

**MARCH 20, 2018**



# **SYSTEMS THINKING ON THE MODERN ECONOMY: SIZE AND STRUCTURE.**

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American Chemical Society, Spring 2018  
New Orleans, LA, USA

**CAREY W. KING, PH.D.**

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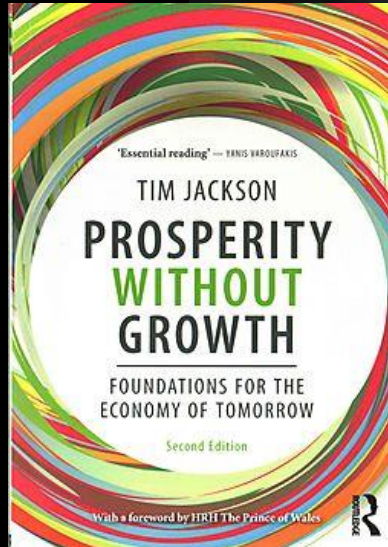
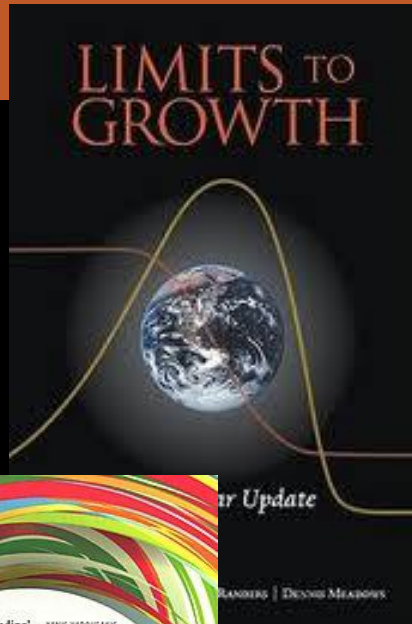
Constraints, costs, and the rate of investment in resources (energy & food) **have influenced** the structure of the economy, thus, with social implications.



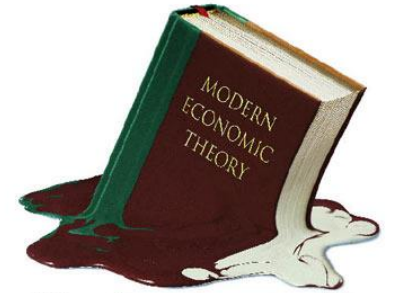
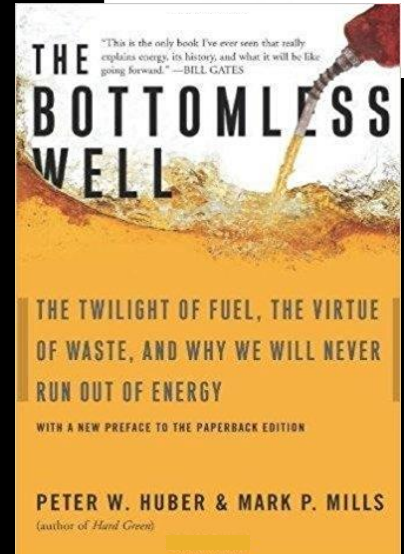
# TEXAS

The University of Texas at Austin  
Energy Institute

## Divergent viewpoints exist regarding resource (energy) and economic coupling



vs.



Where it went wrong-and how the crisis is changing it

## Morris Adelman (1990, *Regulation*):

“There is no such thing [as an exhaustible natural resource ... a fixed stock such as oil]. ... The total mineral in the earth is an irrelevant non-binding constraint. ... **Whatever is left in the ground is unknown, probably unknowable, but surely unimportant; a geological fact of no economic interest.**”

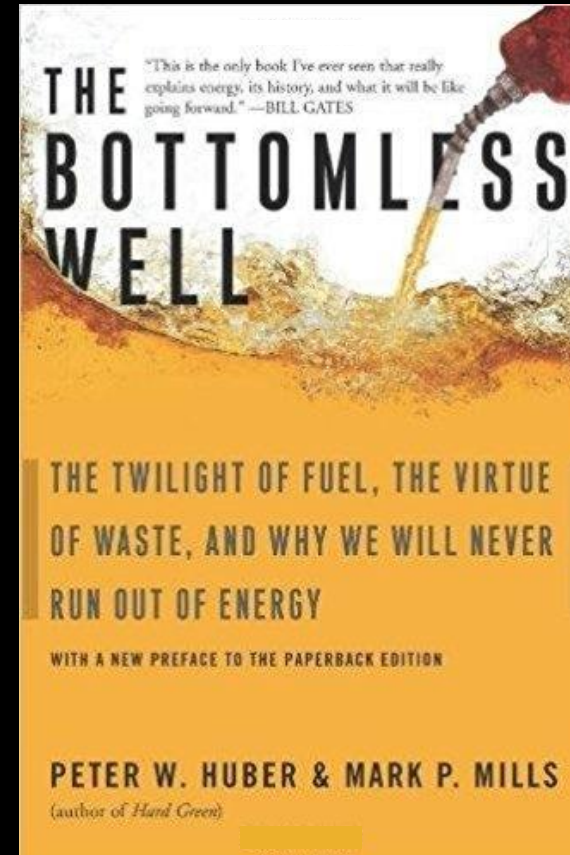


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## *The Bottomless Well* (2005):

“But the issue of exhaustion is resolved. Energy supplies are --- for all practical purposes --- infinite.” [p. 181]



Julian Simon (*The Ultimate Resource 2*, 1996):  
 “So price, together with related measures such as cost of production and share of income, is the appropriate operational test of scarcity at any given moment. What matters to us as consumers is how much we have to pay to obtain goods that give us particular services; from our standpoint, it couldn't matter less how much iron or oil there “really” is in the natural “stockpile.” [p. 26]



# Energy: a major part of the long-term economic story, but usually ignored

- Often discussed by macroeconomists
  - Demographics
  - Debt (time, endogenous money – *rarely*)
  - Education
  - Wages and inequality
- Rarely discussed by macroeconomists
  - Energy & food costs
  - Net energy consumption
  - Efficiency of conversion to services

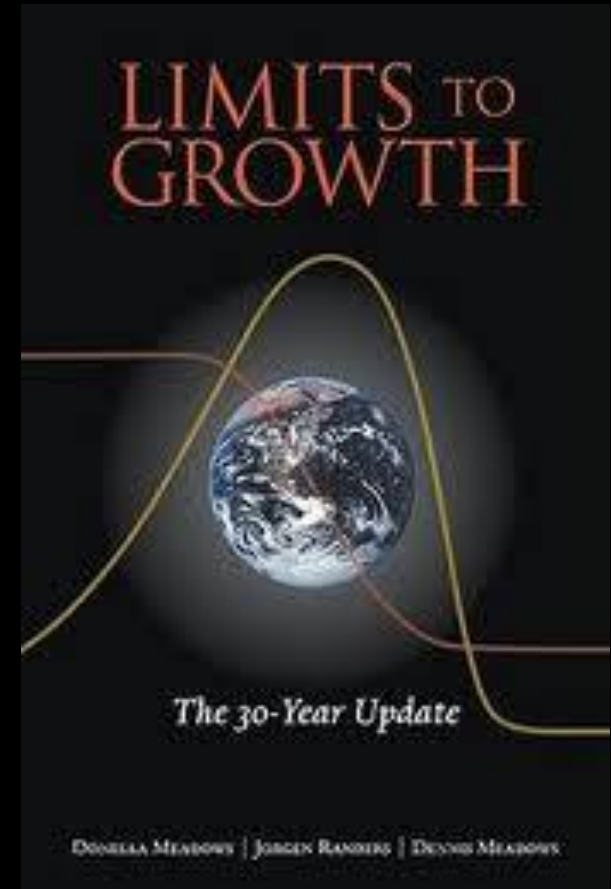






## *Limits to Growth (2004):*

“... global ecological constraints (related to resource use and emissions) would have significant influence on global developments in the twenty-first century.”

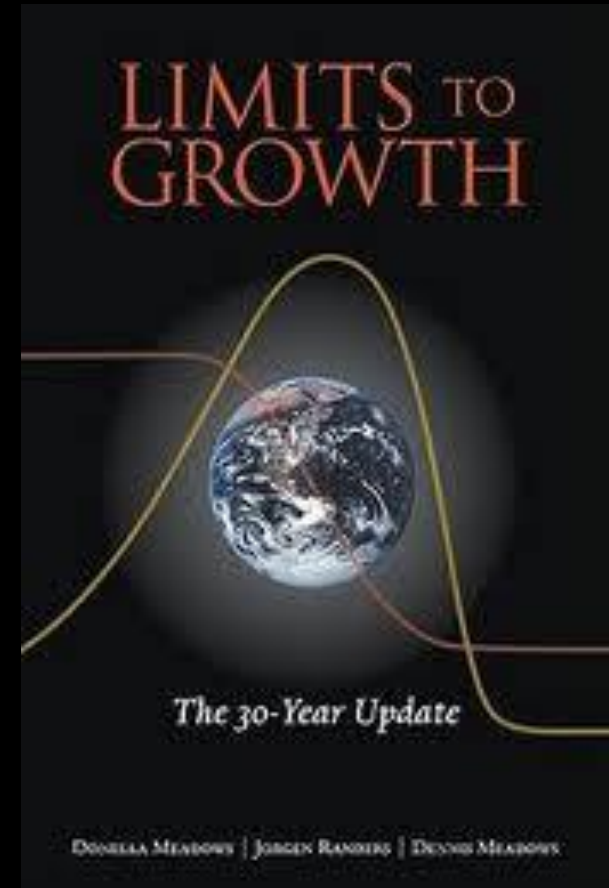




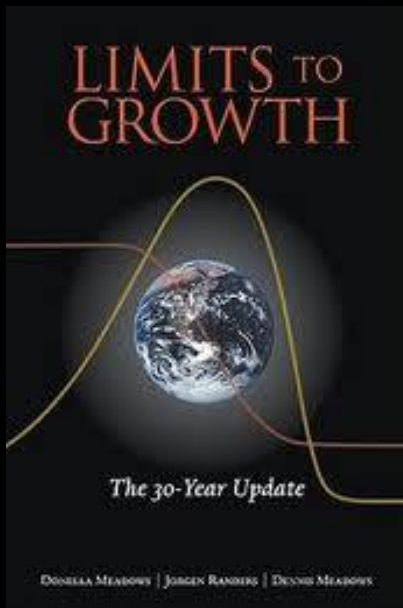
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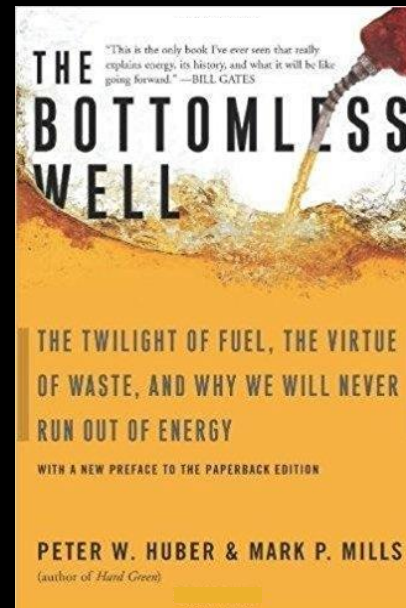
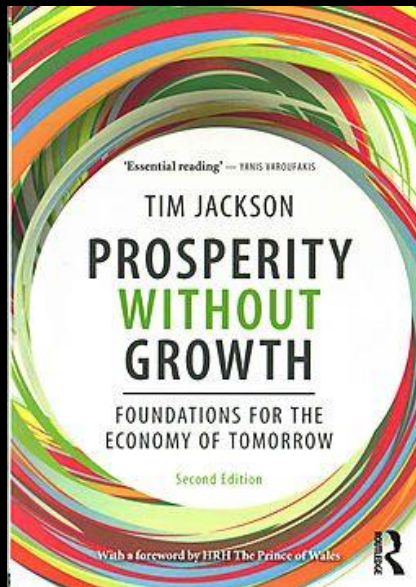
“... humanity might have to divert much capital and manpower to battle these constraints – possibly so much that the average quality of life would decline sometime during the twenty-first century.”



# The Earth is finite. Does it matter?



YES



NO



*The Economist*, July 18-24, 2009

# The Earth is finite. Does it matter?

You don't know if:

1) you don't look,  
or

2) your theory assumes it irrelevant  
(same as not looking).

# What we need from economic modeling

- An economic theory and model must be able to explain history ...
  - agrarian → fossil/industrial economy

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  - agrarian → fossil/industrial economy
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# What we need from economic modeling

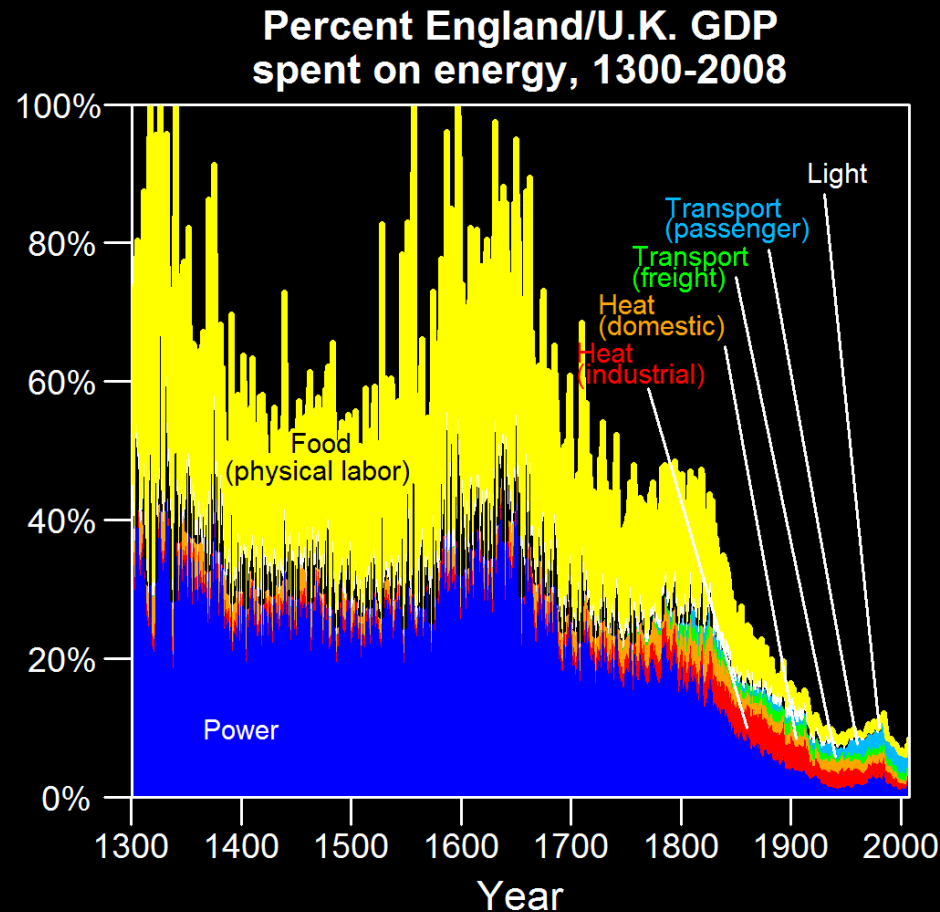
- An economic theory and model must be able to explain history ...
  - agrarian → fossil/industrial economy
- ... to then have basis to inform future ...
  - fossil → renewable (or low-carbon) economy
- Must explain if/how the finite Earth is affecting
  - economic trends (investment, wages, debt)
  - energy flow trends

