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# Sustaining Growth – Energy And Wealth Creation

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betterworld energy

GeoQuest
Mineral Exploration, GIS & Environmental Services

# Summary

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- *Overarching question*: How can sustainable long-term economic growth be achieved ?
- *Pitstop:* What explains past growth?
- *Important energy & quality metrics*
- How does the model perform ?
- A new model which differs from standard theory – How?
- What are the implications of the model ?

# Empirical and estimated US GDP: 1900-2000 (Standard Model, f [K,L,E])

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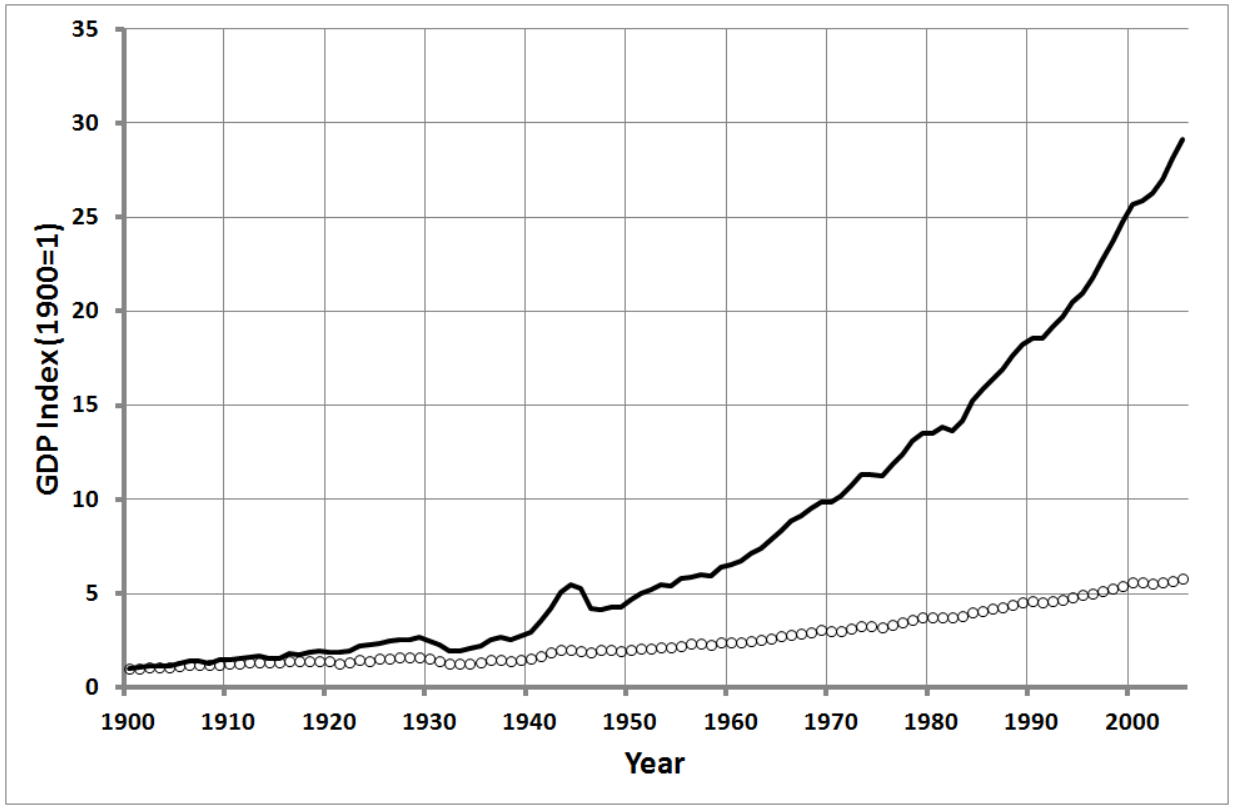


78% of observed growth is unexplained

Technological progress accounts for 1.5% per annum, in 2005 multiplying factor inputs by 4.8.

