



TEXAS
The University of Texas at Austin
Energy Institute

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Worcester Polytechnic Institute, Worcester, MA, USA

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Fall 2020

Conceptual goals for a macroeconomic model

- Provide a model that allows a “basic” level of communication between
 - Economists (orthodox and heterodox)
 - Physical scientists
- “Basic” means
 - Coherently including conservation principles in both economics and physical systems
 - Use of domain-specific language that each side understands

Practical goals for a macroeconomic model

- Explain the past
 - How the finite Earth is affecting “us”
 - economic trends (investment, wages, debt)
 - energy flow trends
 - Mimic broad historical trend ...
 - agrarian → fossil/industrial economy
- Project “more realistic” future scenarios (than neoclassical theory)
 - Have a more realistic and accurate basis to project forward 10s of years
 - E.g., fossil → low-carbon economy



Biophysical Models

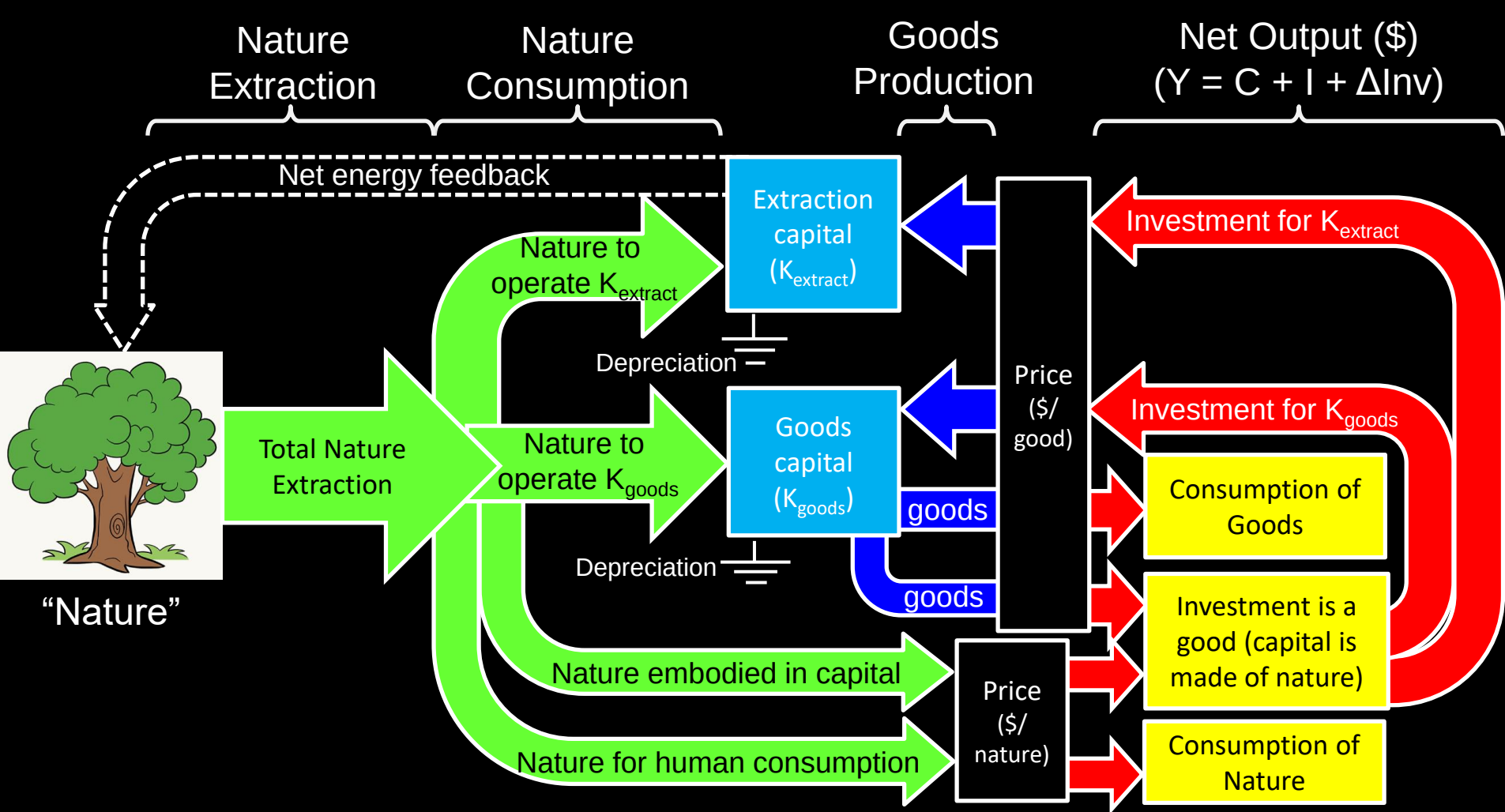
Population
Natural Resources
Capital (sometimes)

Economic Models

Population
Capital
Wages
Employment
Debt (sometimes)

Model Approach

Combine models: Link resource characteristics & consumption to debt, employment, and output



There are two explicit conservation principles:

1. Mass (rate of nature extraction, conversion & “consumption”)
2. Money (stocks and flows)

Implicitly included are:

1. Energy (resources are treated as necessary to operate machines)
2. 2nd law of thermodynamics (one parameter is akin to a conversion efficiency, but not explicitly defined as such)

Not included:

1. Space or networks (distribution of resources, people, capital ...)
2. Distribution of incomes

Summary of the process assumed in the results to be shown ...

- 1st: sectors (or firms) invest in new capital
- 2nd: calculate labor, employment, wages
- 3rd: determine if labor or capital is limiting output
 - If there is not enough labor, capital must be utilized at less than 100% capacity utilization
 - Calculate sector physical output [gross (X) and net (Y)]
- 4th: household consumption (C) to people is “left over” output after investment ($C = Y - I - \Delta Inv$)
 - This consumption affects population growth
 - ΔInv : change in value of inventories

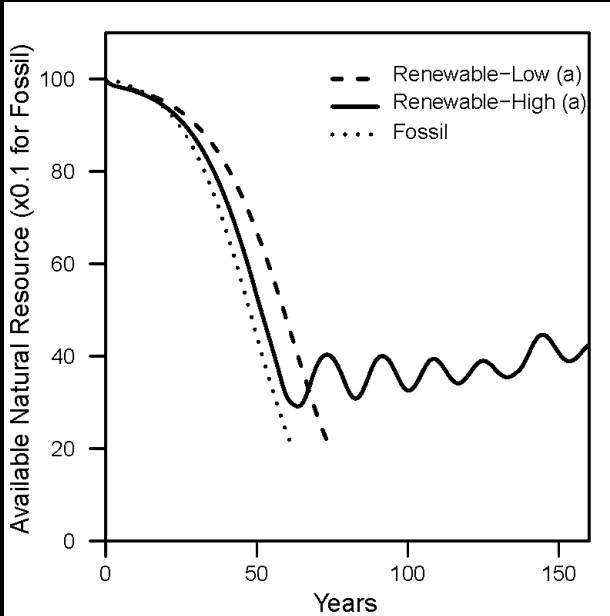
Results for:

Constant markup (assumed) for
prices

(e.g., firms get a guaranteed profit,
 $\text{price} = 1.07 \times \text{cost}$)

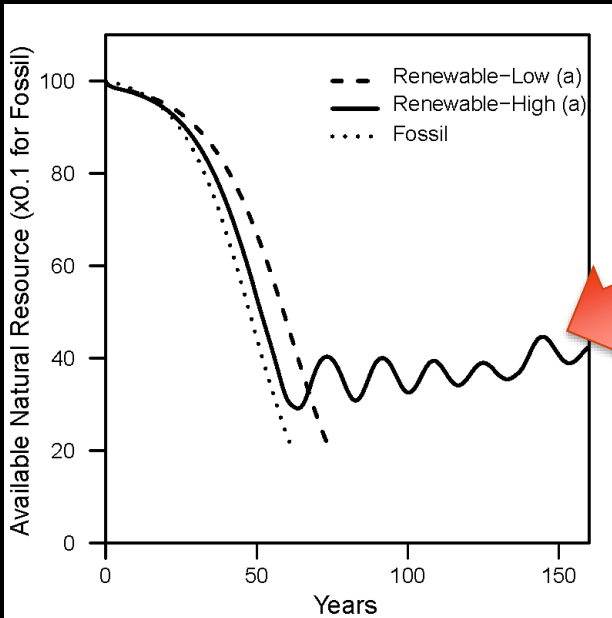
There are two general trends *defined by the relative level of investment*