# HISTORICAL CONTEXT OF ENERGY AND FOOD COSTS



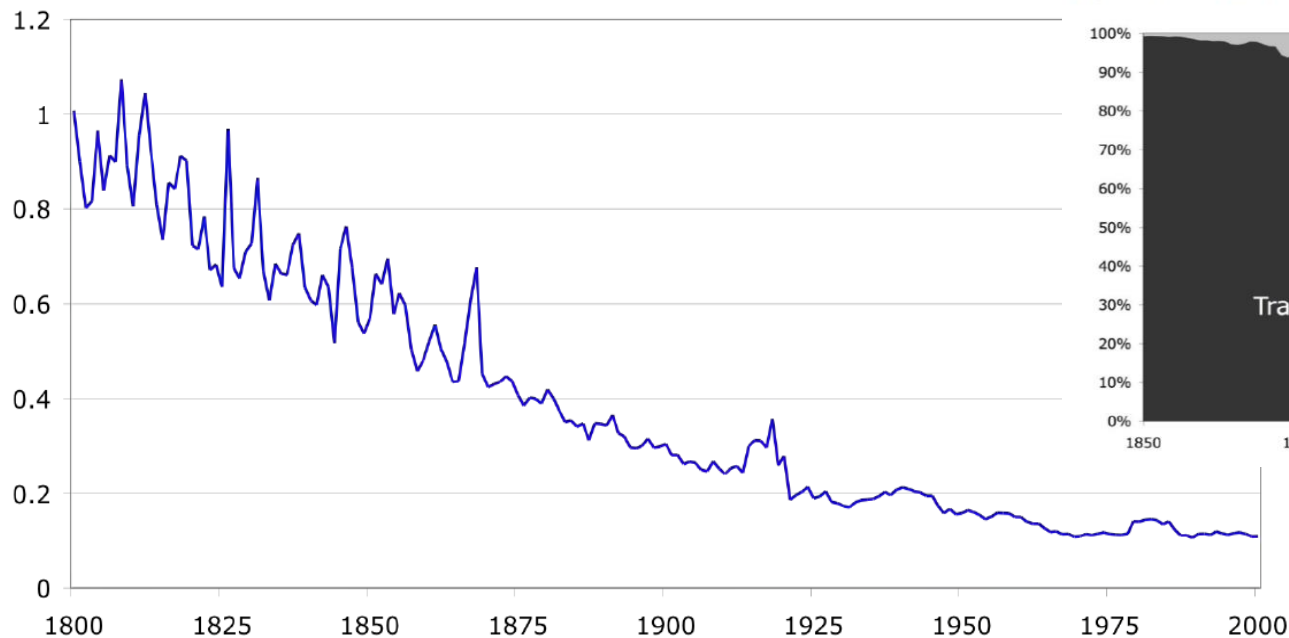
# Declining *energy* & *food* costs are the characteristic trend of the industrial era

- Preindustrial: food and fodder were major energy supply for *mechanical power from humans and animals*



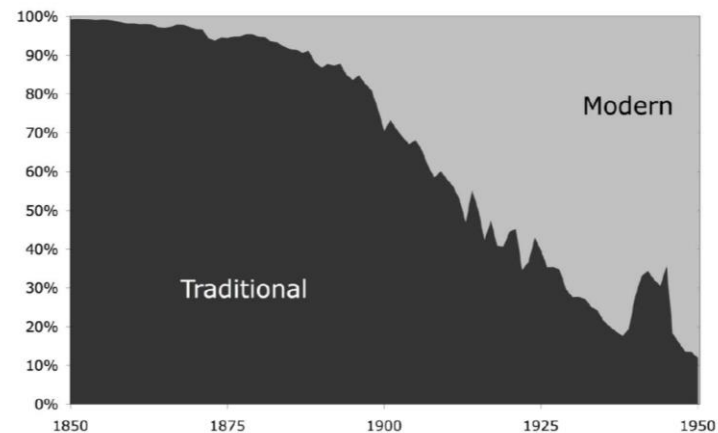
# Sweden (Astrid Kander data)

**Figure 1: Sweden 1800-2000, Value of Energy/GDP**



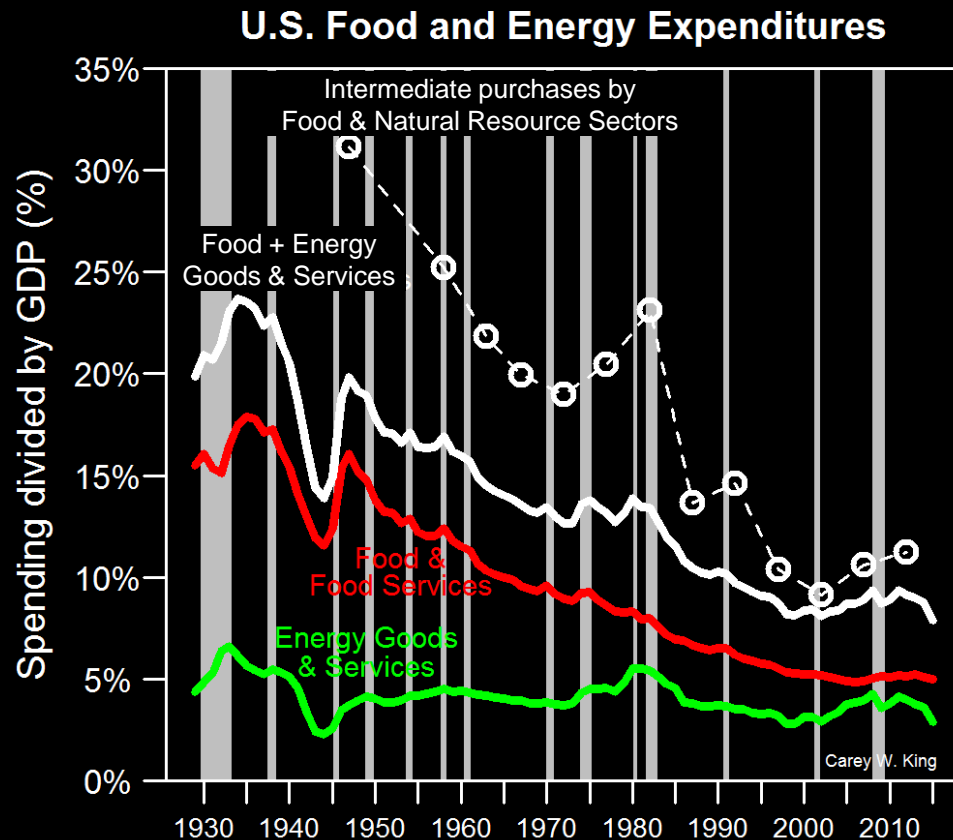
Source: Kander (2002)

**Figure 3. Cost Shares of Traditional and Modern Energy Carriers**



U.S.:  
“Food + Energy”  
costs reached  
historical low  
point ~ 2000

- 2002: Lowest “natural resource” sector spending per GDP



# CONSIDERING ENERGY AND ECONOMIC TREND CHANGES:

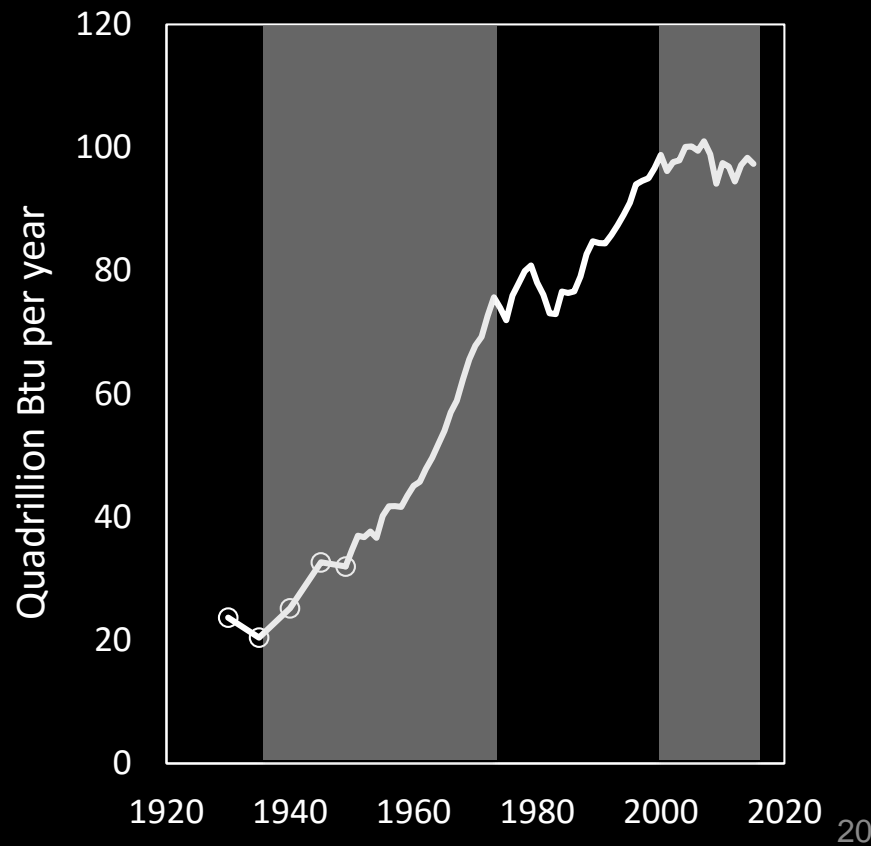
## U.S. DATA POST WW II

# Total U.S. Energy Consumption

	Rate of Change (%/yr)
1935-1973	7.1
1973-2000	1.1
2000-2016	-0.1

Data: U.S. EIA, MER Table 1.1.

## U.S. Data

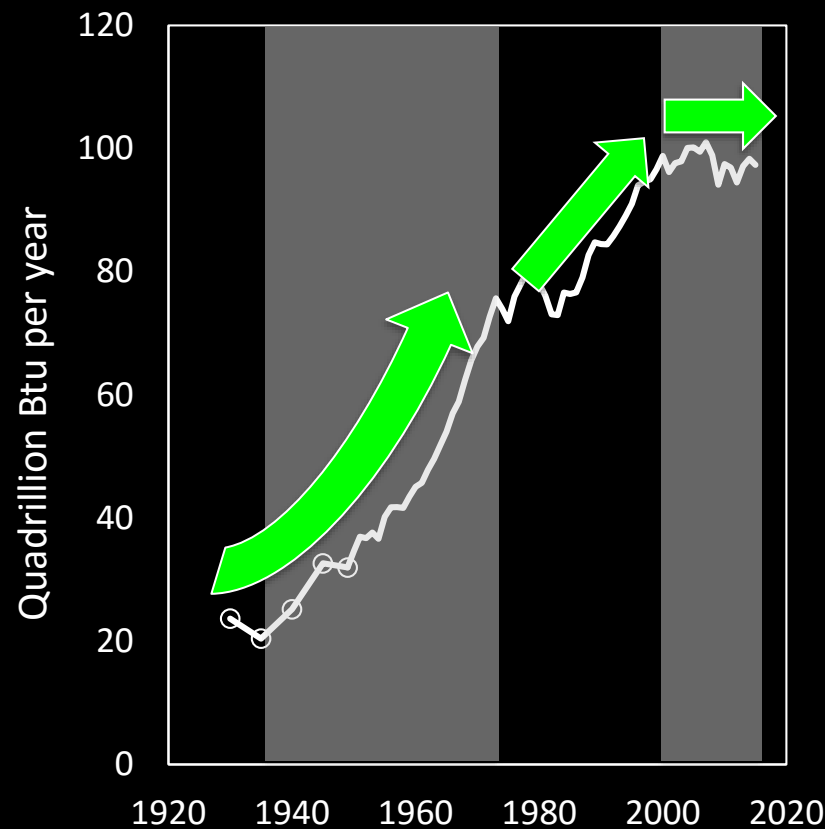


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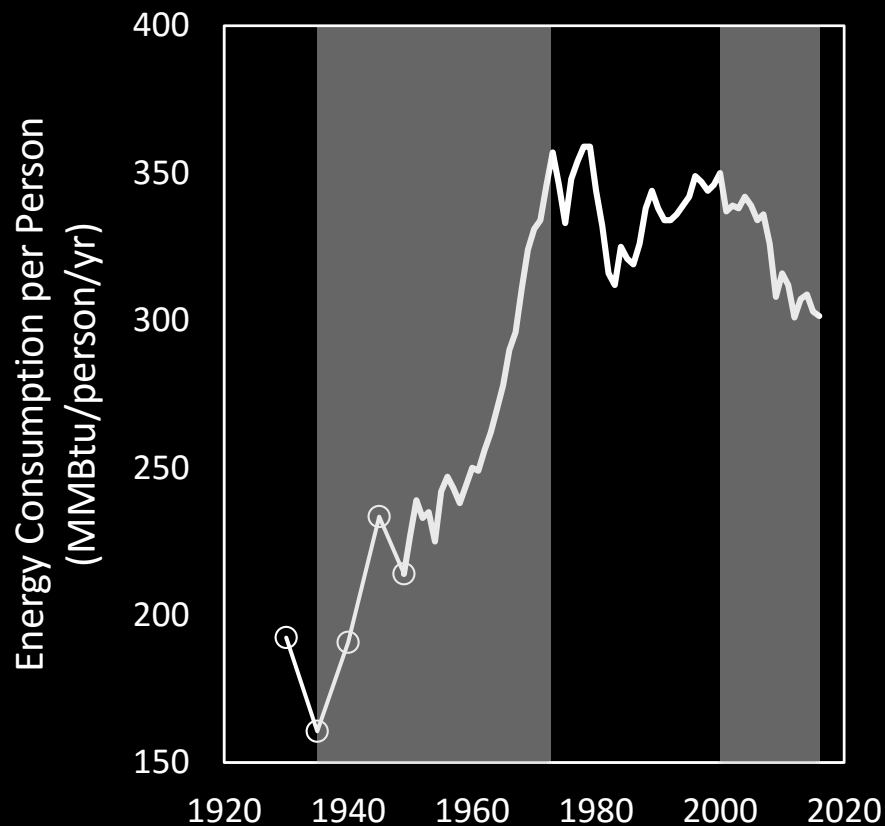


# Energy Consumption per person

	Rate of Change (%/yr)
1935-1973	3.2
1973-2000	-0.1
2000-2016	-0.9

Data: U.S. EIA, MER Table 1.1 and U.S. Census.

## U.S. Data

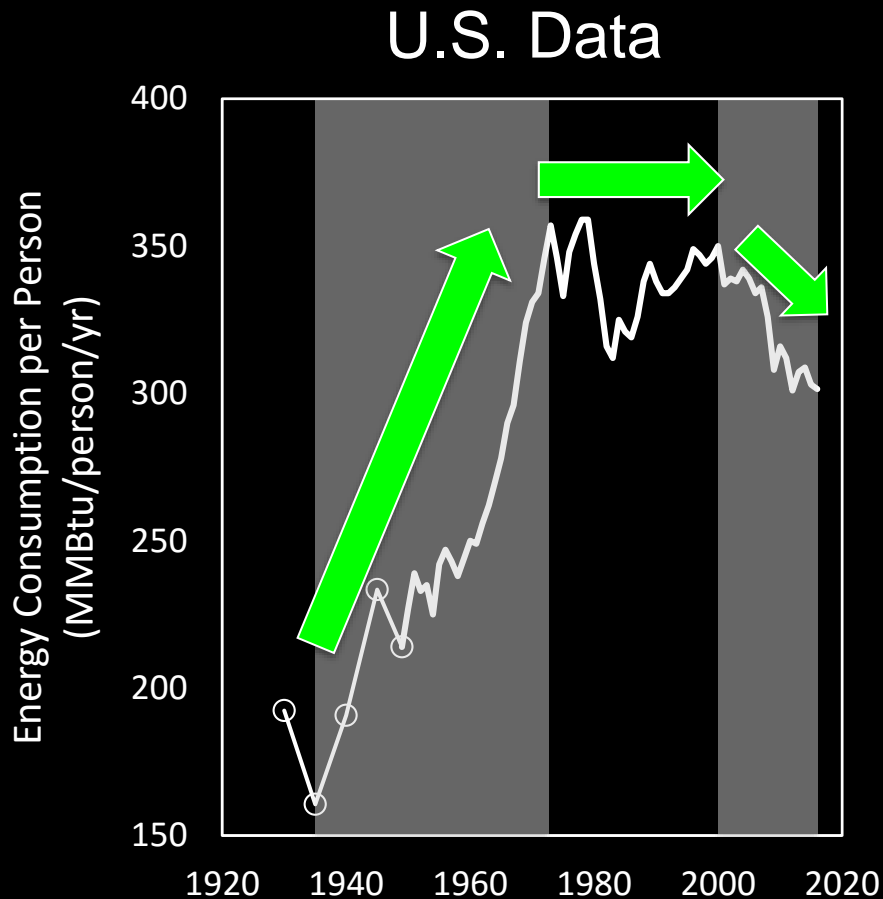




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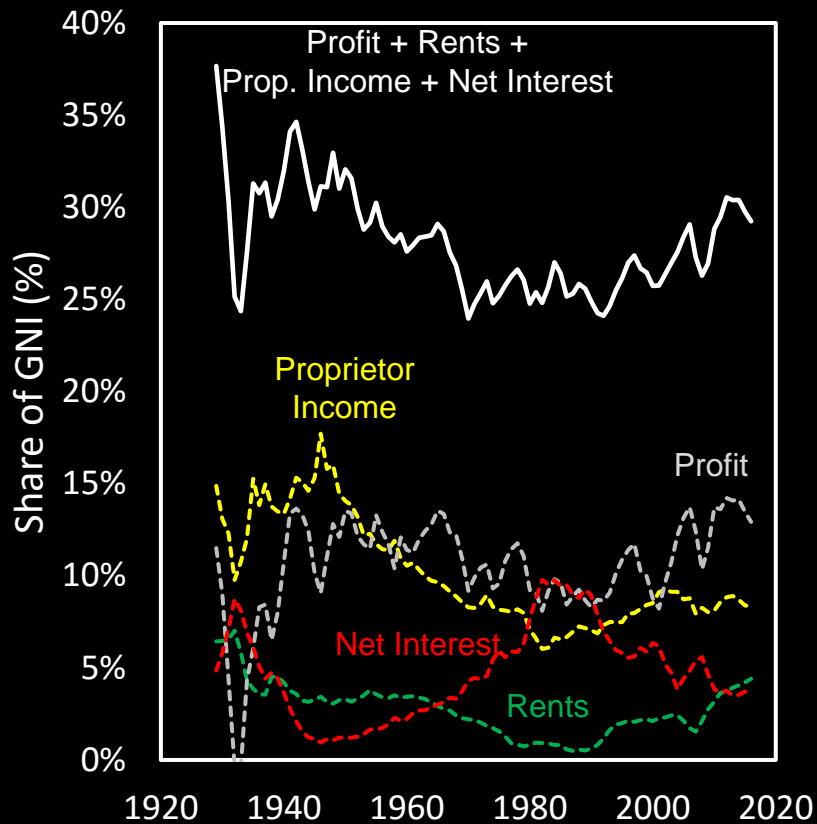
# Total “Capital Income” share of U.S.