*"technological development will be the motor for economic growth in the long run".*

# Central Concept of Ayres-Warr Theory

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## Exergy to Useful Work

**1** **2** **3**

**EXERGY INPUT x EFFICIENCY → USEFUL WORK**

1. Food & feed
2. Fossil fuels
3. Alternative fuels
4. Recycled fuels

↓

**WASTE EXERGY**

(OFTEN LOW QUALITY HEAT OR POLLUTION)

**2nd law Thermodynamic Efficiency can be measured on a unique [0,1] scale**

# Exergy to useful work conversion efficiency

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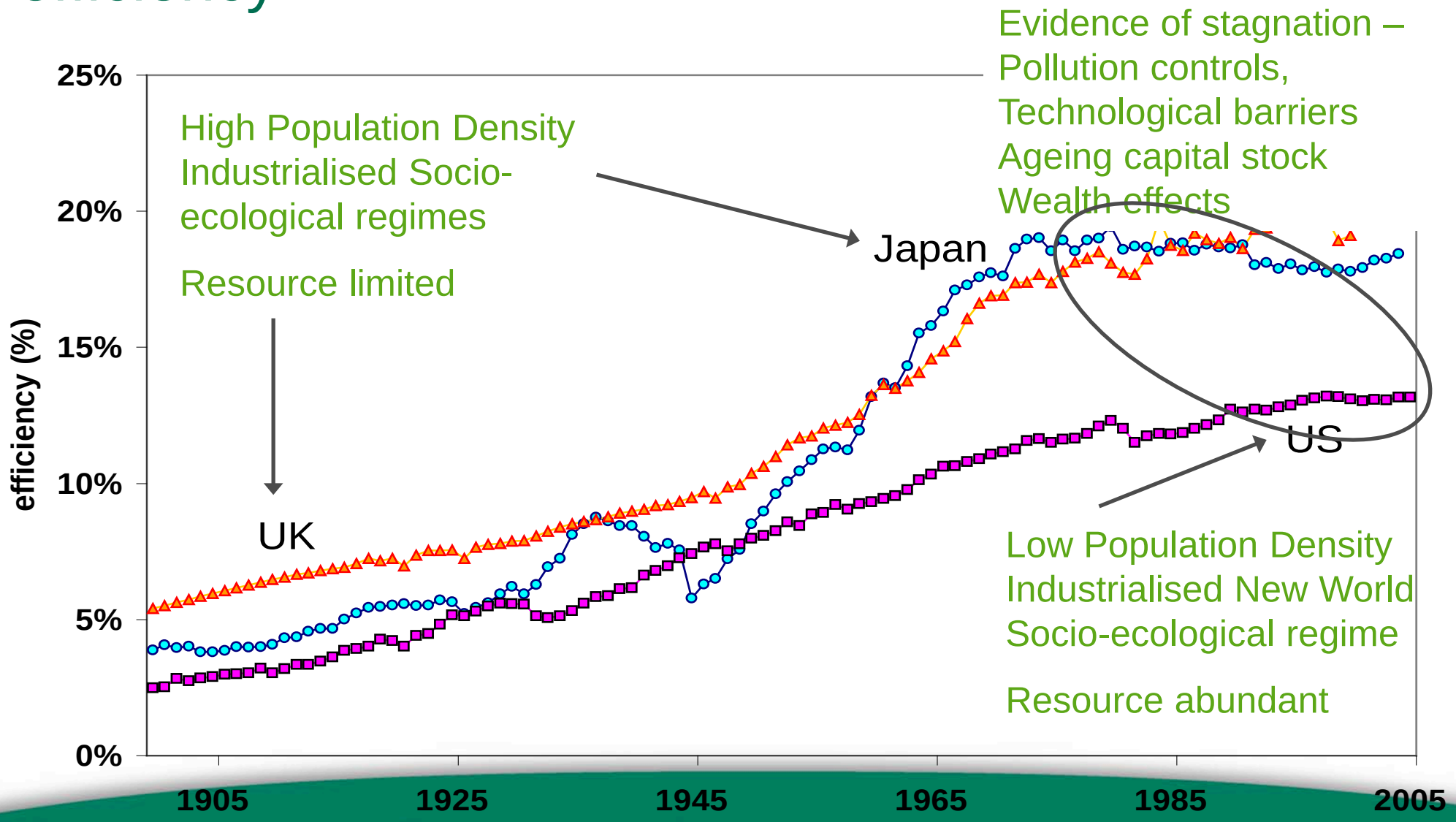