- “Investment level” defined as multiple of profits and depreciation

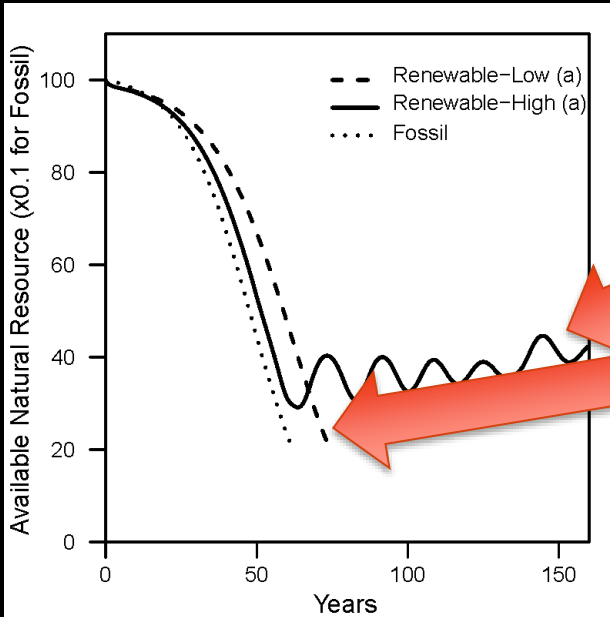


There are two general trends *defined by the relative level of investment*

- “Investment level” defined as multiple of profits and depreciation
- Solid line
 - “high” investment

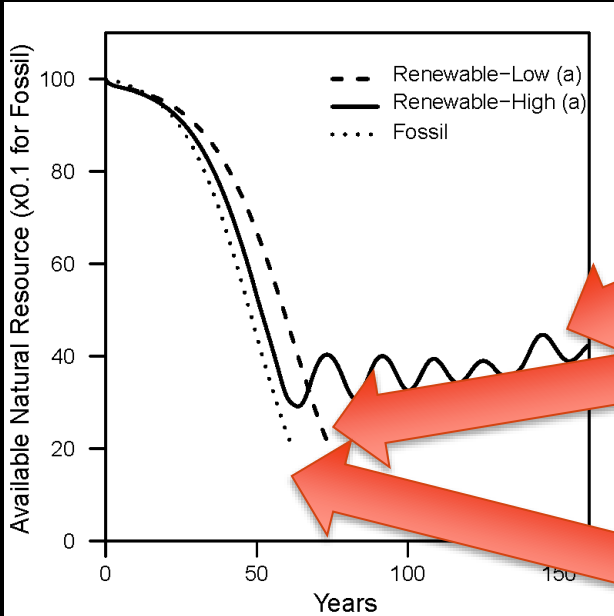


There are two general trends *defined by the relative level of investment*



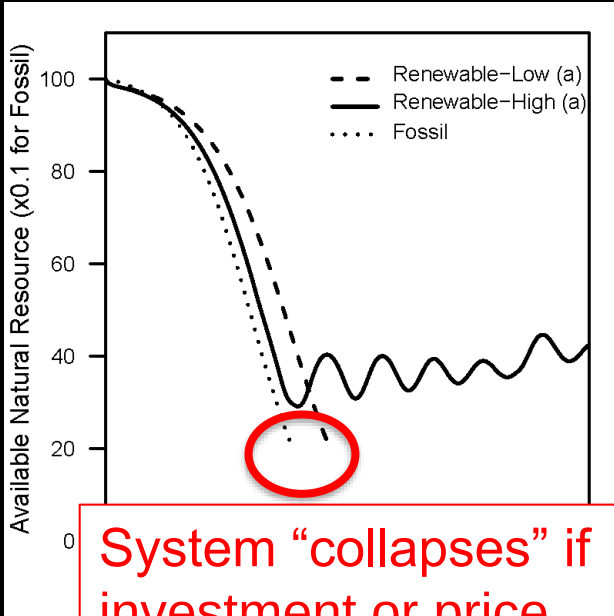
- “Investment level” defined as multiple of profits and depreciation
- Solid line
 - “high” investment
- Dashed line
 - “low” investment

There are two general trends *defined by the relative level of investment*



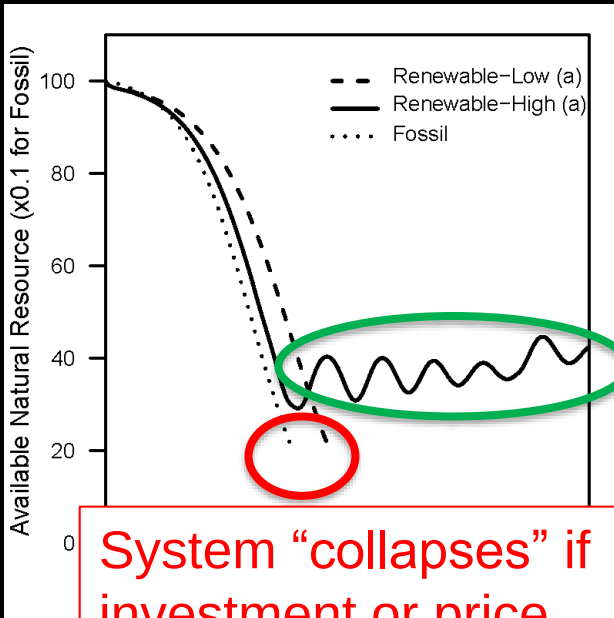
- “Investment level” defined as multiple of profits and depreciation
- Solid line
 - “high” investment
- Dashed line
 - “low” investment
- Dotted line
 - Fossil resource

There are two general trends *defined by the relative level of investment*



System “collapses” if investment or price markup is *too low*.

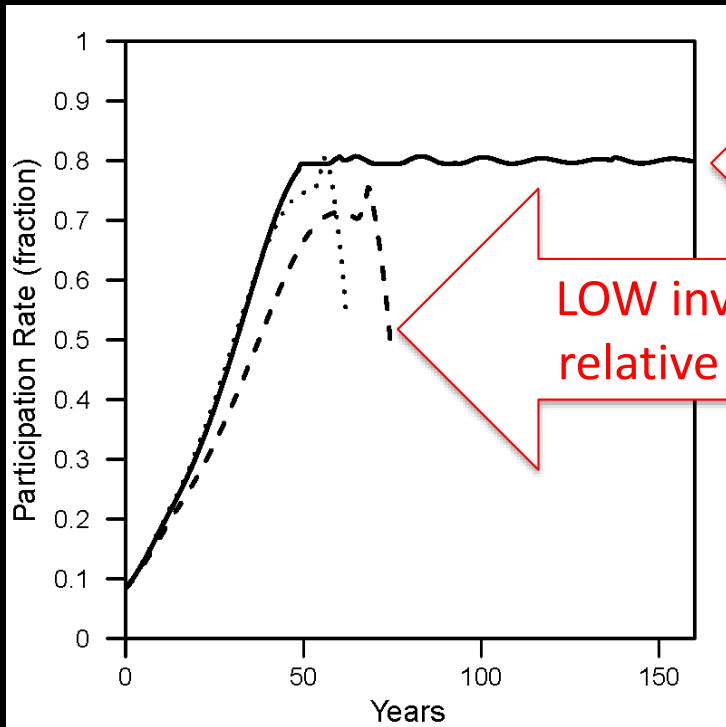
There are two general trends *defined* by the *relative level of investment*



System “collapses” if investment or price markup is *too low*.

System “stable” if investment or price markup is *high enough*.