(Corp. profit + Rents +  
Proprietor Income + Net Interest of banks)

	Rate of Change (%/yr)
1945-1973	
1973-2000	
2000-2016	

Change in share of GNI.  
Data: U.S. BEA Table 1.12, National Income by Type of Income

## U.S. Data



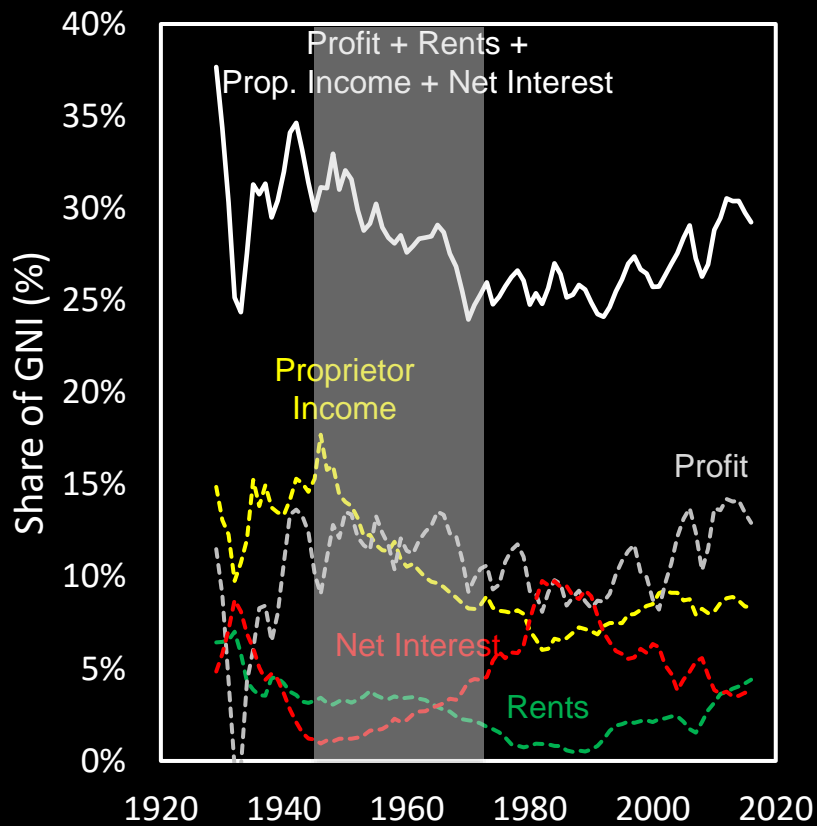
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1973-2000	
2000-2016	

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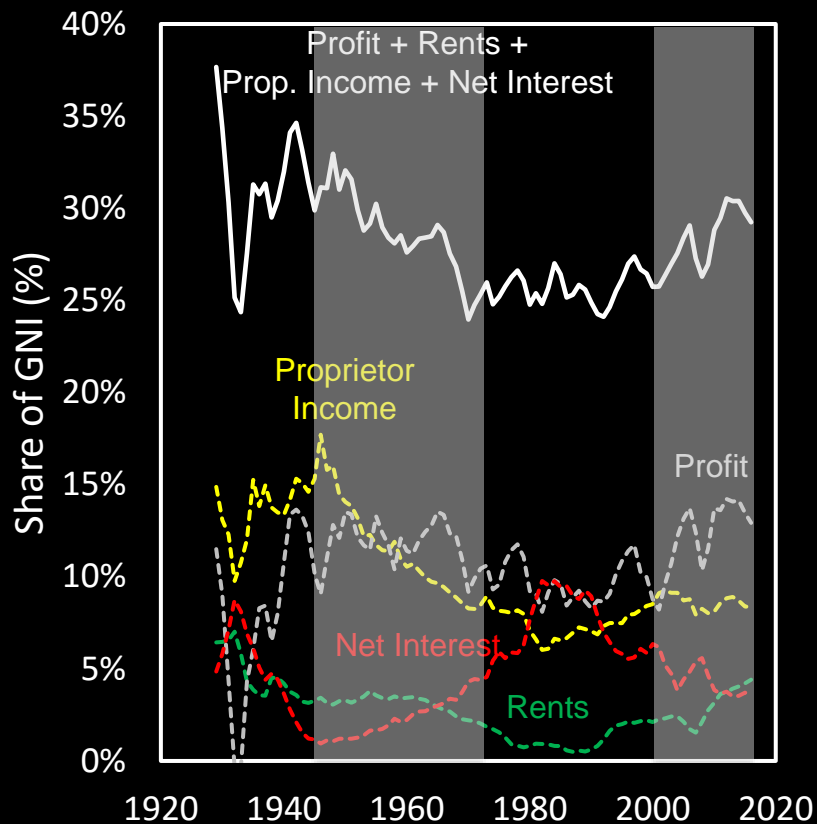
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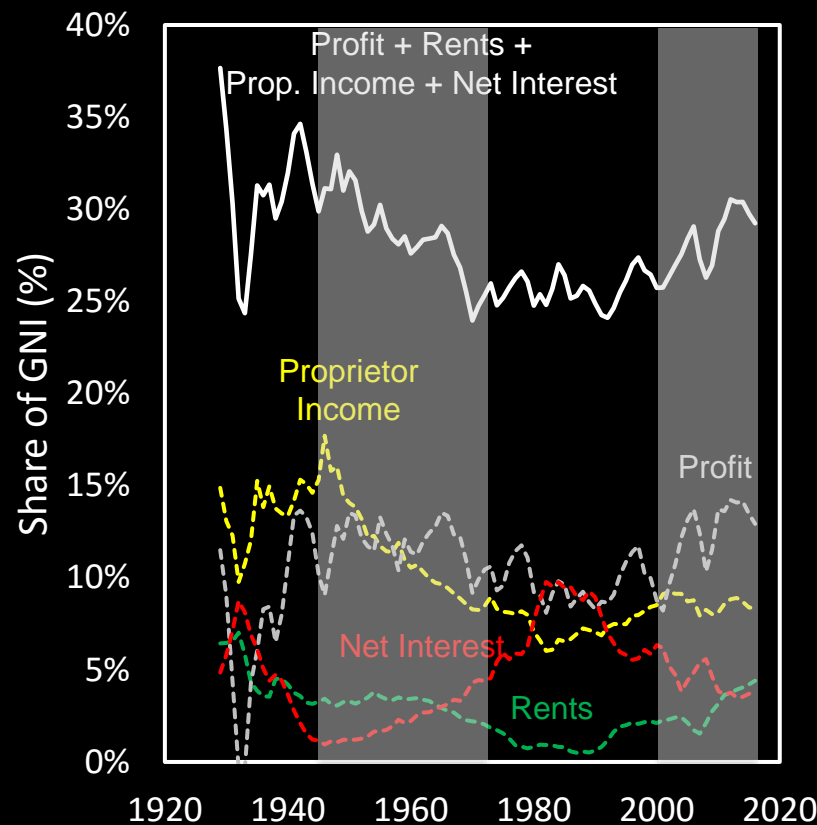
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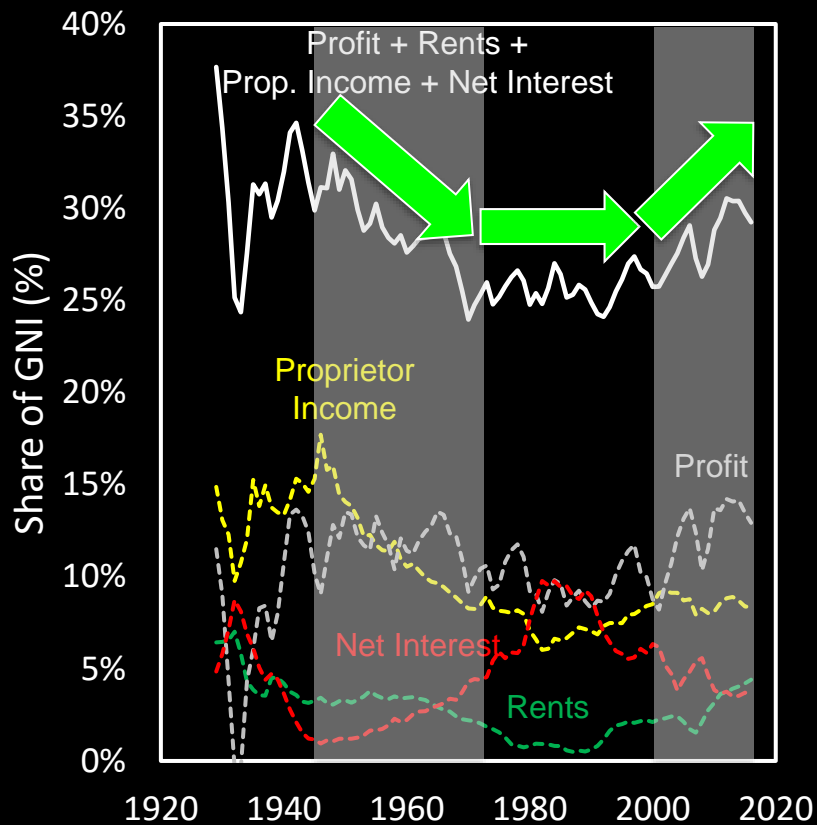
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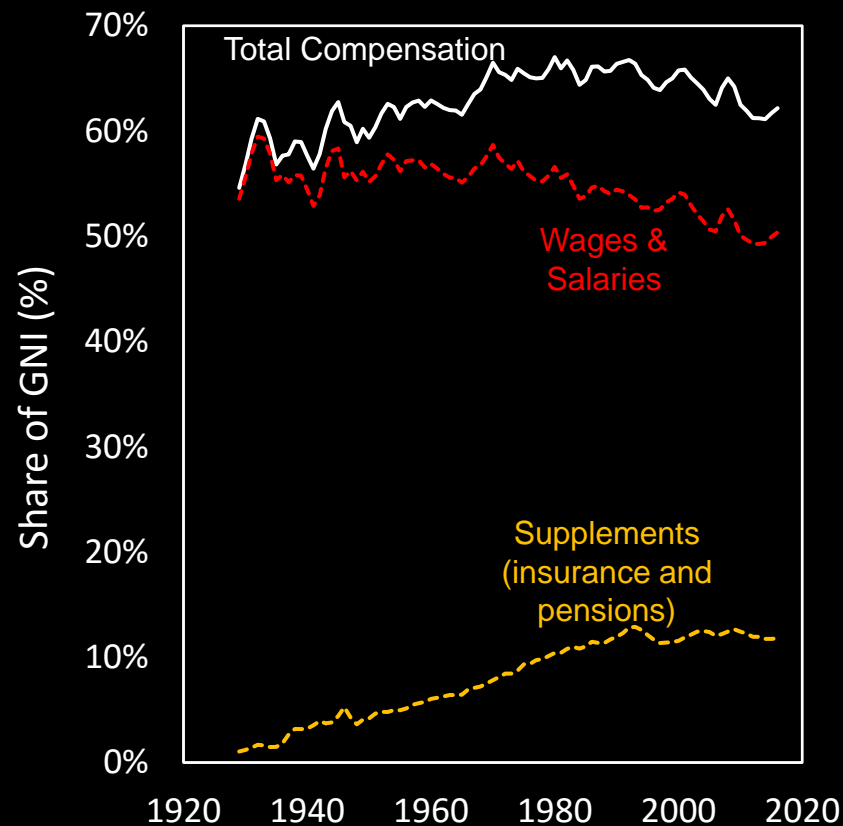


# Total Employee Compensation Share of U.S.

	Rate of Change (%/yr)
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## U.S. Data







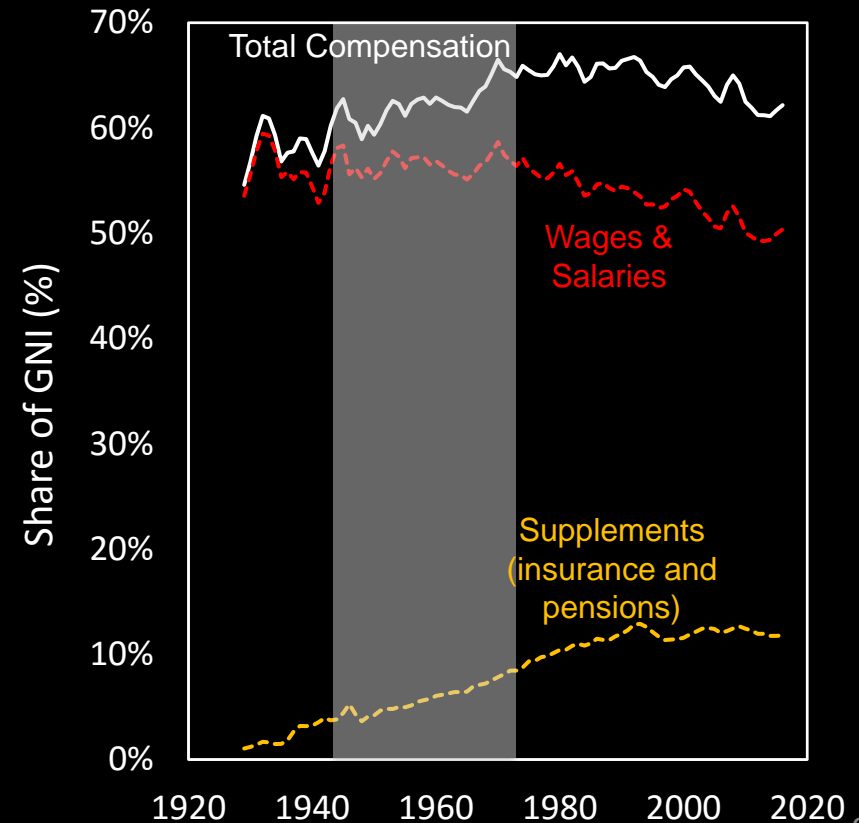
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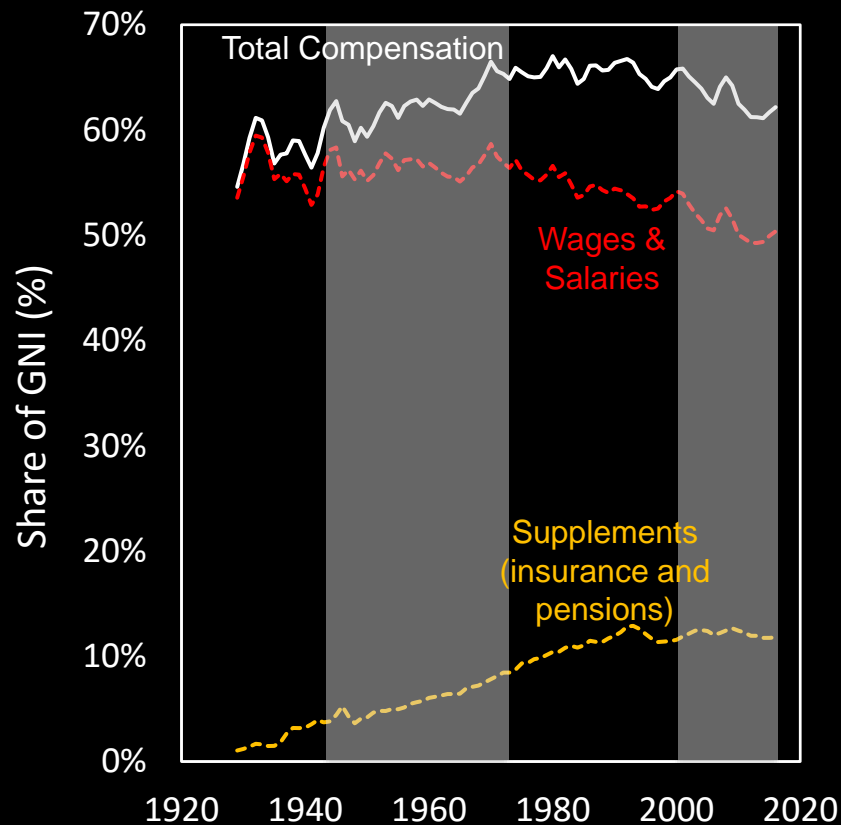


