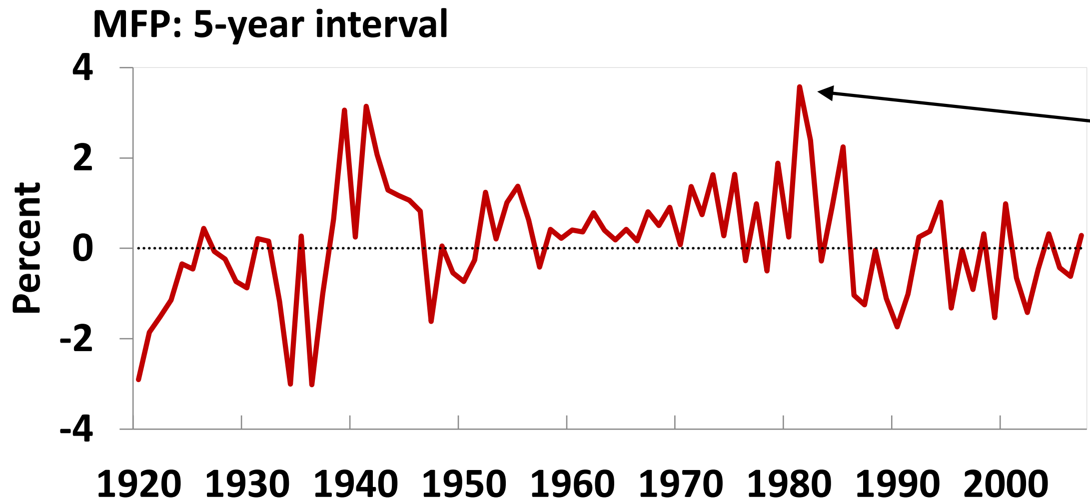
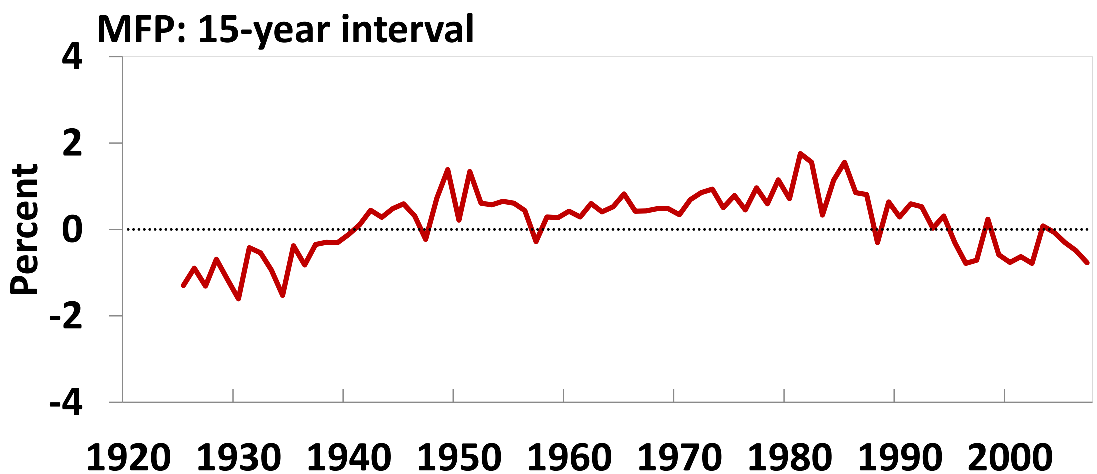