Threshold in outcomes driven by whether economy reaches maximum participation rate (= 80%)



HIGH investment
relative to profit

$1.5 \times \text{profit}$

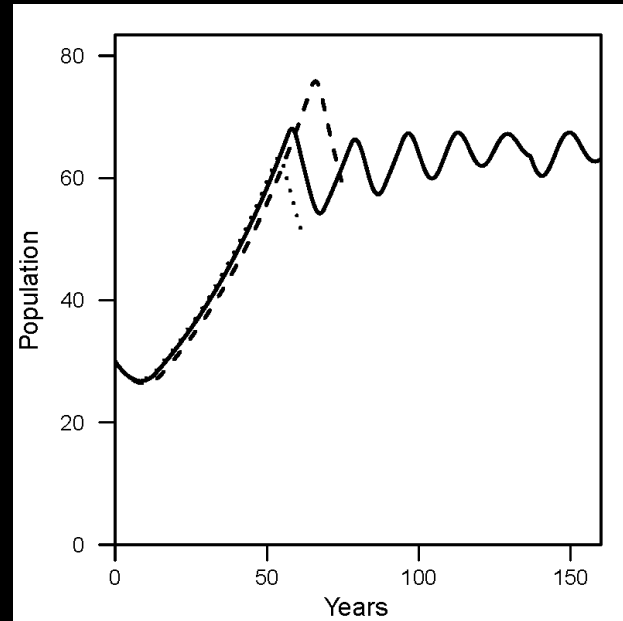
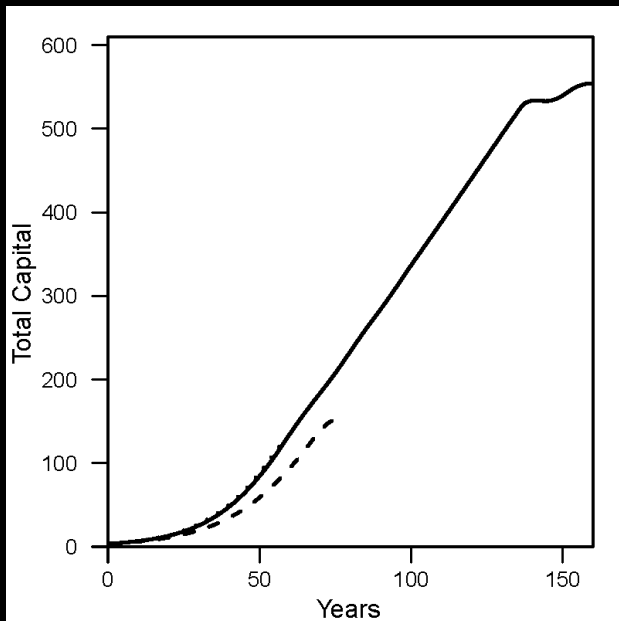
LOW investment
relative to profit

$1.3 \times \text{profit}$

Investment rate effects:

“Low”: Accumulate “too many” people per capital & resources

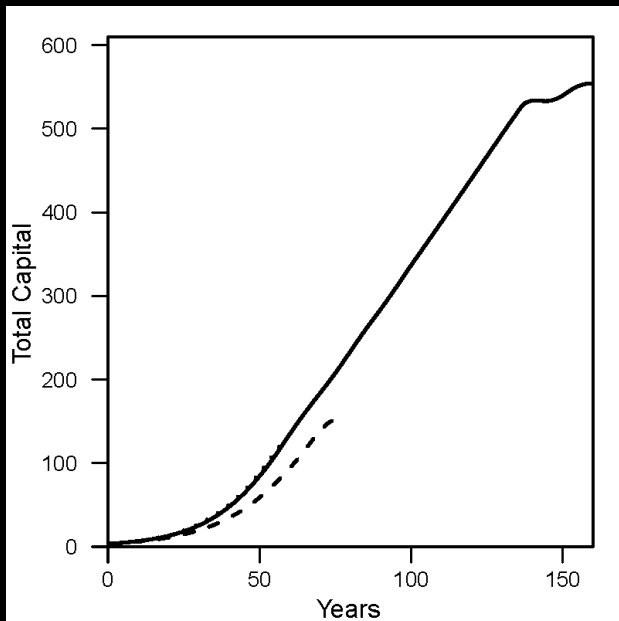
“High”: Accumulate enough capital to keep population low



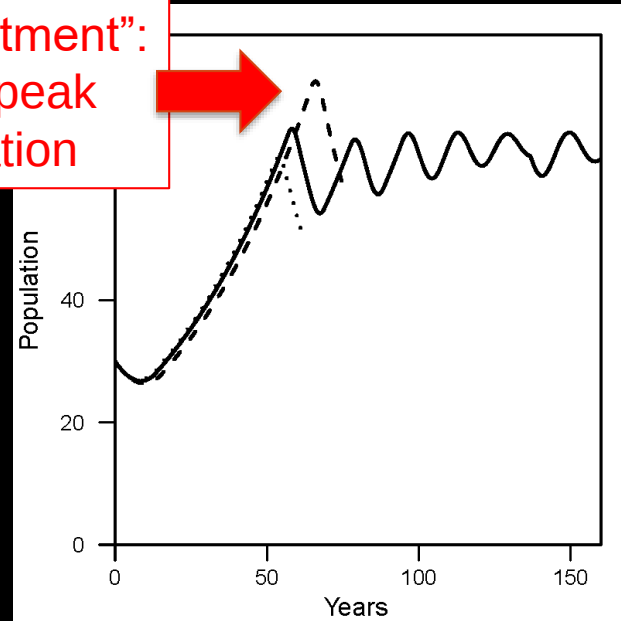
Investment rate effects:

“Low”: Accumulate “too many” people per capital & resources

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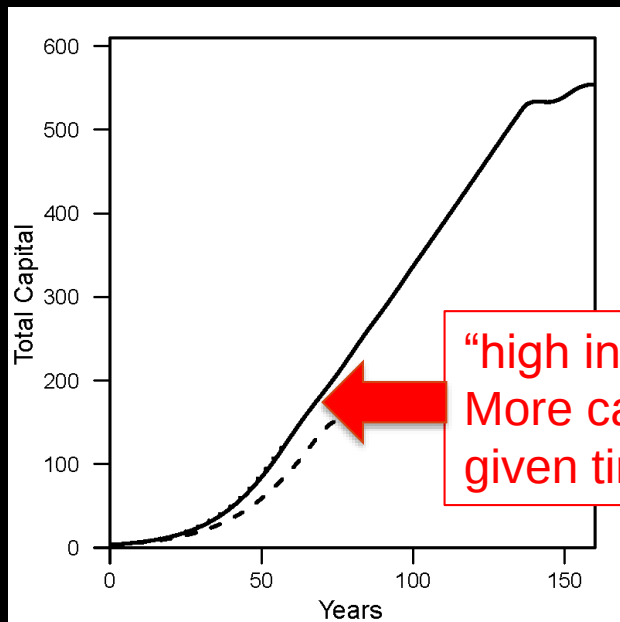
“low investment”:
Higher peak
population



Investment rate effects:

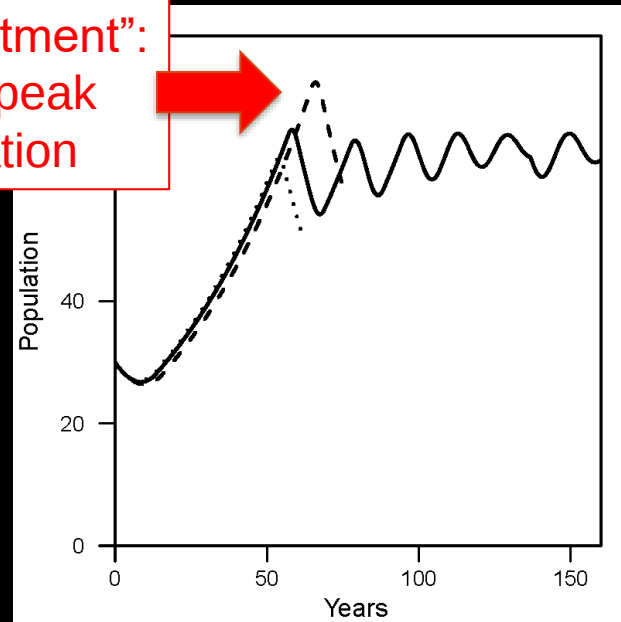
“Low”: Accumulate “too many” people per capital & resources

“High”: Accumulate enough capital to keep population low



“high investment”:
More capital at any
given time

“low investment”:
Higher peak
population

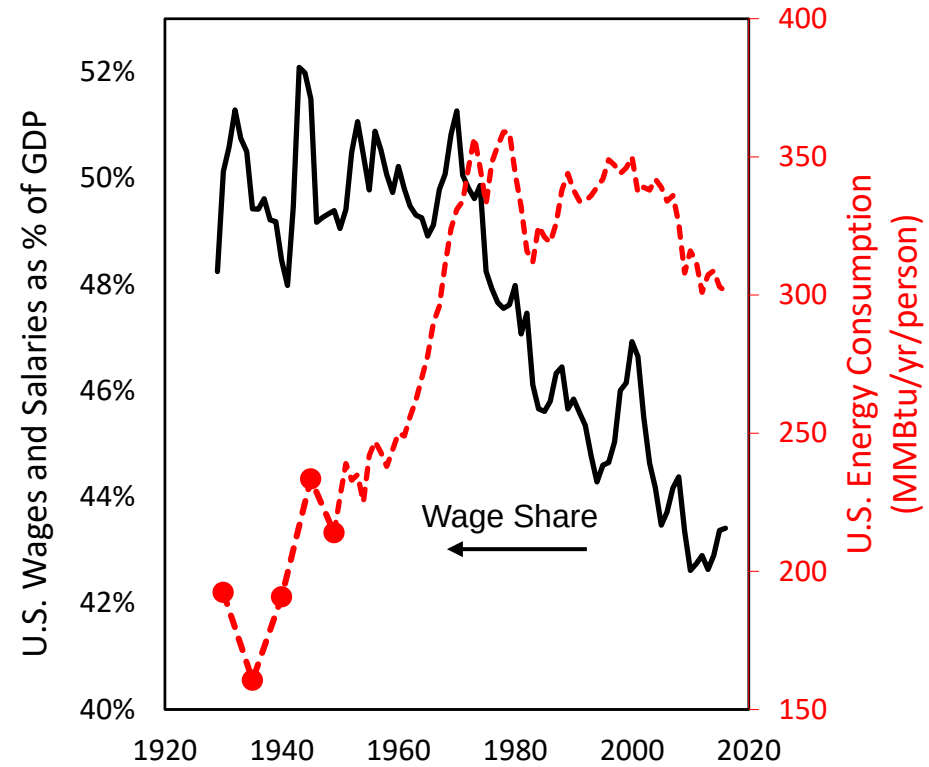


If you invest too slowly, the economy “collapses” because ...