# Total Employee Compensation Share of U.S.

	Rate of Change (%/yr)
1945-1973	0.12
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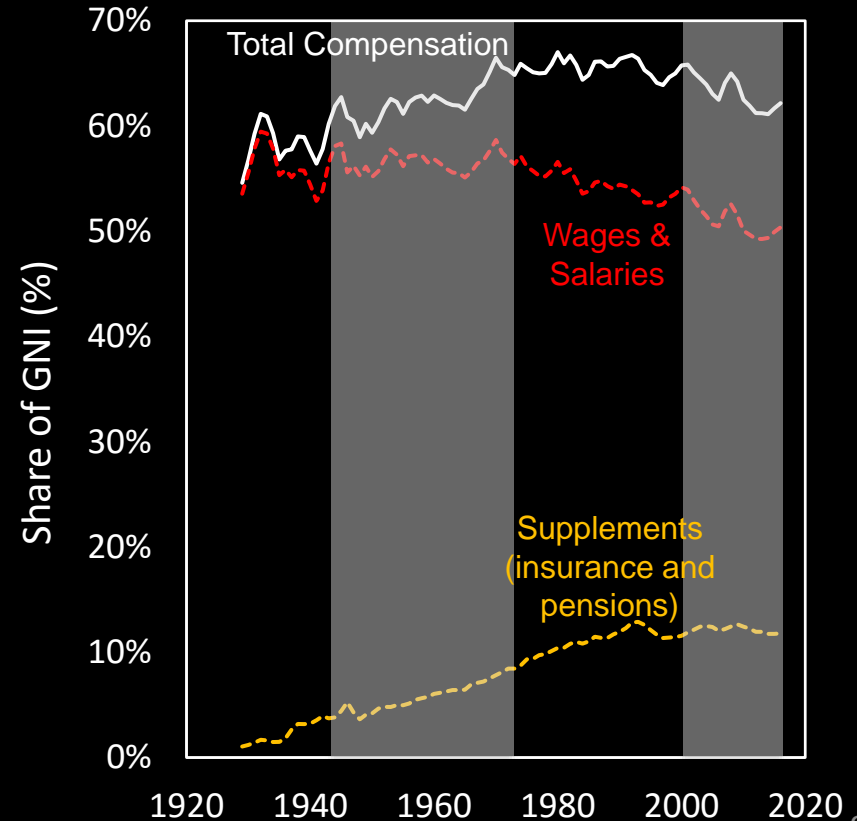
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1945-1973	0.12
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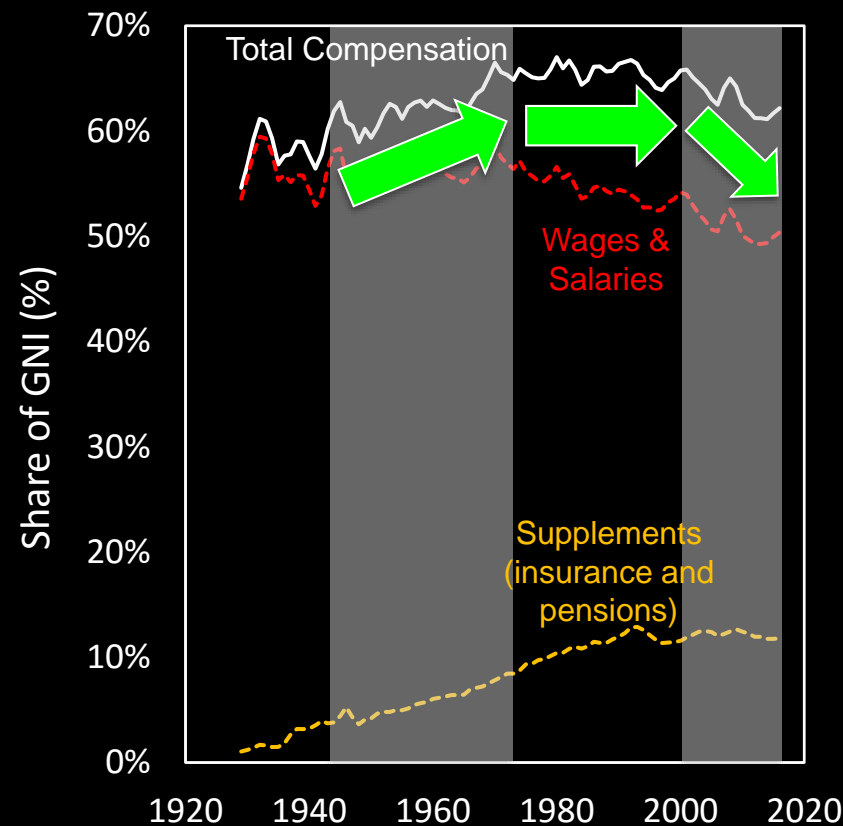


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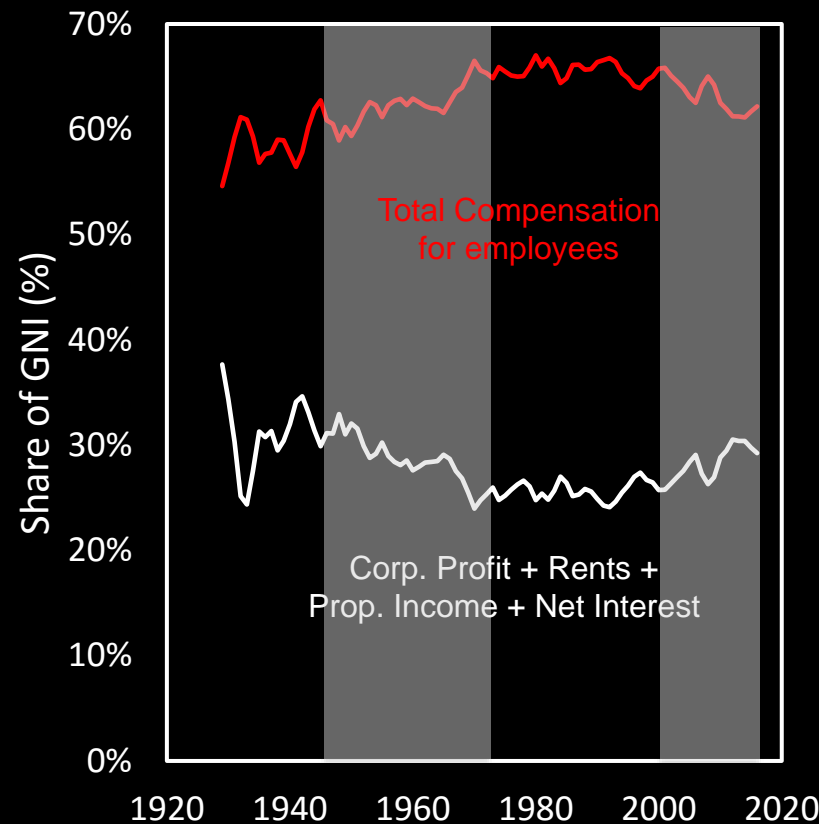
# Rate of growth of income share: Workers vs. Capital

	Capital (%/yr)	Workers (%/yr)
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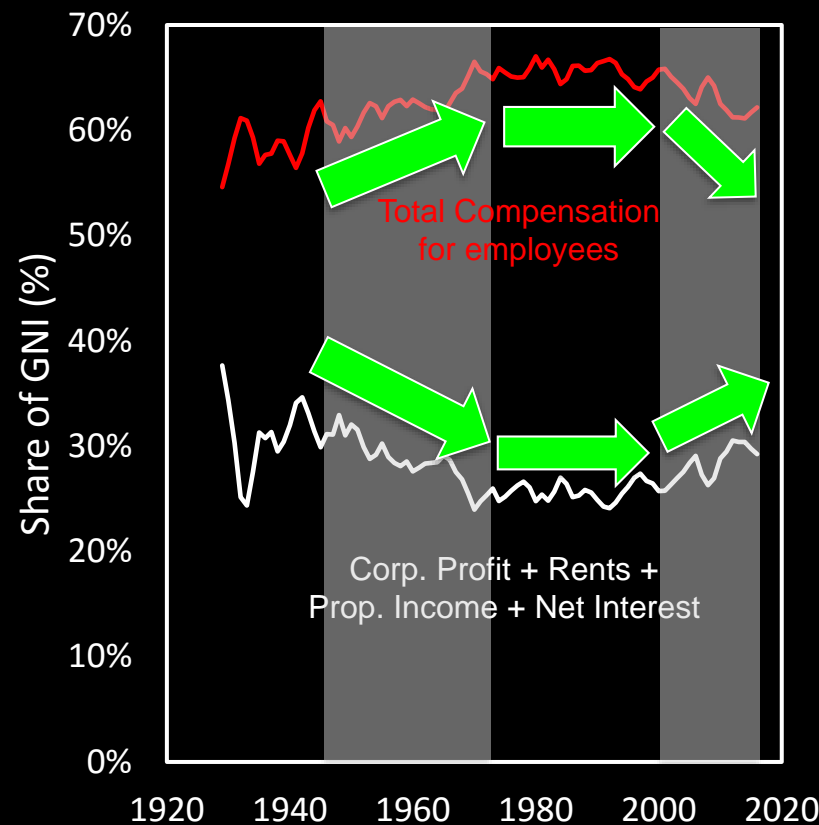
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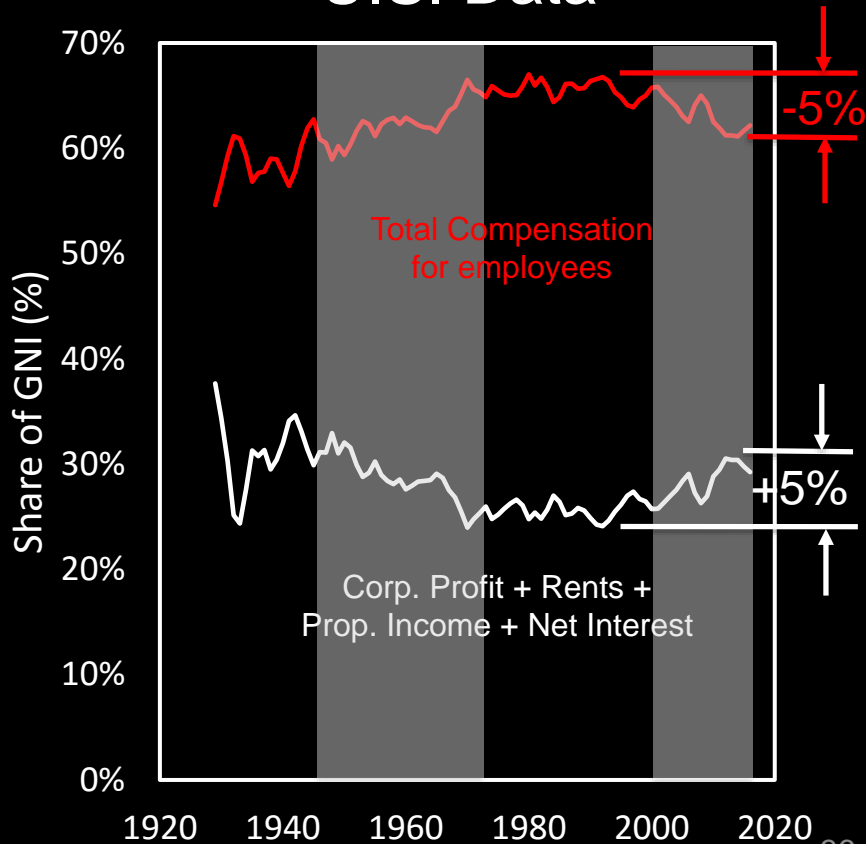
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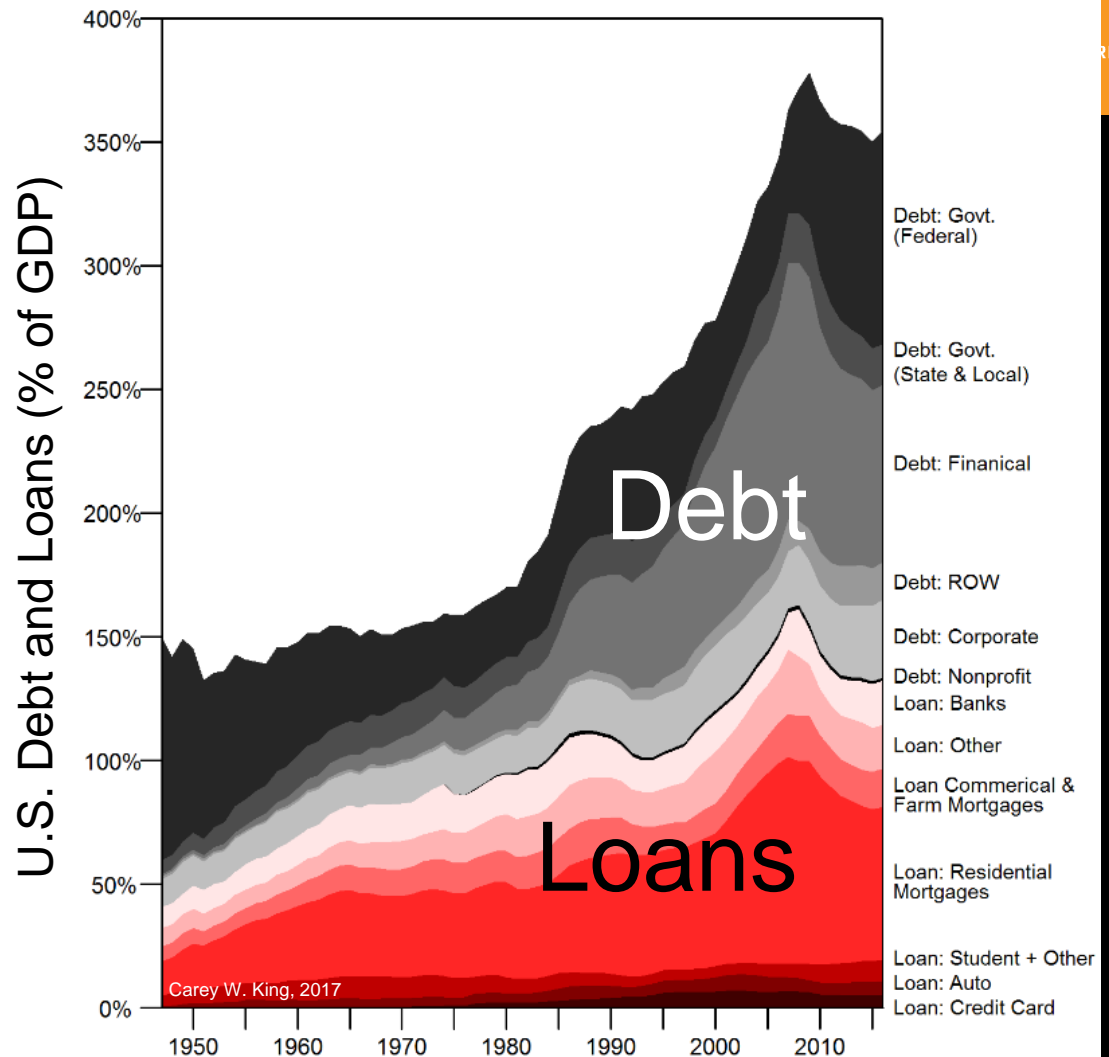