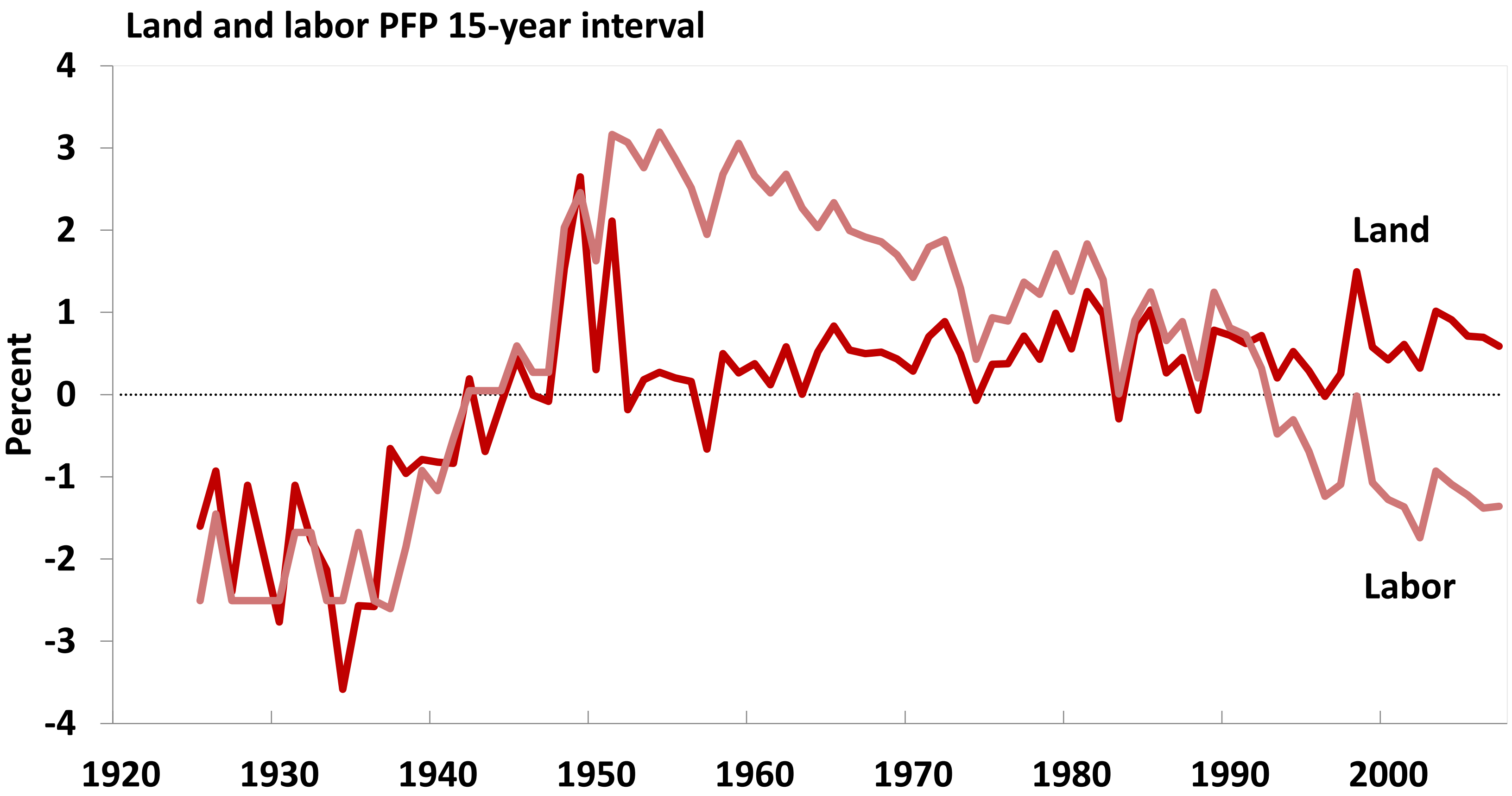