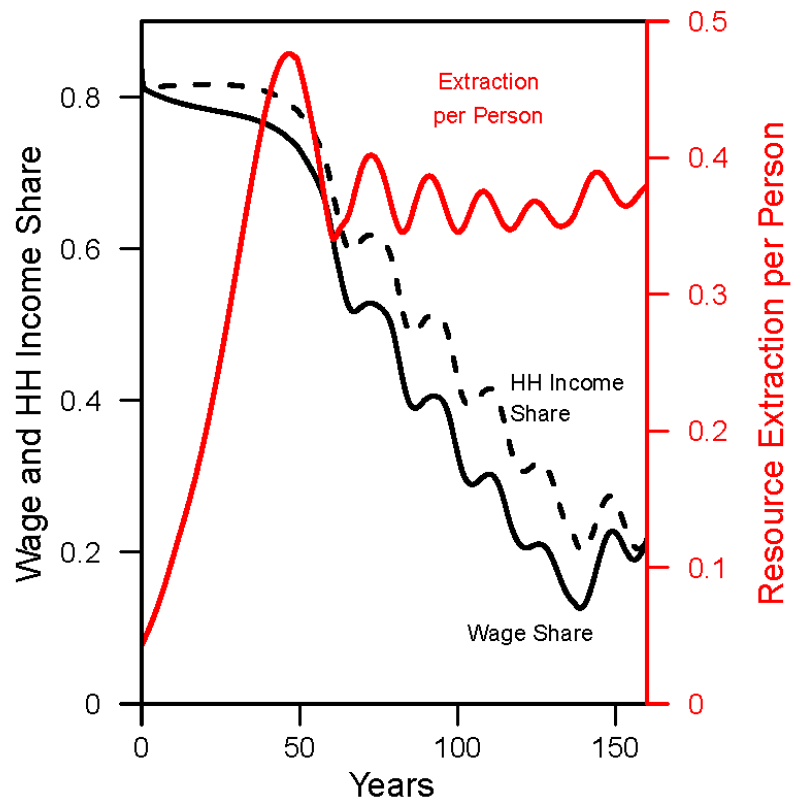
- Population reaches “too high” of a peak (at the expense of capital)
- Population is assumed to have some minimum resource consumption
 - So 100% of population does not die instantly
- When resource extraction rate stops increasing ...
 - Extraction capital must keep operating at full capacity to deliver “mandated minimum” resources to people
 - Resources keep getting depleted
 - As resource depletes, a higher fraction of the resource is required to extract the next unit of resource (net energy goes to zero)
 - Population does not decline fast enough to prevent a physical constraint in resource extraction (100% of resource output is required to extract resources)

Does the theoretical model match
anything interesting in the data?