# Total U.S. Debt & Loans

- Debt
  - Sold to public
  - Treasury bills & bonds (municipal, corporate, foreign)
  - Borrower pays interest and principle at end of period
- Loans
  - Borrowed \$ from a bank
  - Make scheduled repayment (e.g., mortgage)

Data: U.S. Federal Reserve, z.1  
Tables L.208 (debt by liabilities), L.214, L.222

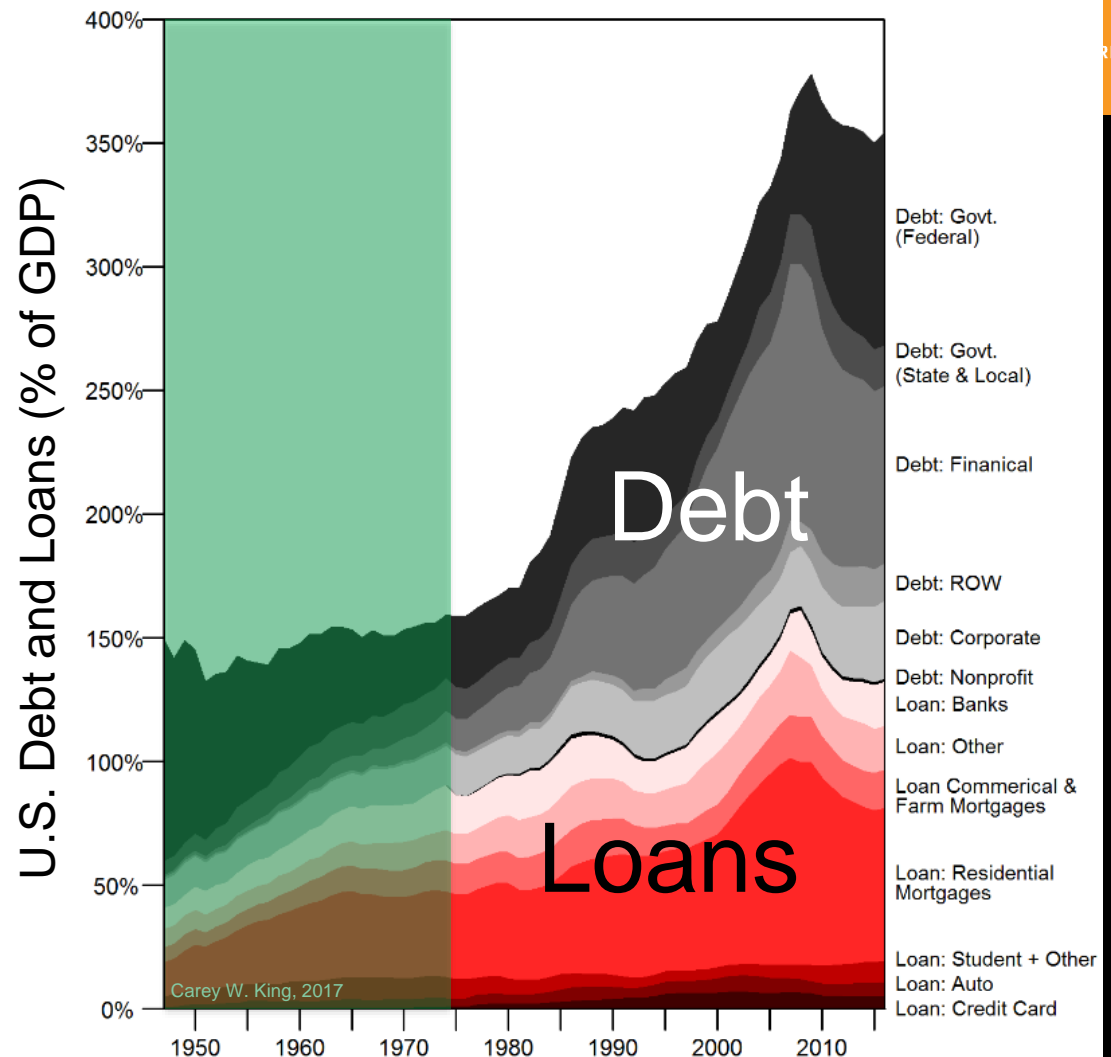


# Debt & Loans

1947-1973/1980

- Total debt ratio remained constant
- Federal debt ratio declined
- Household debt ratio increased (to mid 1960s)

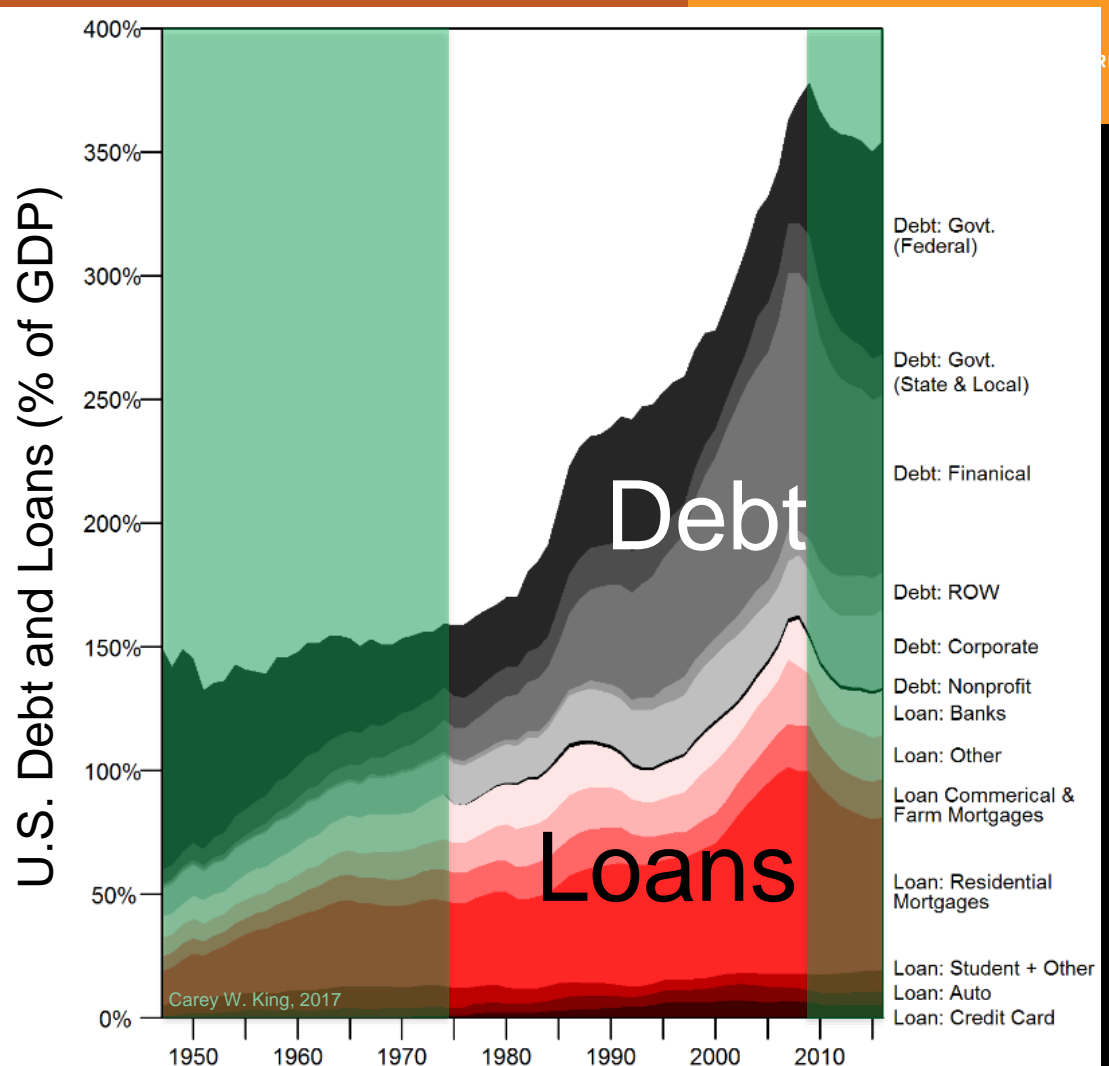
Data: U.S. Federal Reserve, z.1  
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# Debt & Loans

1973/1980-2008

- Total debt ratio more than doubled
- Financial sector debt increased the most
- Household mortgage debt ratio increased rapidly (2000-2008)



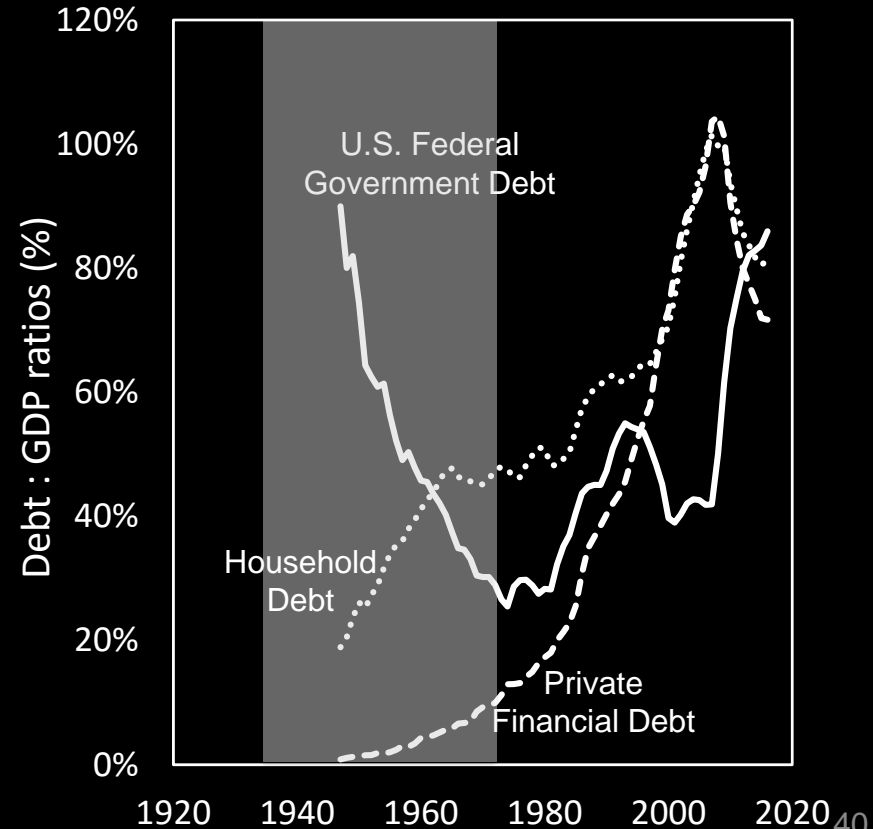
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Tables L.208 (debt by liabilities), L.214, L.222

# Debt: GDP ratios

	U.S. Govt. (%/yr)	Private Financial (%/yr)	House- hold (%/yr)
1945-1973	-2.7	45	5.9

Change in debt:GDP ratio.  
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## U.S. Data

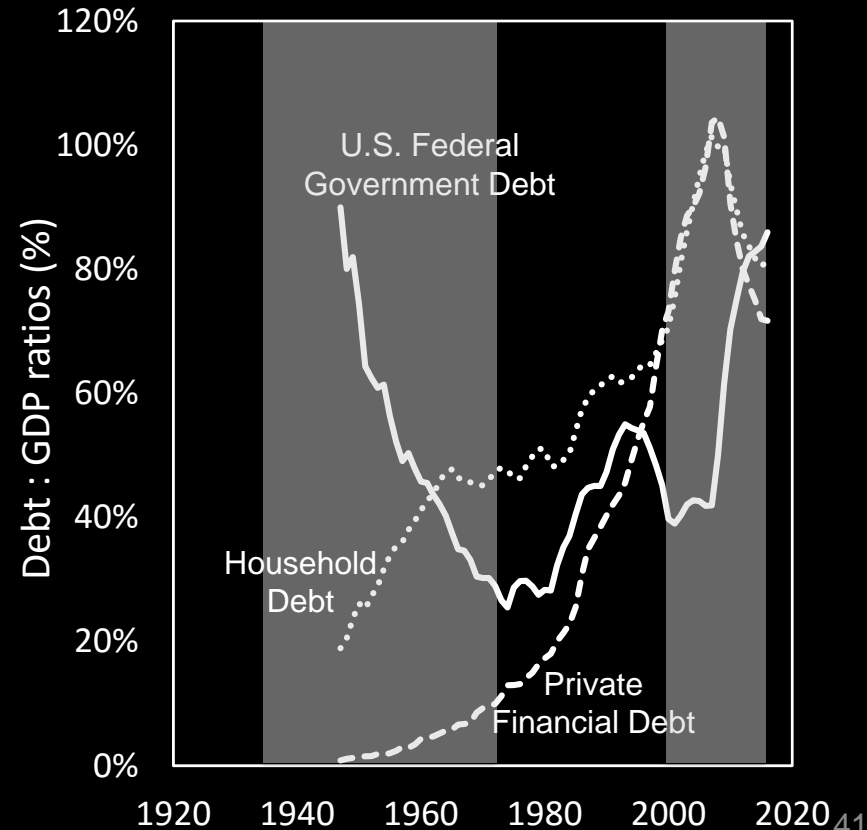


# Debt: GDP ratios

	U.S. Govt. (%/yr)	Private Financial (%/yr)	House- hold (%/yr)
1945-1973	-2.7	45	5.9
1973-2000	1.8	20	1.7

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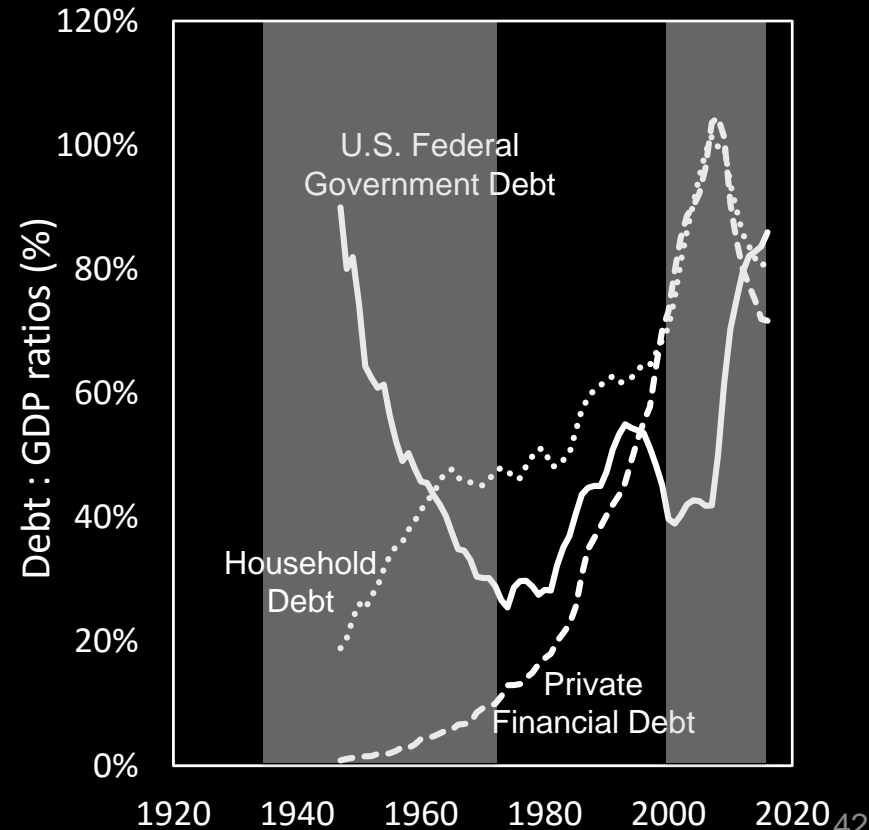


# Debt: GDP ratios

	U.S. Govt. (%/yr)	Private Financial (%/yr)	House- hold (%/yr)
1945-1973	-2.7	45	5.9
1973-2000	1.8	20	1.7
2000-2016	7.3	~0	1.0
2007-2016	12	-3.4	-2.2