For example, the 1981 figure is average *MFP* growth rate for 1977–1981, minus the average growth rate for all other years in sample.

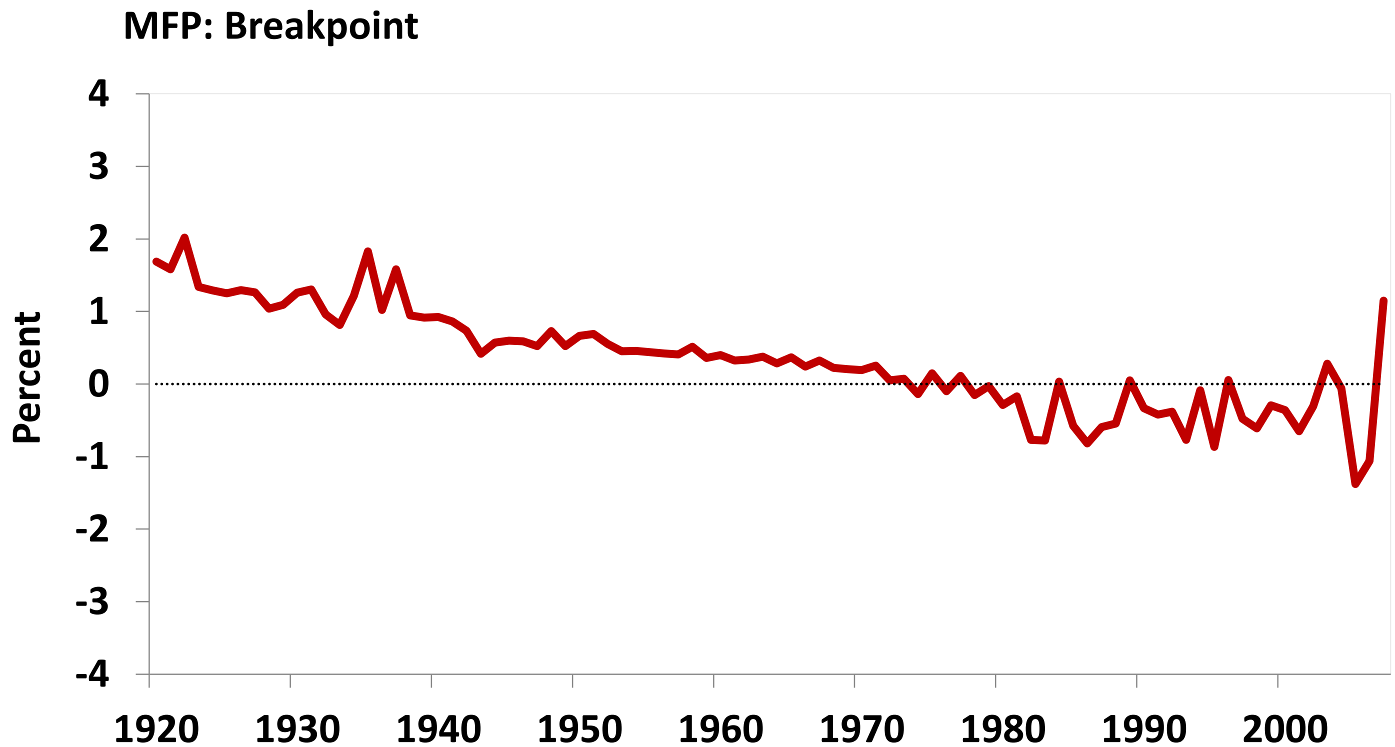


Rolling Regressions



Rolling Regressions (Breakpoint)

With the 'breakpoint' version, the dummy variable, D_{t}, was assigned a value of 0 for each year prior to a breakpoint and 1 thereafter. Breakpoints were set at each year from 1920 to 2006, and a rolling series of dummies was constructed accordingly.



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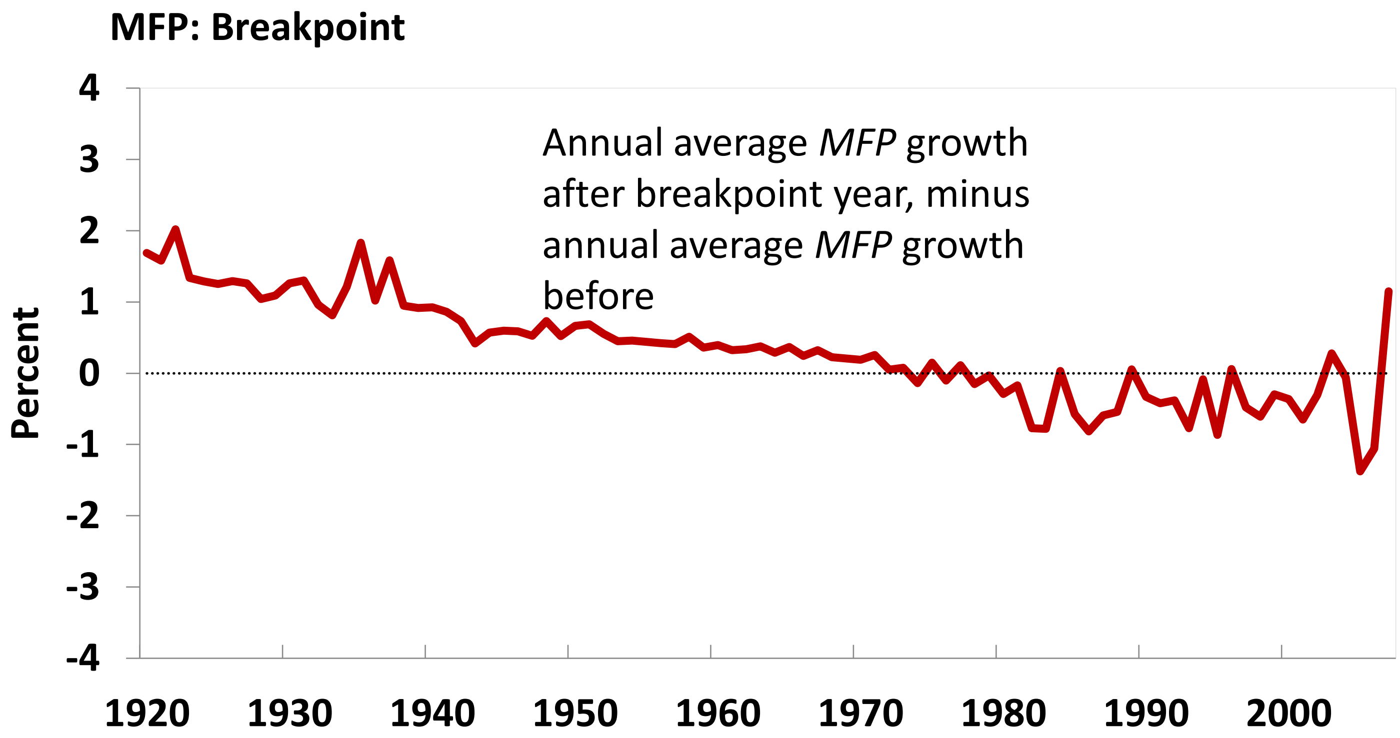

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