U.S. Data

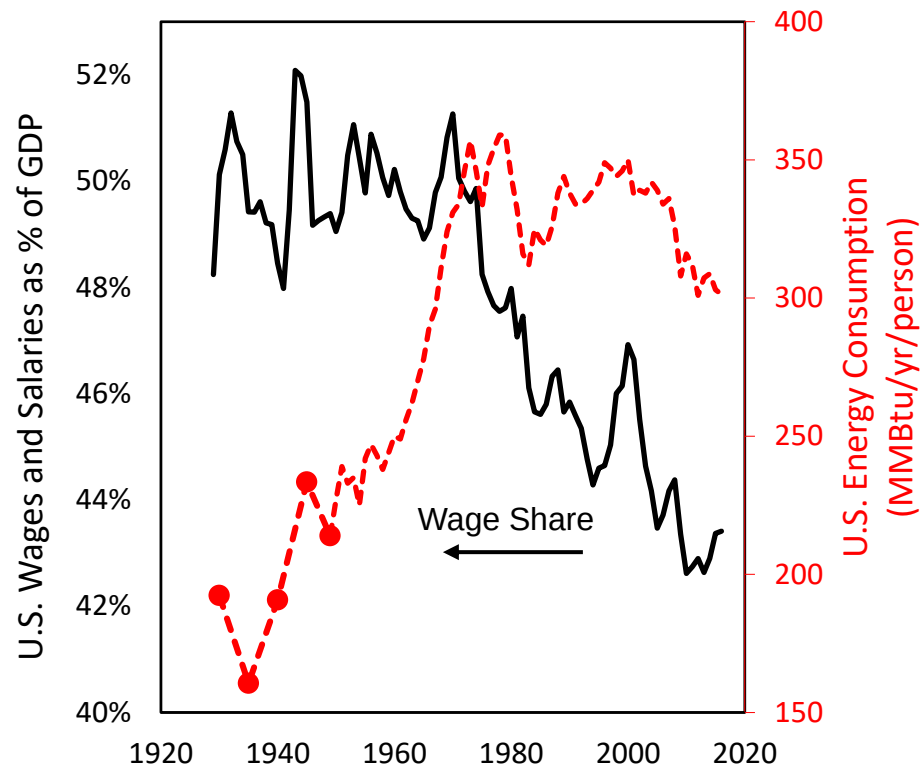


HARMONEY Model

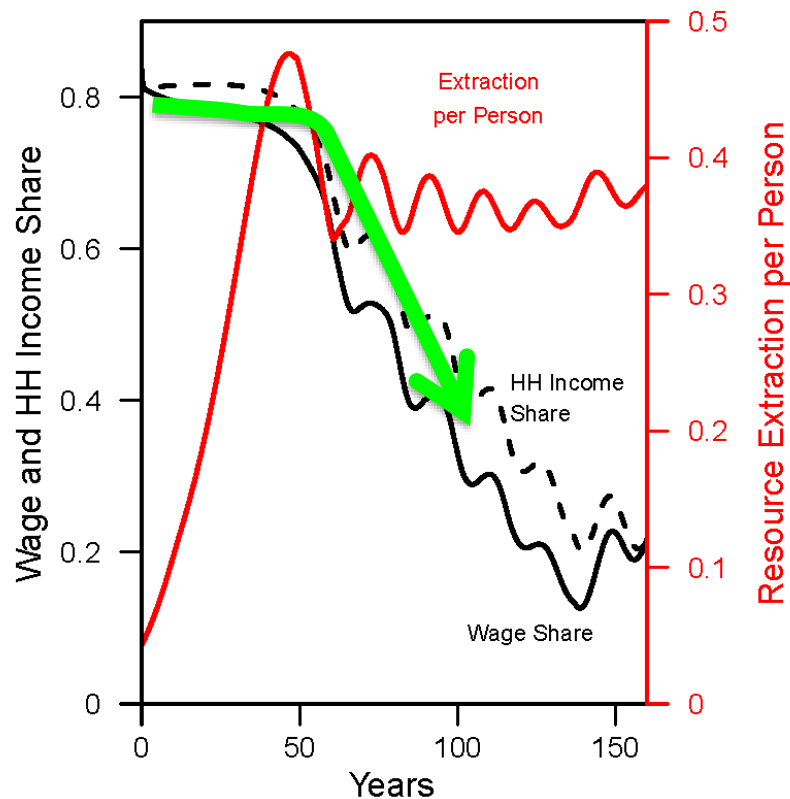


“High” investment scenario

U.S. Data

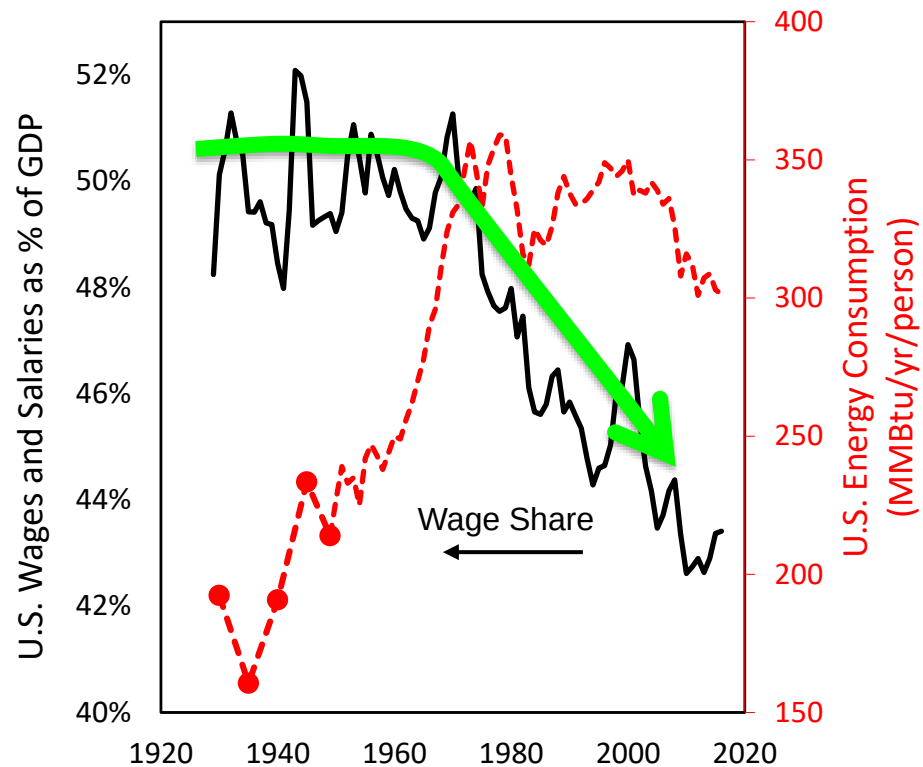


HARMONEY Model

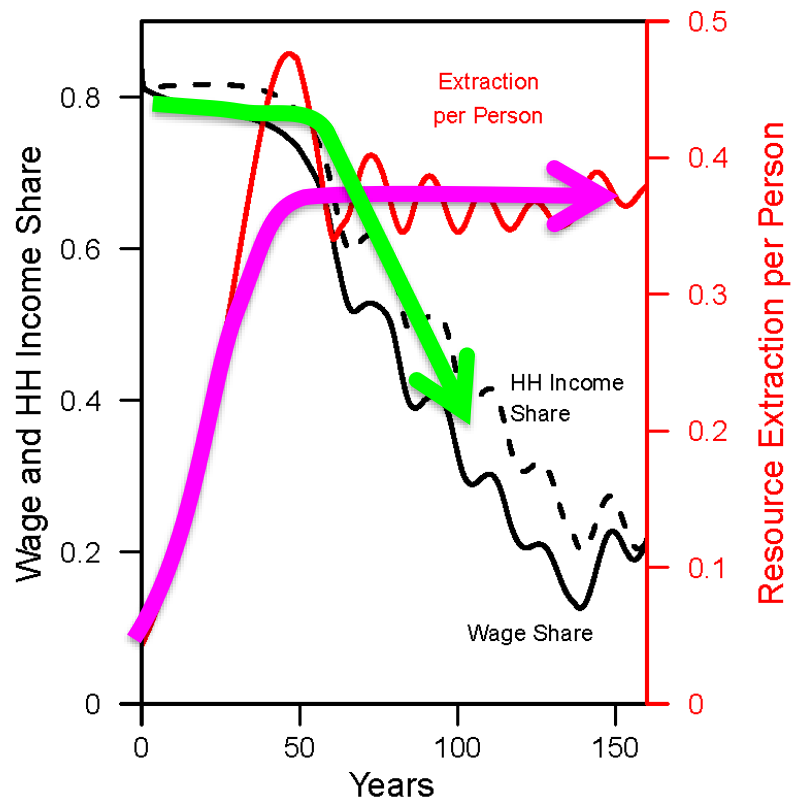


“High” investment scenario

U.S. Data

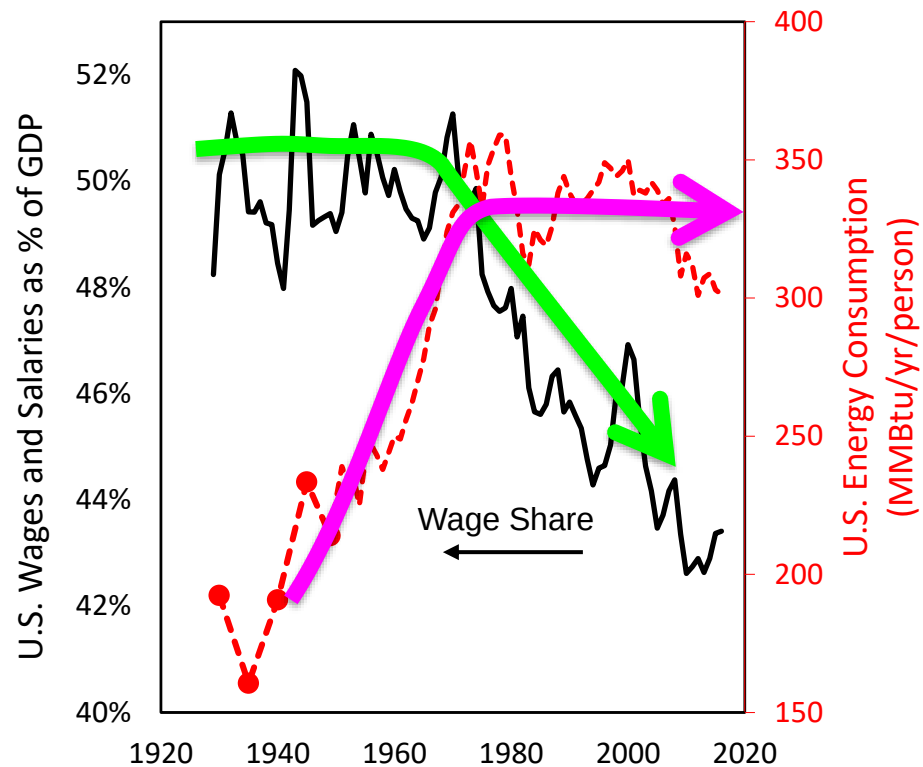


HARMONEY Model

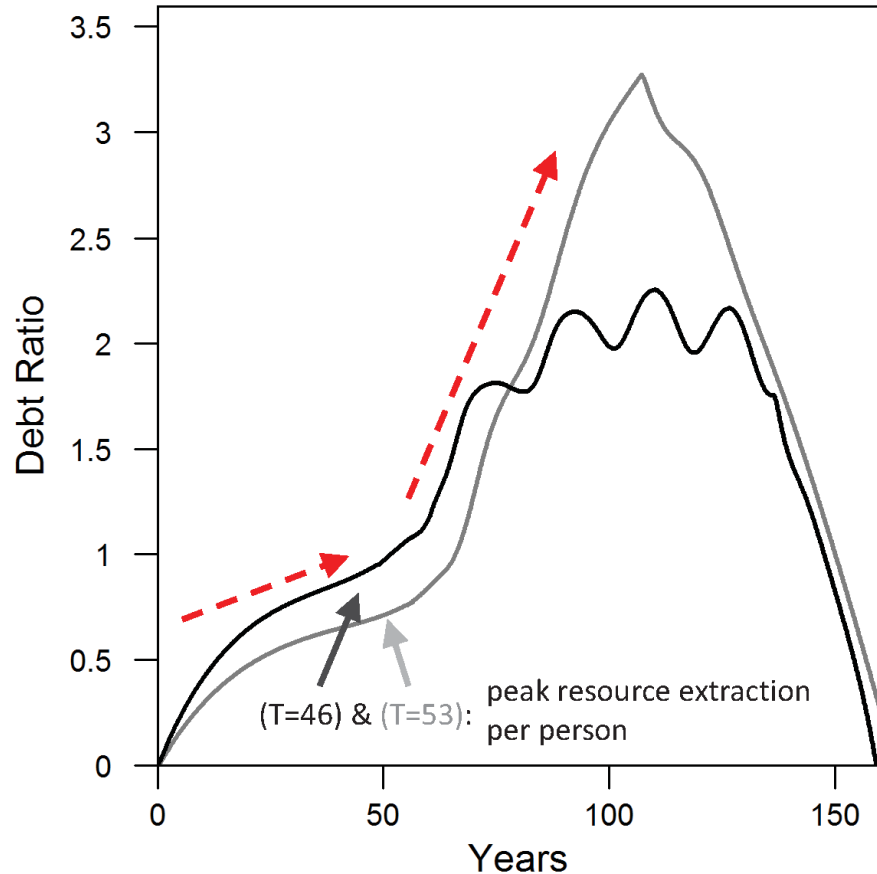