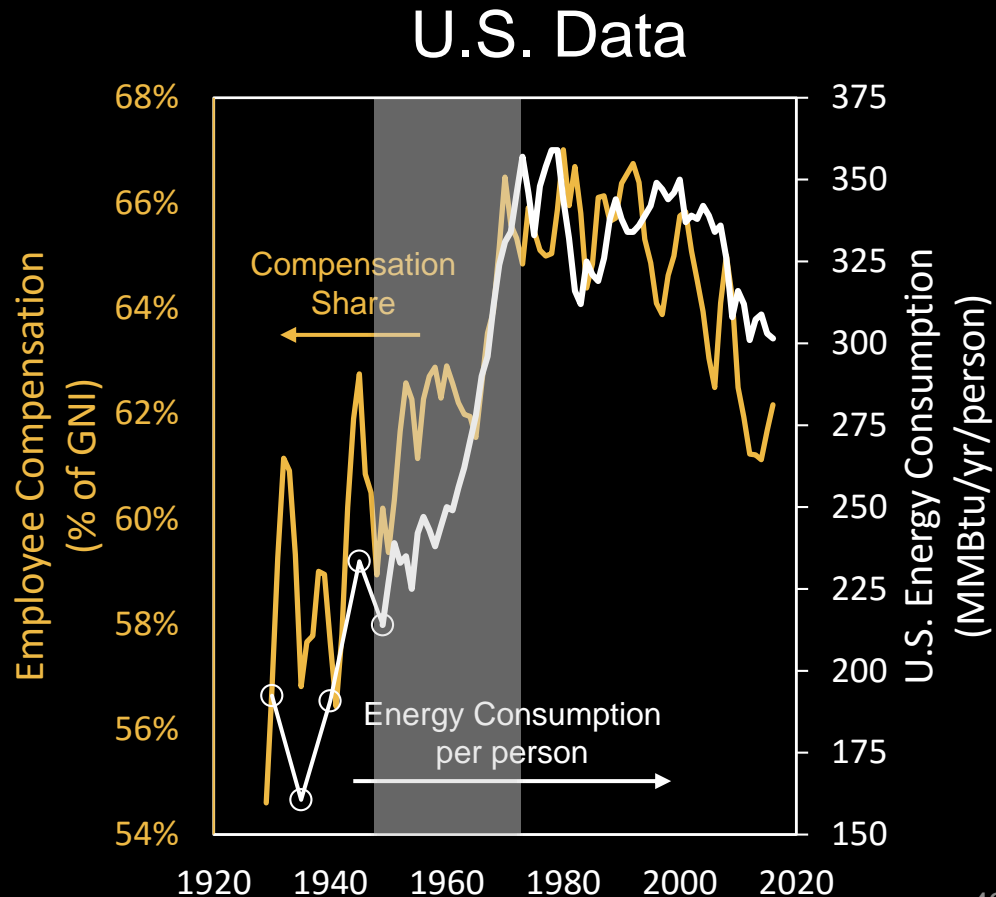
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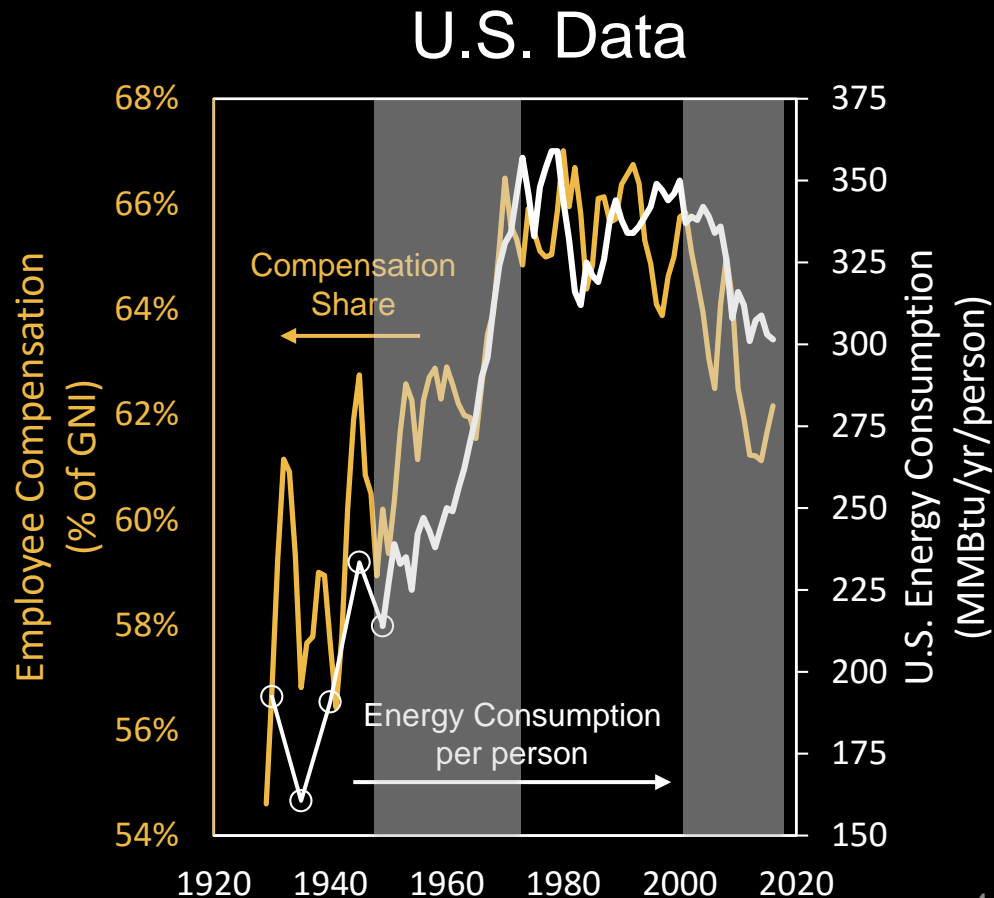
# Total Compensation & energy consumption per person

	Energy/ person (%/yr)	Workers share (%/yr)
1945-1973	1.9	0.12



# Total Compensation & energy consumption per person

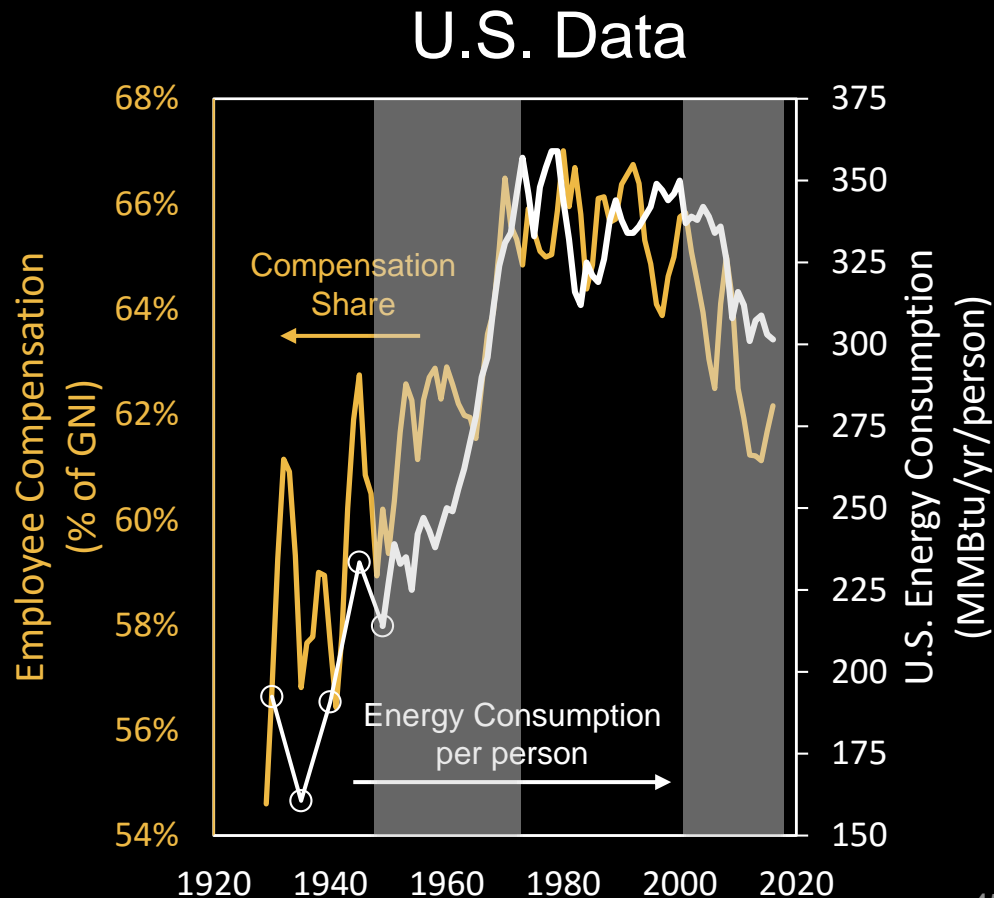
	Energy/ person (%/yr)	Workers share (%/yr)
1945-1973	1.9	0.12
1973-2000	-0.07	0.05





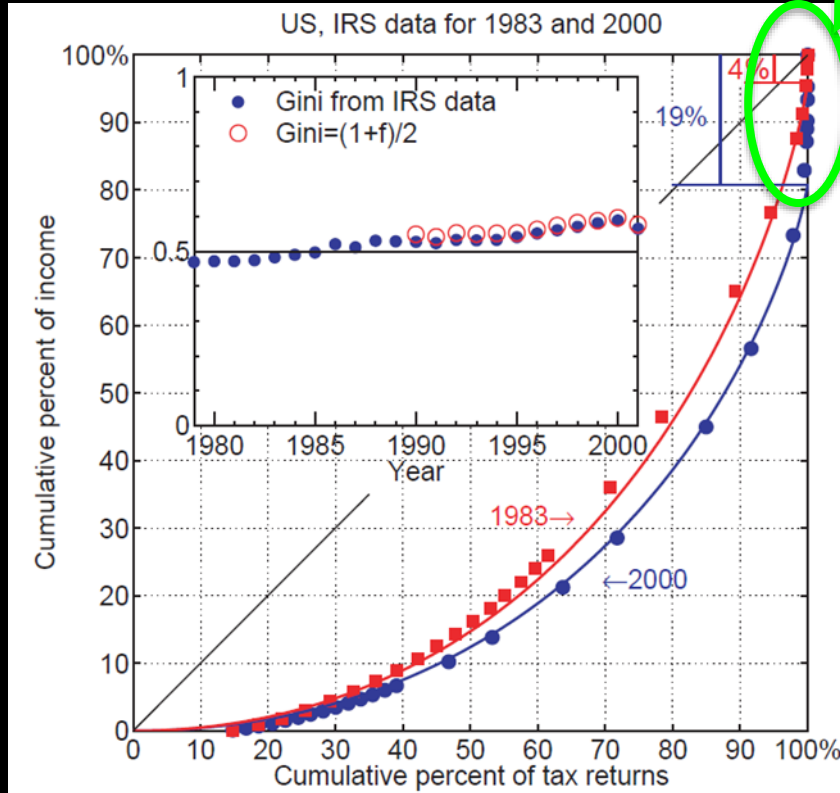
# Total Compensation & energy consumption per person

	Energy/ person (%/yr)	Workers share (%/yr)
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1973-2000	-0.07	0.05
2000-2016	-0.87	-0.34



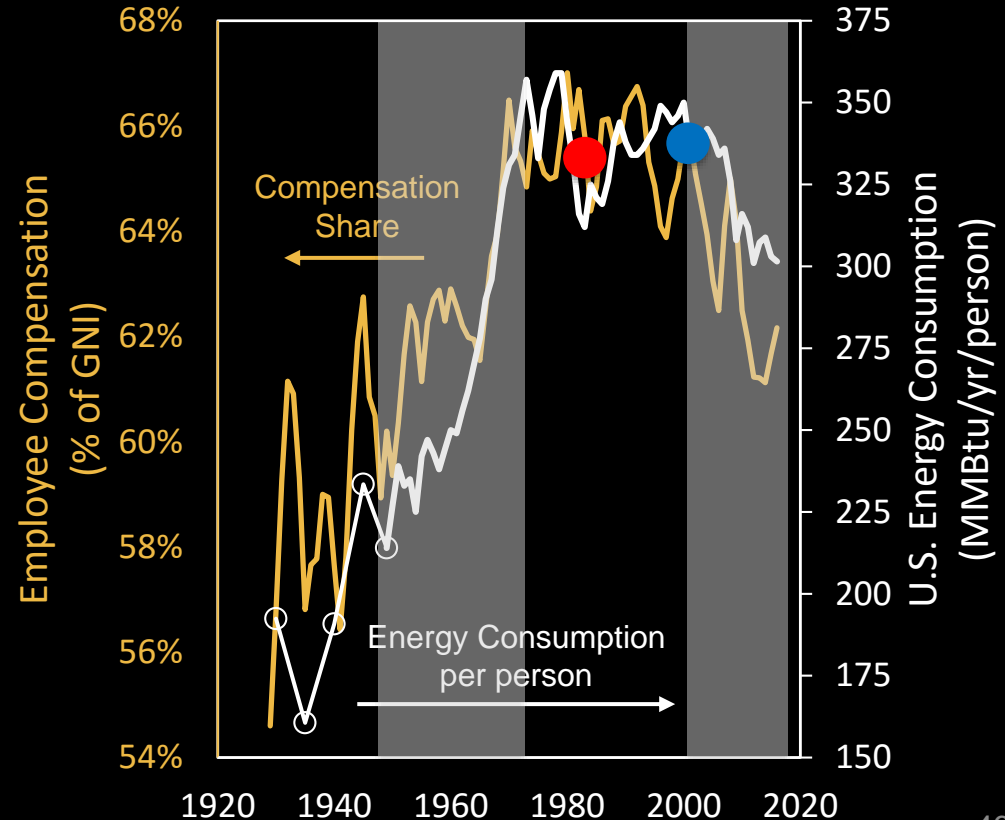
# "Superthermal" elite rich 1-3%.

WHAT STARTS HERE CHANGES THE WORLD



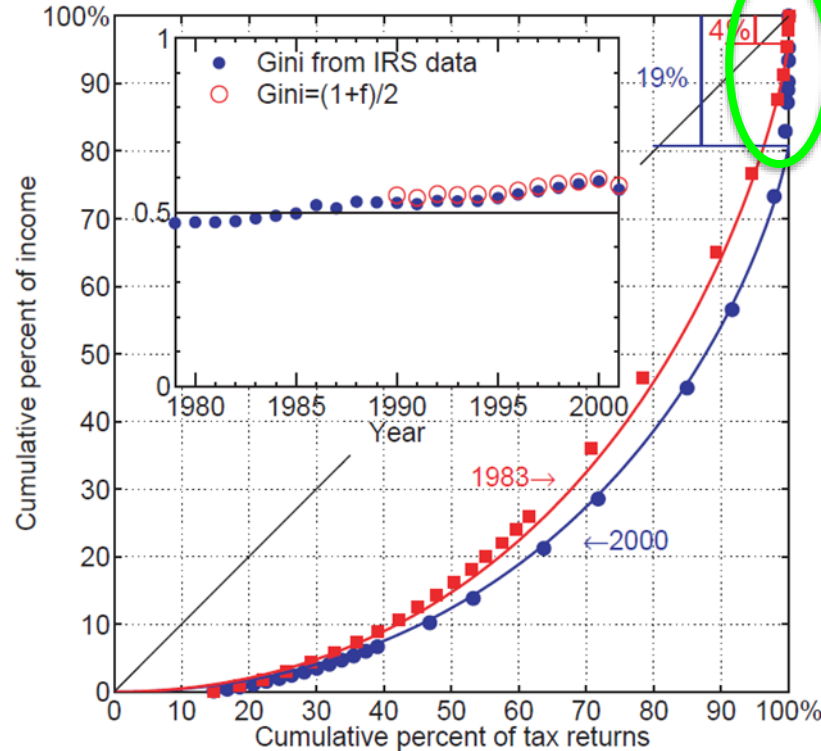
Silva and Yakovenko (2005),  
*Europhysics Letters*.

## U.S. Data



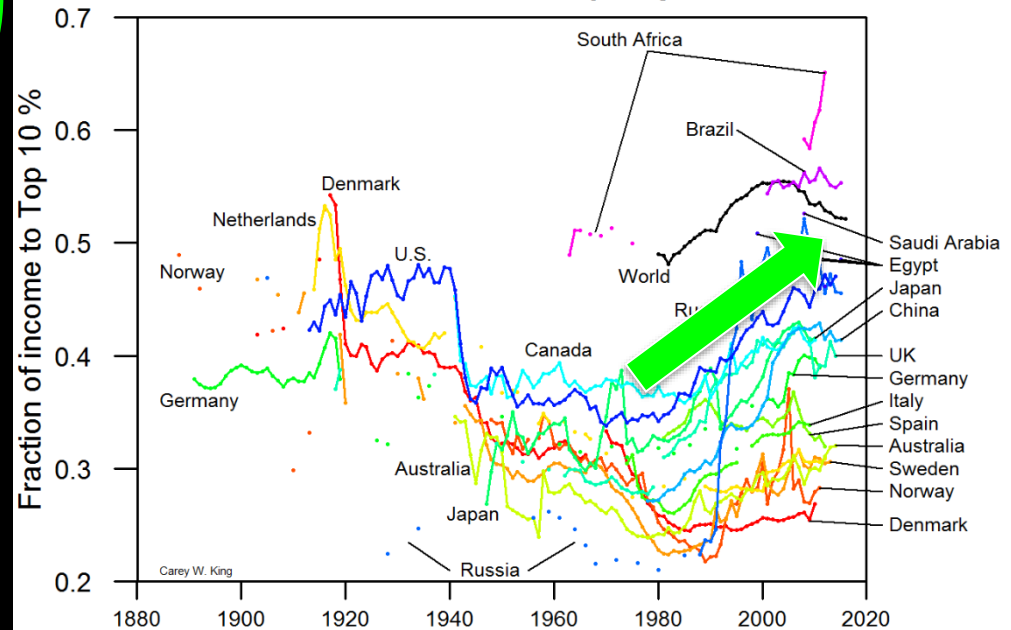
# “Superthermal” elite rich 1-3%.

US, IRS data for 1983 and 2000



Silva and Yakovenko (2005),  
*Europhysics Letters*.

World Income Inequality



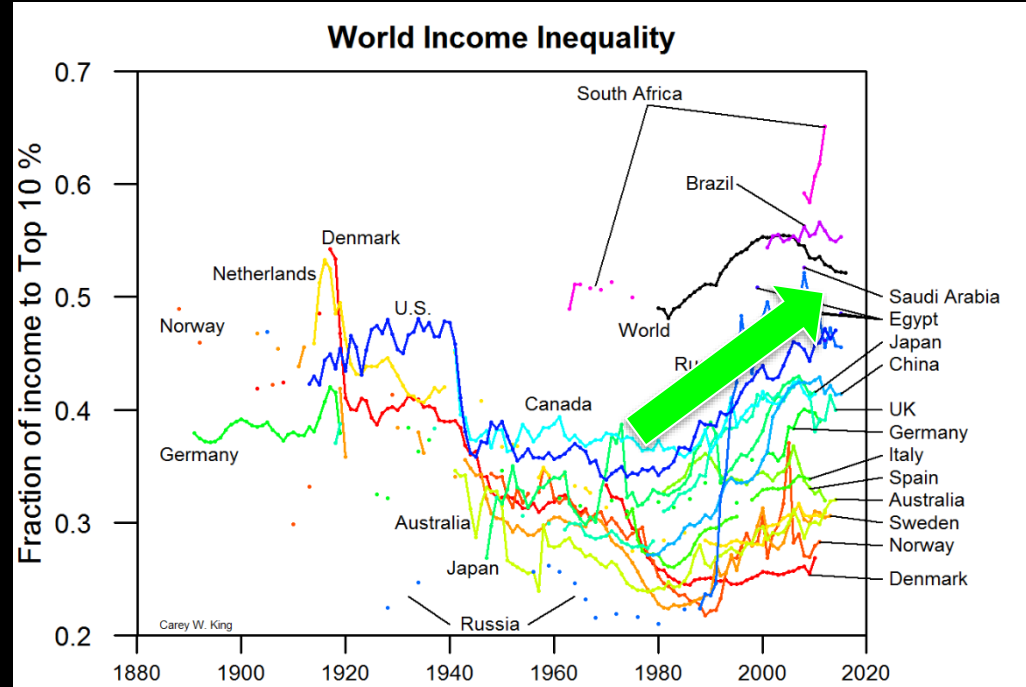
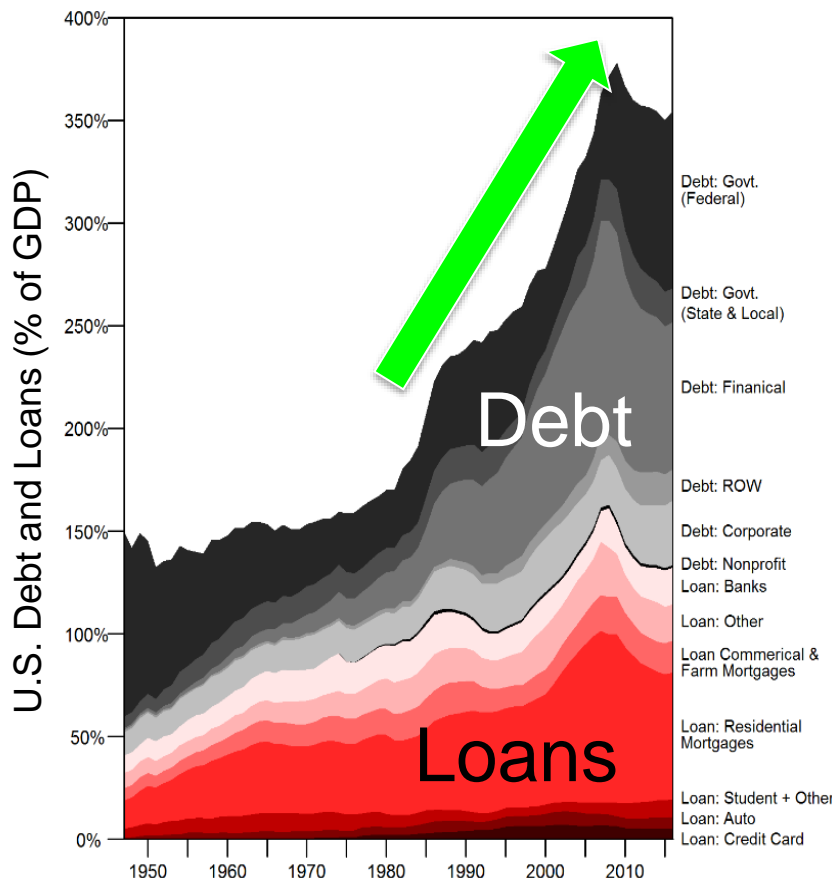
World Inequality Database



# TEXAS










The University of Texas at Austin  
Energy Institute

WHAT STARTS HERE CHANGES THE WORLD












World Inequality Database

# Takeaway on distribution of U.S. income shares

	<b>“Worker” share of Economic Output</b>	<b>“Capital” &amp; “Skilled” share of Economic Output</b>	<b>Energy Consumption per person</b>
1945 to early 1970s			
Early 1970s to 2000			
2000 to present			

# Are these economic changes (driven by policy) reactions to energy cost and availability?

	<b>“Worker” share of Economic Output</b>	<b>“Capital” &amp; “Skilled” share of Economic Output</b>	<b>Energy Consumption per person</b>
1945 to early 1970s			
Early 1970s to 2000			
2000 to present			

# Energy and food cost, and “structure” of the U.S. economy

## Summary of:

King, Carey W. Information Theory to Assess Relations Between Energy and Structure of the U.S. Economy Over Time. *Biophysical Economics and Resource Quality*, **2016**, 1 (2).



# I use information theory. What is it?

- Information content
  - Predicated on the probability of an 'event'
  - Less probable event  $\rightarrow$  More Information



# I use information theory. What is it?

- Information content
  - Predicated on the probability of an 'event'
  - Less probable event → More Information
- Information entropy
  - Describes average information content of the *entire set of possible events*



# I use information entropy to describe the U.S. economy *as a system*

- The events are the transactions of one sector from another
  - Data are economic Input-Output tables from U.S. BEA (1947-2012)

# I use information entropy to describe the U.S. economy *as a system*

- The events are the transactions of one sector from another
  - Data are economic Input-Output (Use) tables from BEA (1947-2012)
- The probabilities are sectoral transaction as a fraction of all intermediate transactions



# Three information theory metrics describe structure of I-O tables

## 1) Information Entropy

– The larger it is

- the more 'complex' is the economy
- the more 'equally informative' is each transaction

# Three information theory metrics describe structure of I-O tables

## 2) Redundancy

– Describes transactions

100%  
Redundancy

1/16	1/16	1/16	1/16
1/16	1/16	1/16	1/16
1/16	1/16	1/16	1/16
1/16	1/16	1/16	1/16

0%  
Redundancy

	1		

# Three information theory metrics describe structure of I-O tables

## 2) Redundancy

- Describes transactions
- 100% redundancy when each transaction is the same

100%  
Redundancy

1/16	1/16	1/16	1/16
1/16	1/16	1/16	1/16
1/16	1/16	1/16	1/16
1/16	1/16	1/16	1/16

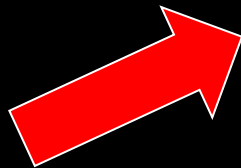
0%  
Redundancy

	1		

# Three information theory metrics describe structure of I-O tables

## 2) Redundancy

- Describes transactions
- 100% redundancy when each transaction is the same
- Also maximum information entropy



100%  
Redundancy

1/16	1/16	1/16	1/16
1/16	1/16	1/16	1/16
1/16	1/16	1/16	1/16
1/16	1/16	1/16	1/16

0%  
Redundancy

	1		

# Three information theory metrics describe structure of I-O tables

## 3) Equality

– Describes sectors

100%  
Equality

•	•	•	•
•	•	•	•
•	•	•	•
•	•	•	•

0%  
Equality

	1		

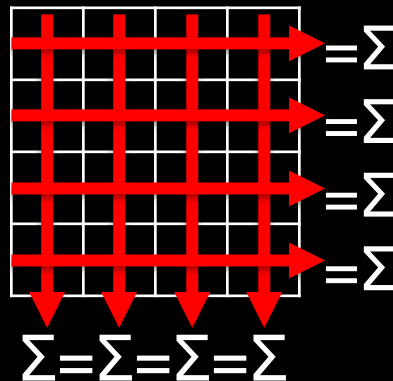


# Three information theory metrics describe structure of I-O tables

## 3) Equality

- Describes sectors
- 100% equality when all sectors have equal total transactions

100%  
Equality

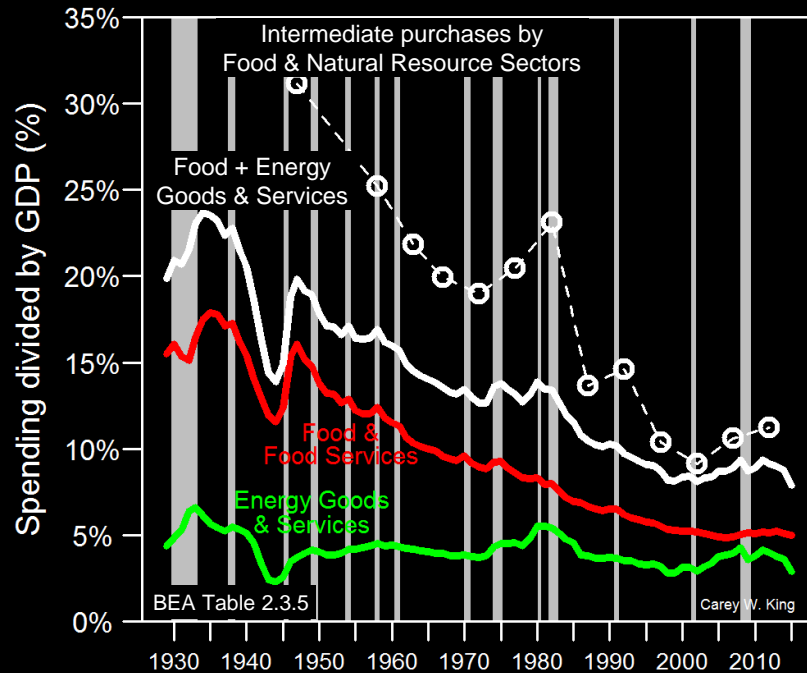


0%  
Equality

	1		

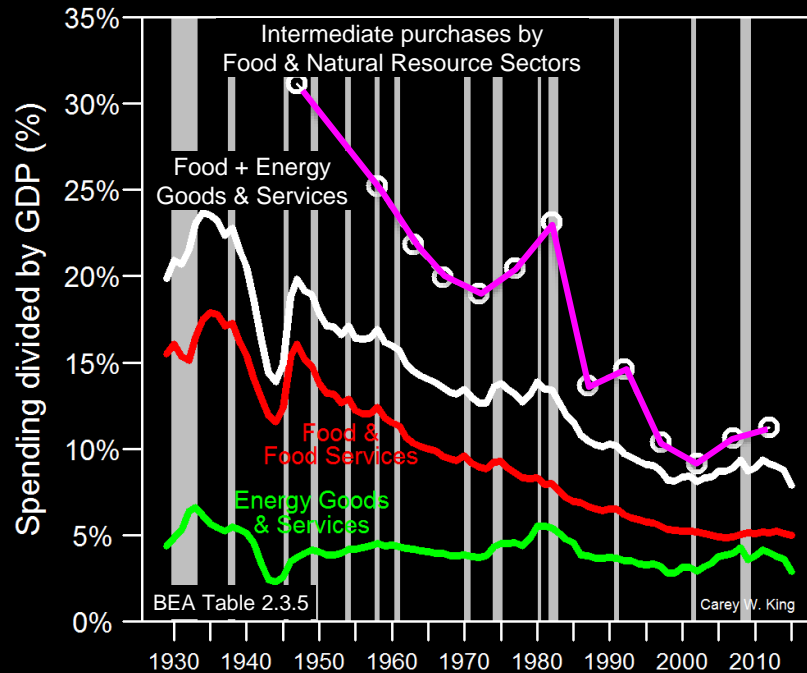
# I present results in a “net energy” context per U.S. “Food + Energy” costs

**U.S. Food and Energy Expenditures**



# I present results in a “net energy” context per U.S. “Food + Energy” costs

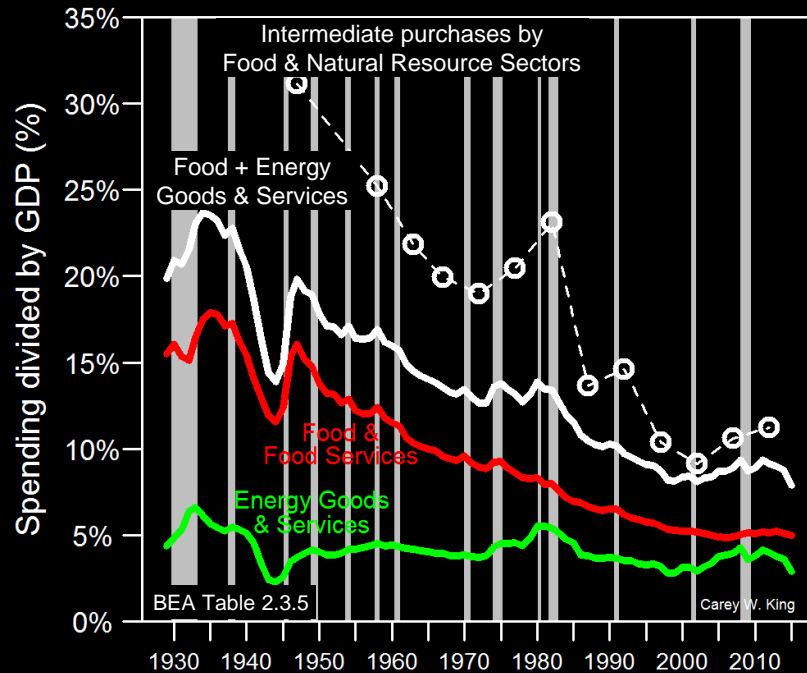
**U.S. Food and Energy Expenditures**



# I present results in a “net energy” context per U.S. “Food + Energy” costs

Food + Energy Sector Spending  
/ GDP

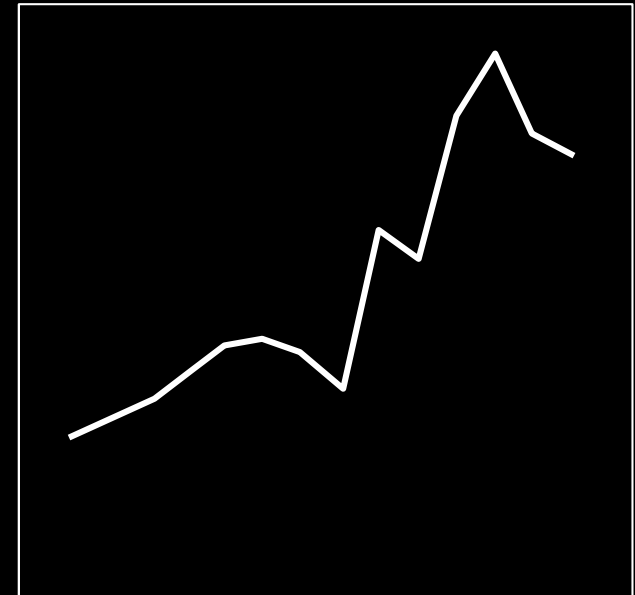
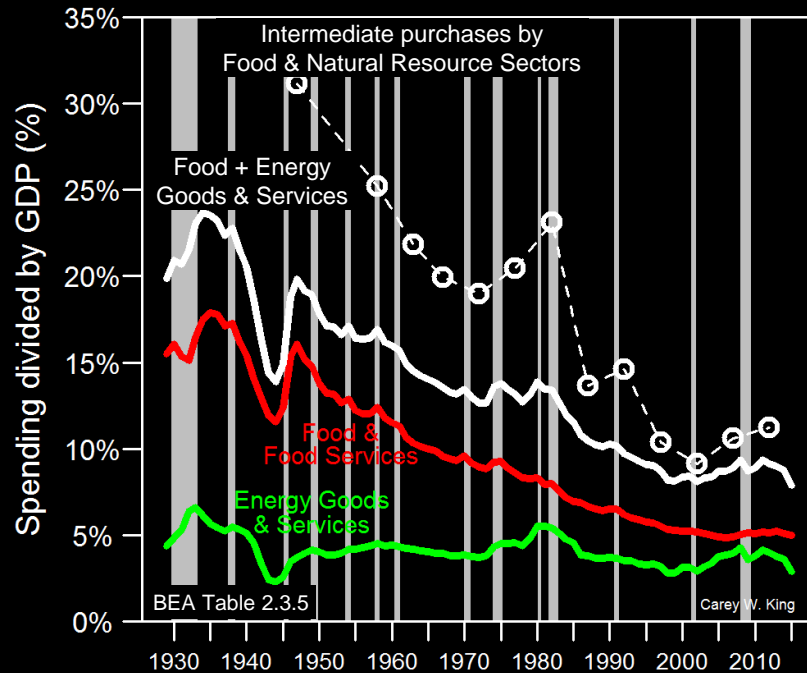
**U.S. Food and Energy Expenditures**