“High” investment scenario

U.S. Data

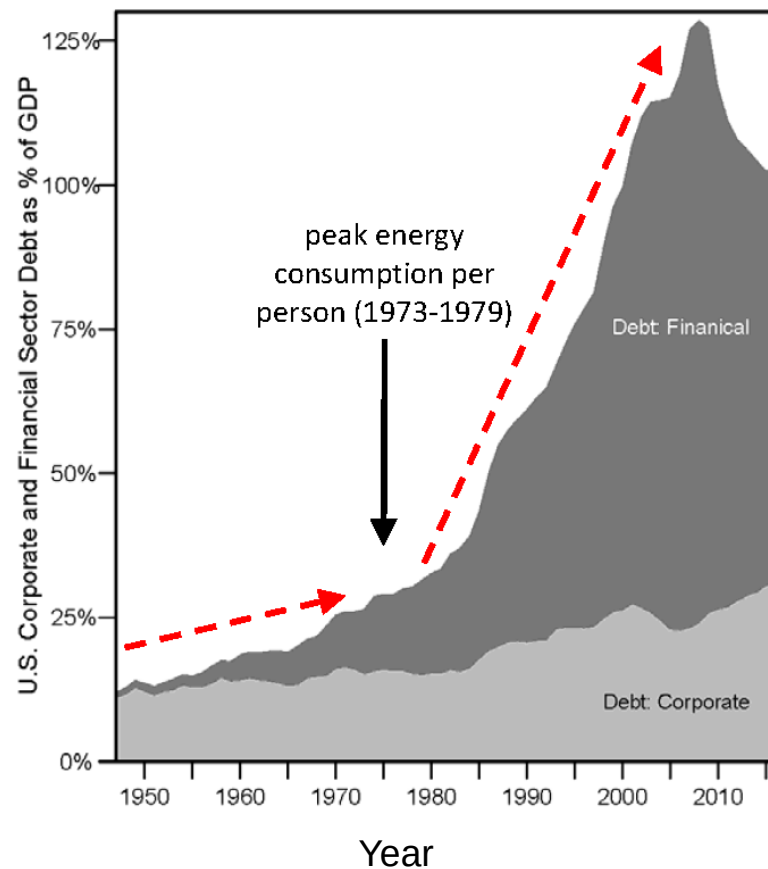


“HARMONEY” Model

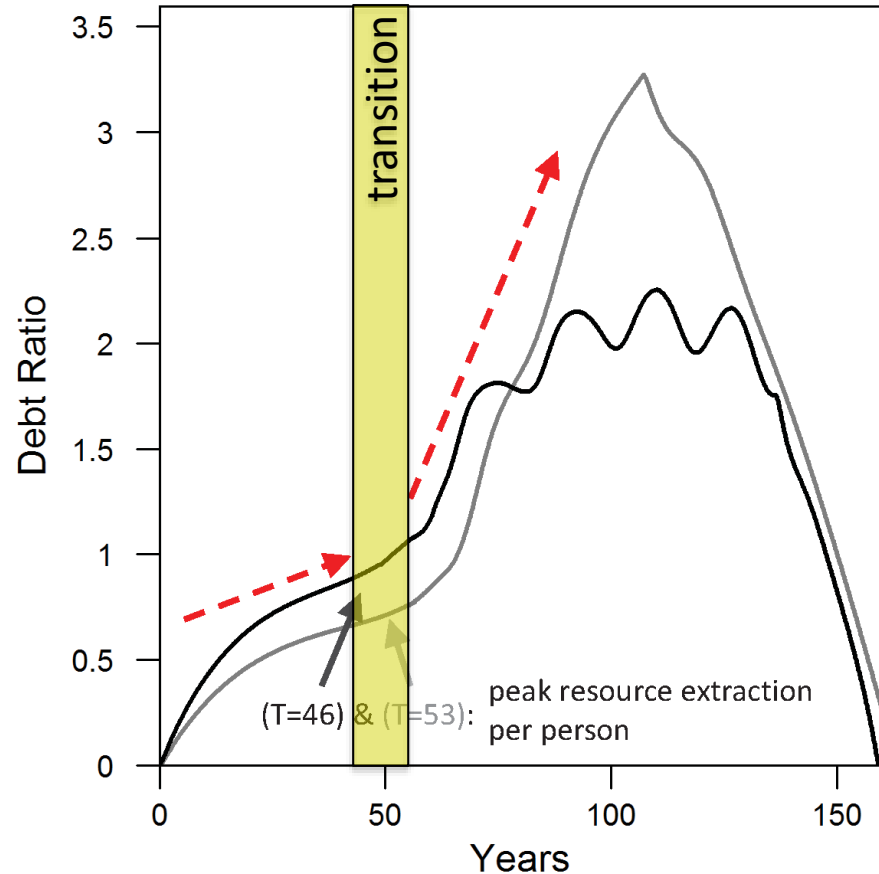


“High” investment scenario

U.S. Data

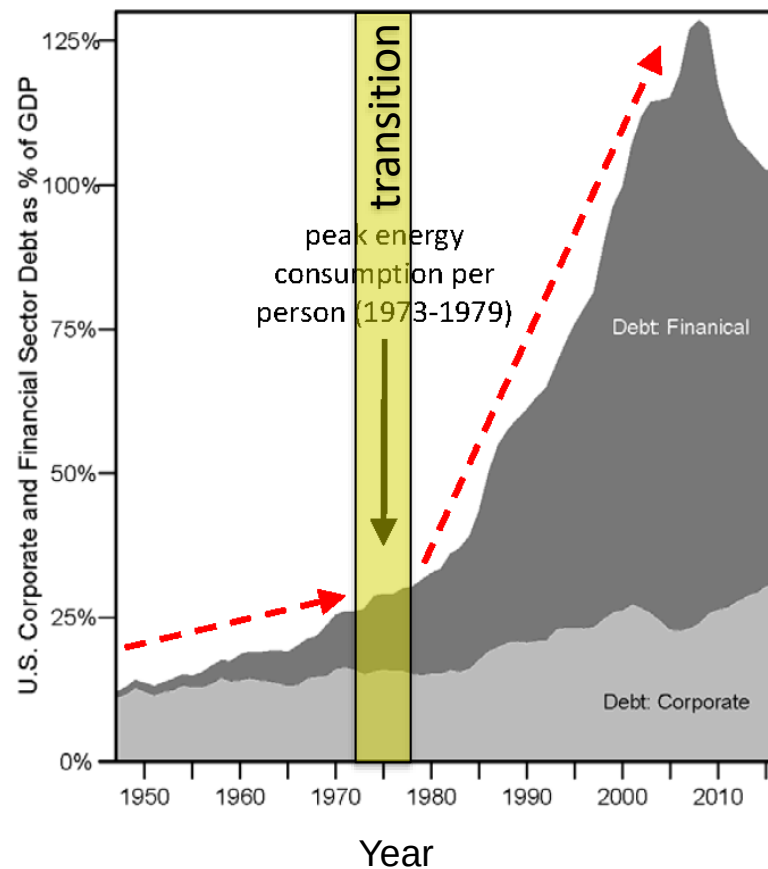


“HARMONEY” Model



“High” investment scenario

U.S. Data



The model also mimics an interesting
“structural” trend of the U.S.