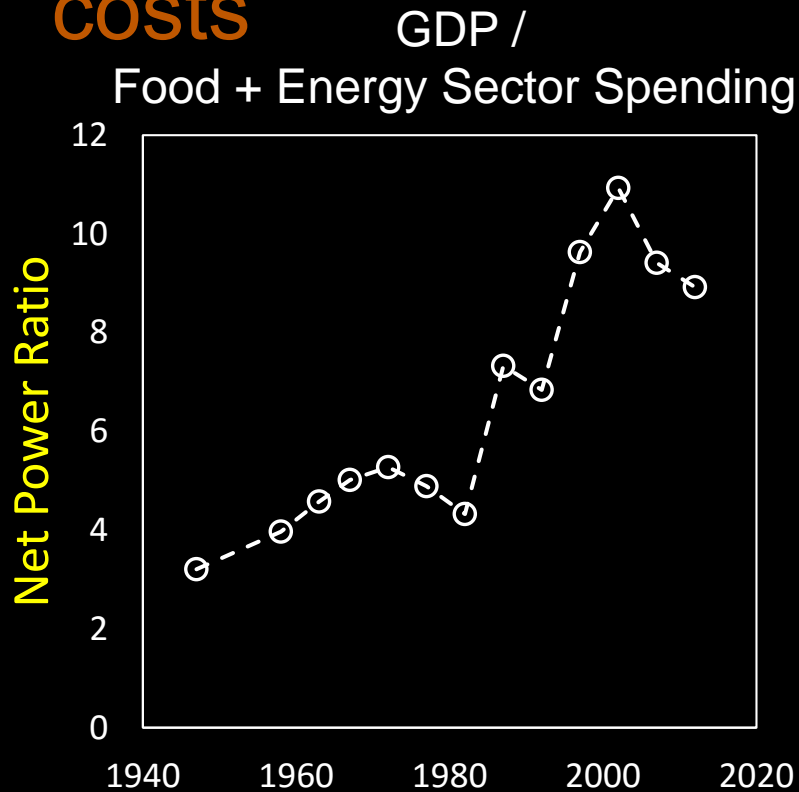
# I present results in a “net energy” context per U.S. “Food + Energy” costs

GDP /

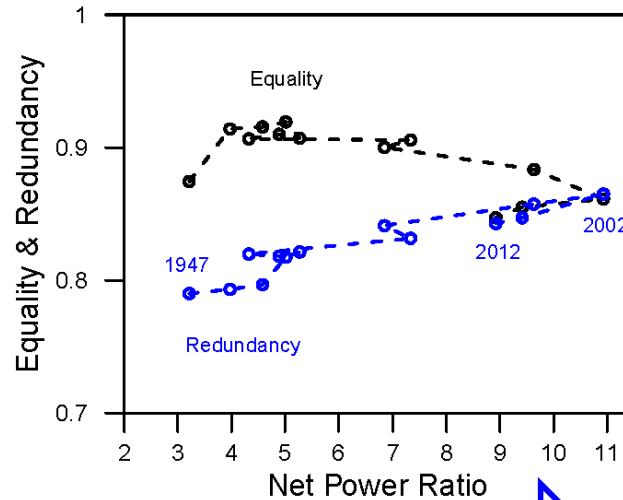
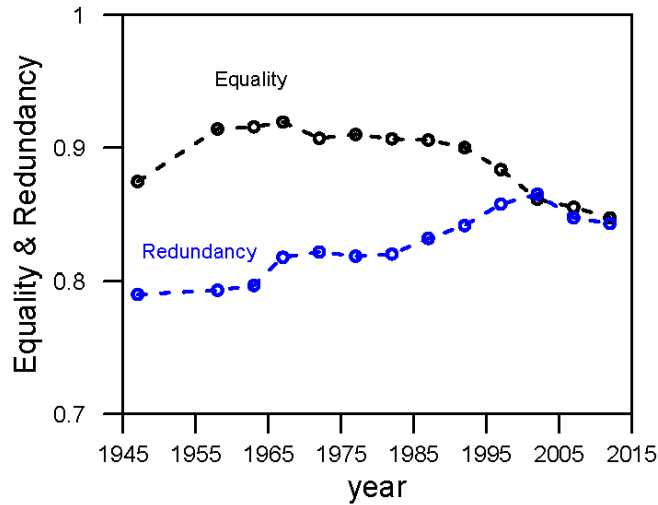
Food + Energy Sector Spending

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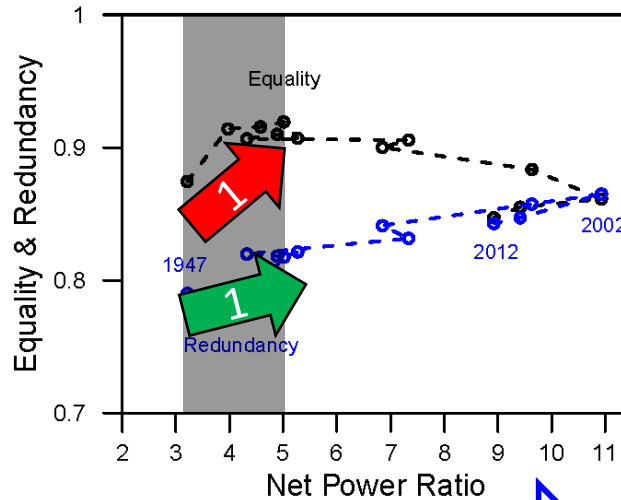
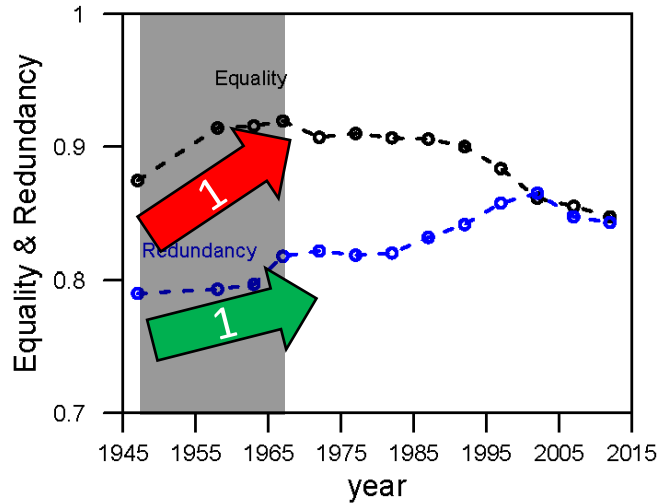
# U.S. economy had 3 Phases of structural change from 1947 to 2012



Decreasing cost of  
Energy, food, and water

King, Carey W. *Biophysical Economics and Resource Quality*, 2016.

# Phase 1 (1947-1967): Increasing Complexity on all metrics



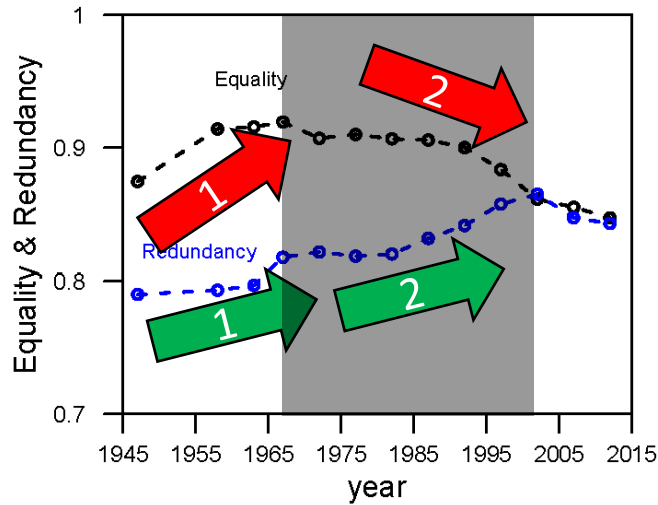
Decreasing cost of  
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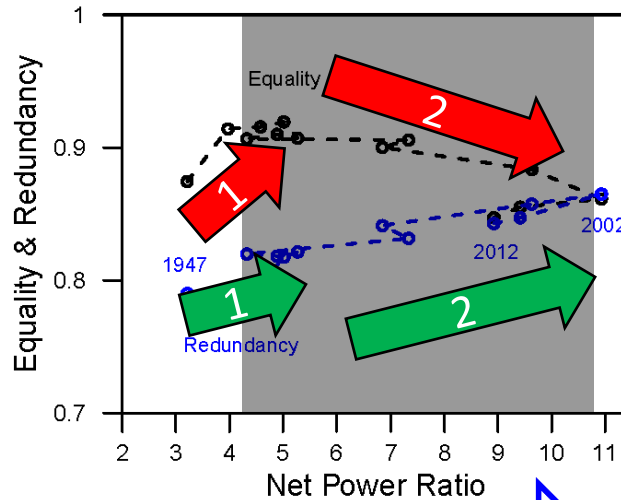
Metric	Change (%/yr)
Gross Power	+4.1
Net Power Ratio	+2.8
H (infor. Entropy)	+0.4
Equality	+0.3
Redundancy	+0.2



# Phase 2 (1967-2002): Mixed Complexity indicators



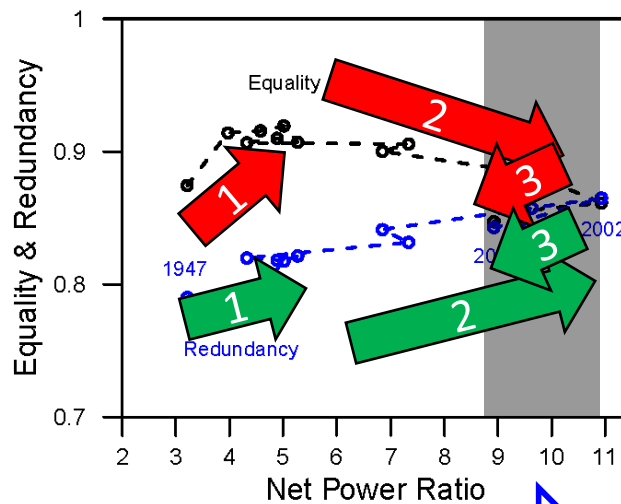
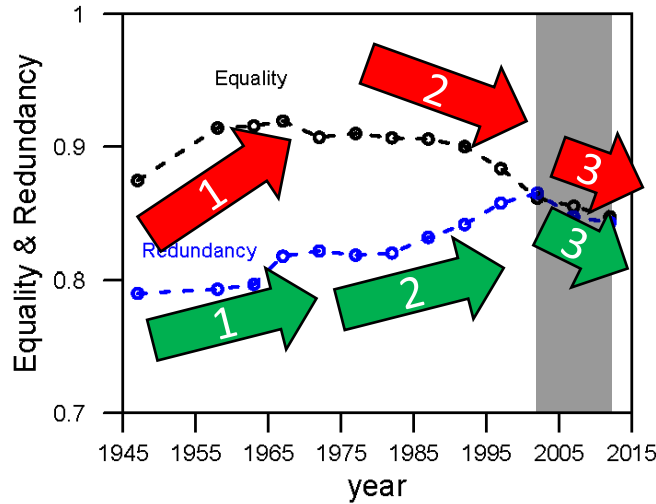
King, Carey W. *Biophysical Economics and Resource Quality*, 2016.



Decreasing cost of  
Energy, food, and water

Metric	Change (%/yr)
Gross Power	+1.9
Net Power Ratio	+3.4
H (infor. Entropy)	-0.1
Equality	-0.2
Redundancy	+0.2

# Phase 3 (2002-2012): Decreasing Complexity on all metrics



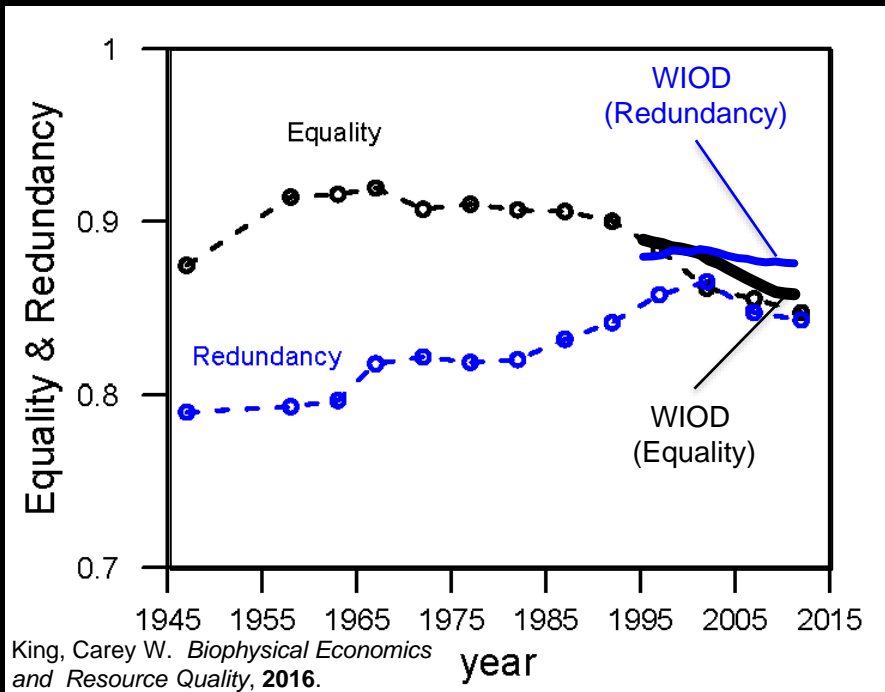
Decreasing cost of  
Energy, food, and water

King, Carey W. *Biophysical Economics  
and Resource Quality*, 2016.

Metric	Change (%/yr)
Gross Power	-0.3
Net Power Ratio	-1.8
H (infor. Entropy)	-0.4
Equality	-0.2
Redundancy	-0.3

# World I-O Database shows a similar trend as the U.S. from 1995 to 2011

(each country weighted by GDP)



# Overall takeaways

- 3 phases of money distribution in U.S. are discernable in two contexts
  - Wages versus capital (profits)
  - Sector-to-sector transactions



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  - Wages versus capital (profits)
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- Both contexts consistent in showing change of distribution of money among people and sectors (by phase)
  - 1<sup>st</sup> (1940s-1970s): Increasingly even distribution of money
  - 2<sup>nd</sup> (1970s to 2000): Constant distribution of money (some shift to capital)
  - 3<sup>rd</sup> (2000 to present): Increasingly concentrated distribution of money

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