Using Information Theory to calculate changing
patterns of money flows within the economy

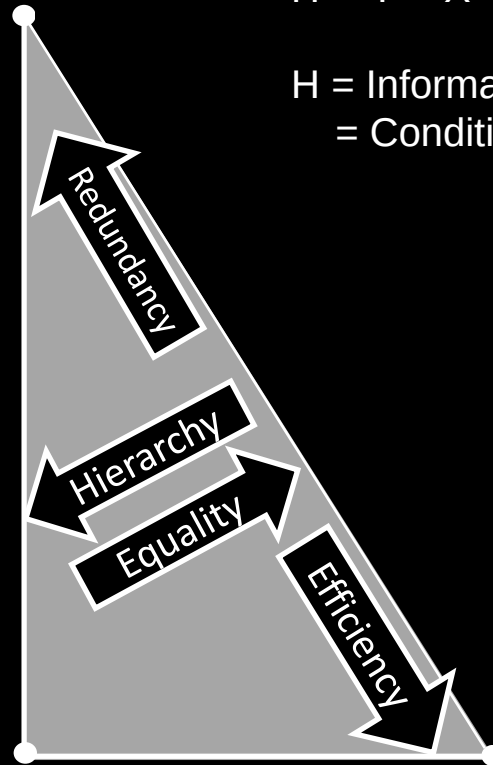
King, Carey W. **Information Theory to Assess Relations Between Energy and Structure of the U.S. Economy Over Time.** *Biophysical Economics and Resource Quality*, 2016, 1 (2), 10. doi: 10.1007/s41247-016-0011-y. [read free online](#)



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

	1		

Conditional Entropy (Ψ)



$$H = \Psi + X$$

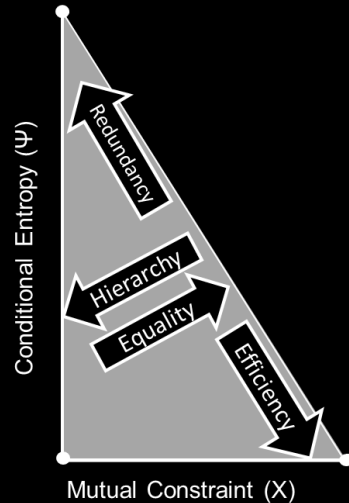
H = Information Entropy
= Conditional Entropy + Mutual Constraint

	1/4		
		1/4	
			1/4
1/4			

The model mimics the trend in “structural” flow of money within the U.S. economy (tracking money flows in input-output tables)

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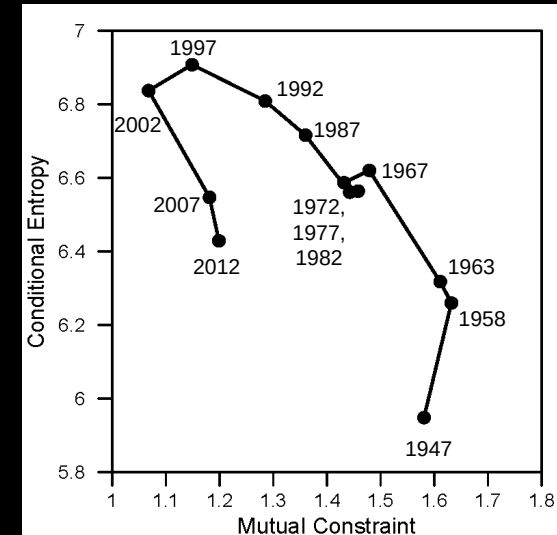
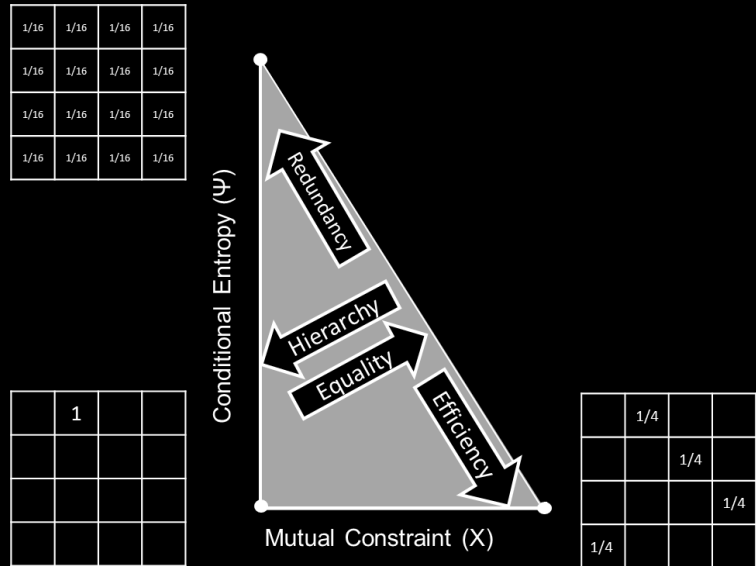
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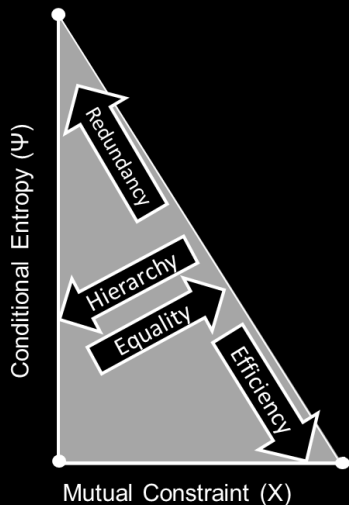
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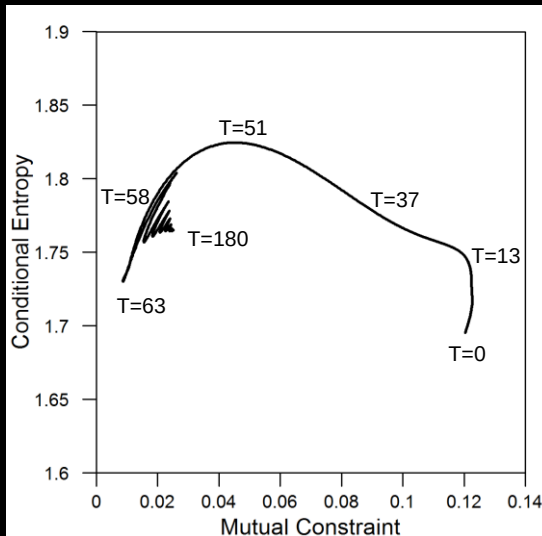
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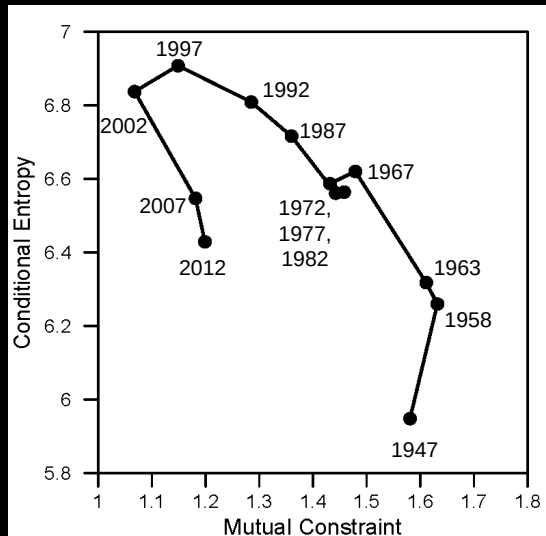


	1/4		
		1/4	
			1/4
1/4			

Model



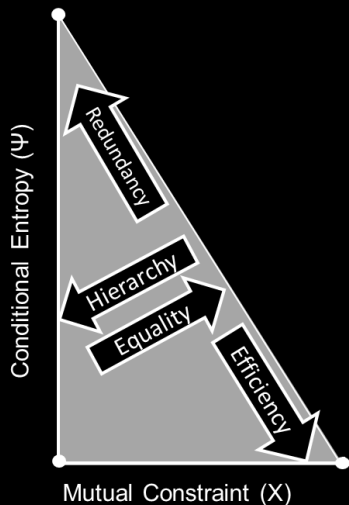
U.S. Data



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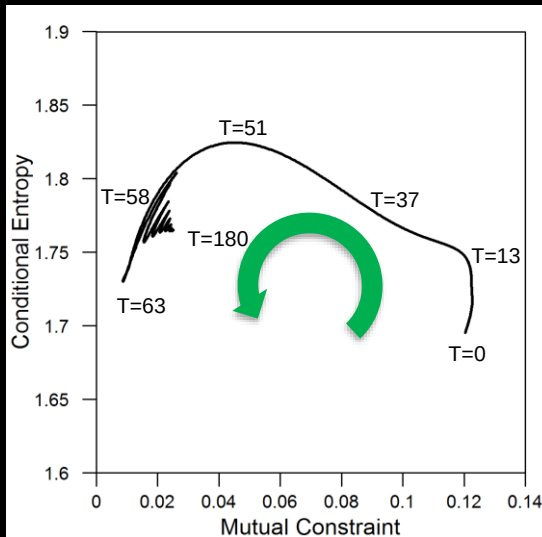
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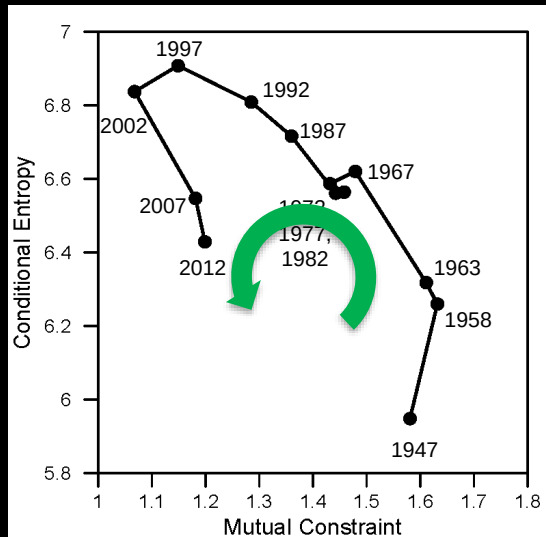


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1/4			

Model



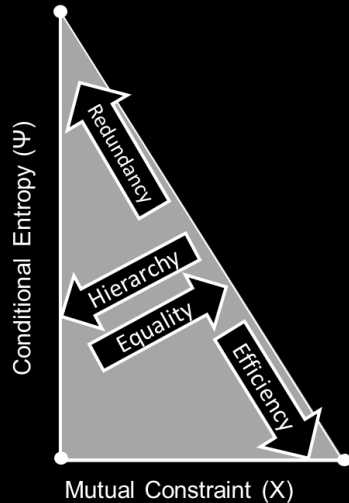
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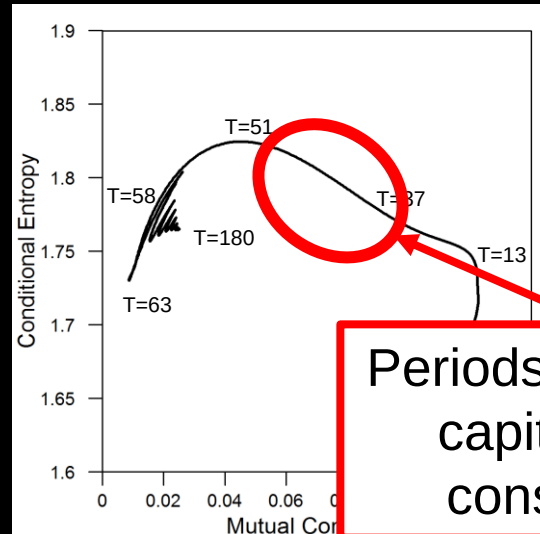
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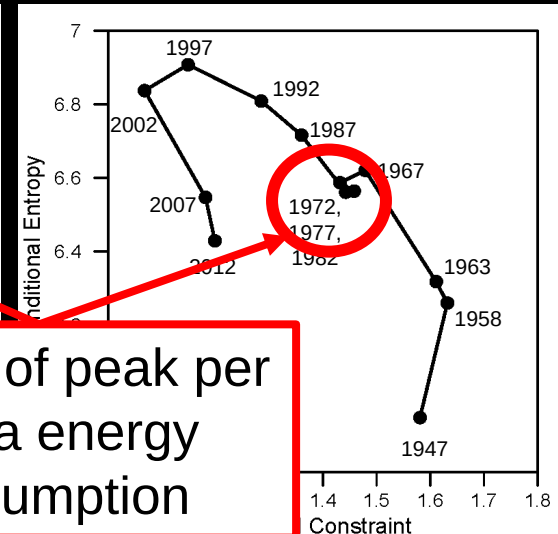


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Model

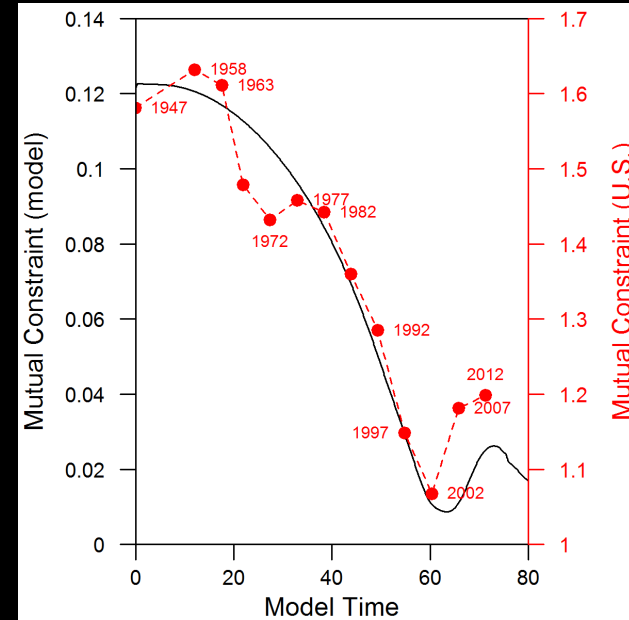
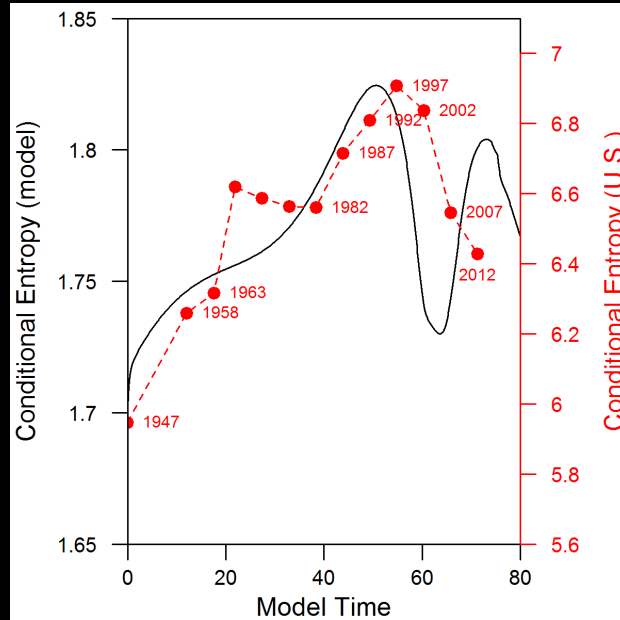
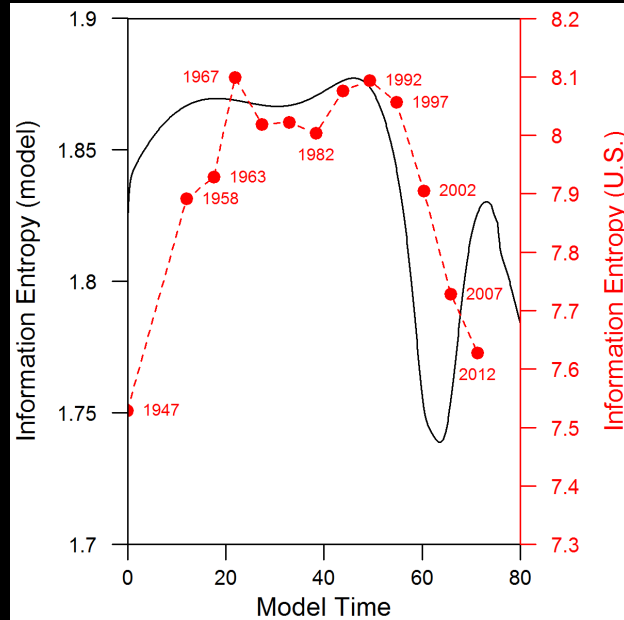


U.S. Data



Periods of peak per
capita energy
consumption

The model mimics the trend in “structural” flow of money within the U.S. economy



$$\text{Information Entropy} = \text{Conditional Entropy} + \text{Mutual Constraint}$$

Takeaways: The HARMONEY model ...

- ... consistently tracks physical and economic flows via conservation principles,
- ... serves as a base model to add components (e.g., government, renewable energy sector, climate)
- ... explains important coincident trends in energy and money distribution (e.g., wage share, debt)
- ... shows how economic decisions (e.g., rate of investment) relate to physical resources and population.

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For longer
presentations see
website:

<http://careyking.com/presentations>

King, Carey W., **An Integrated Biophysical and Economic Modeling Framework for Long-Term Sustainability Analysis: the HARMONEY Model**, *Ecological Economics*, [Volume 169](#), March 2020, 106464

<https://www.sciencedirect.com/science/article/abs/pii/S0921800919302034?via%3Dihub>

THE ECONOMIC SUPERORGANISM



COMPETING NARRATIVES ON
ENERGY, GROWTH, AND POLICY

CAREY KING

 Springer

Fall 2020