# The virtuous-cycle driving historical economic growth

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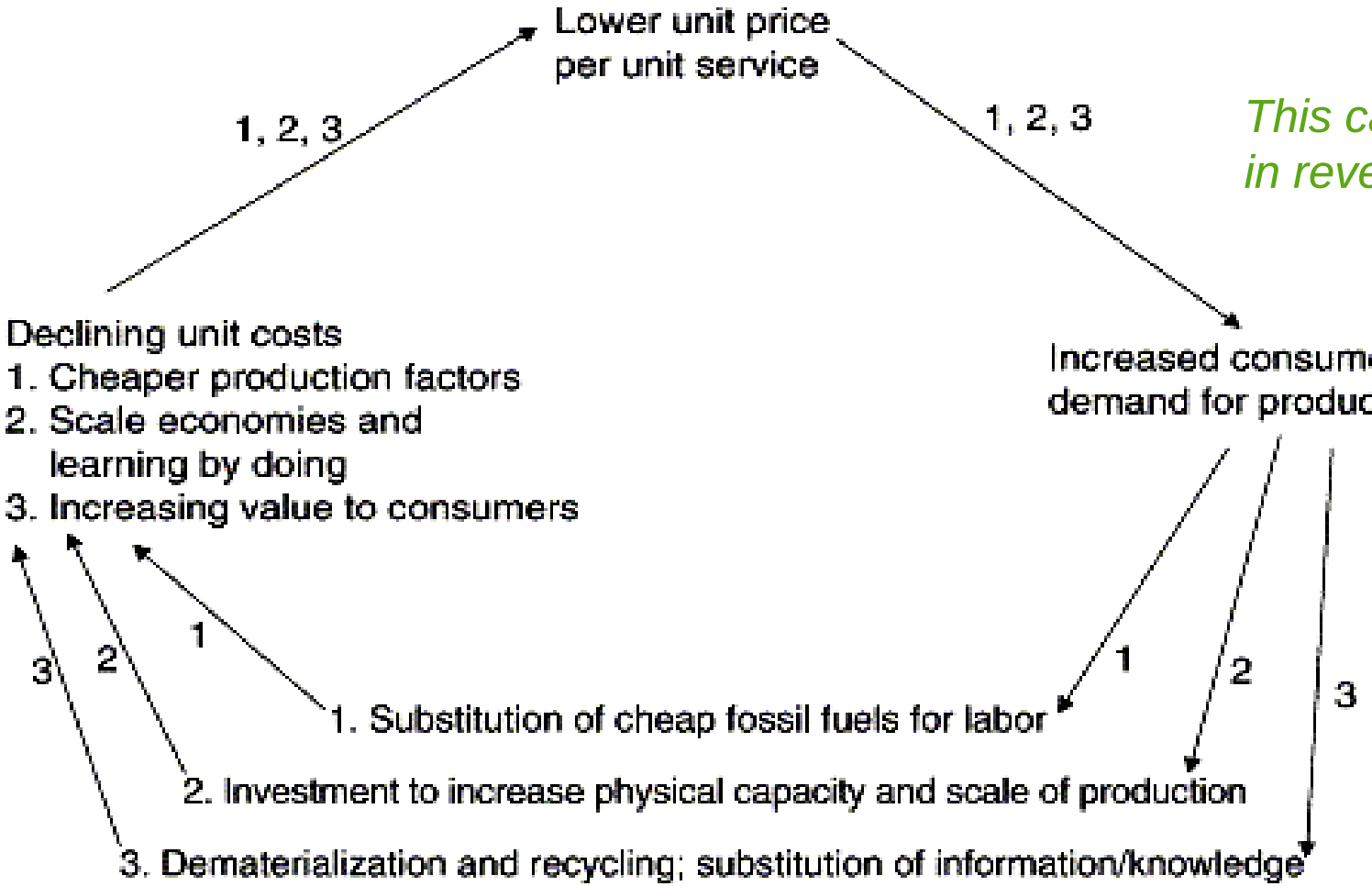


*This can all go in reverse !*

# Empirical and estimated US GDP: 1900-2000

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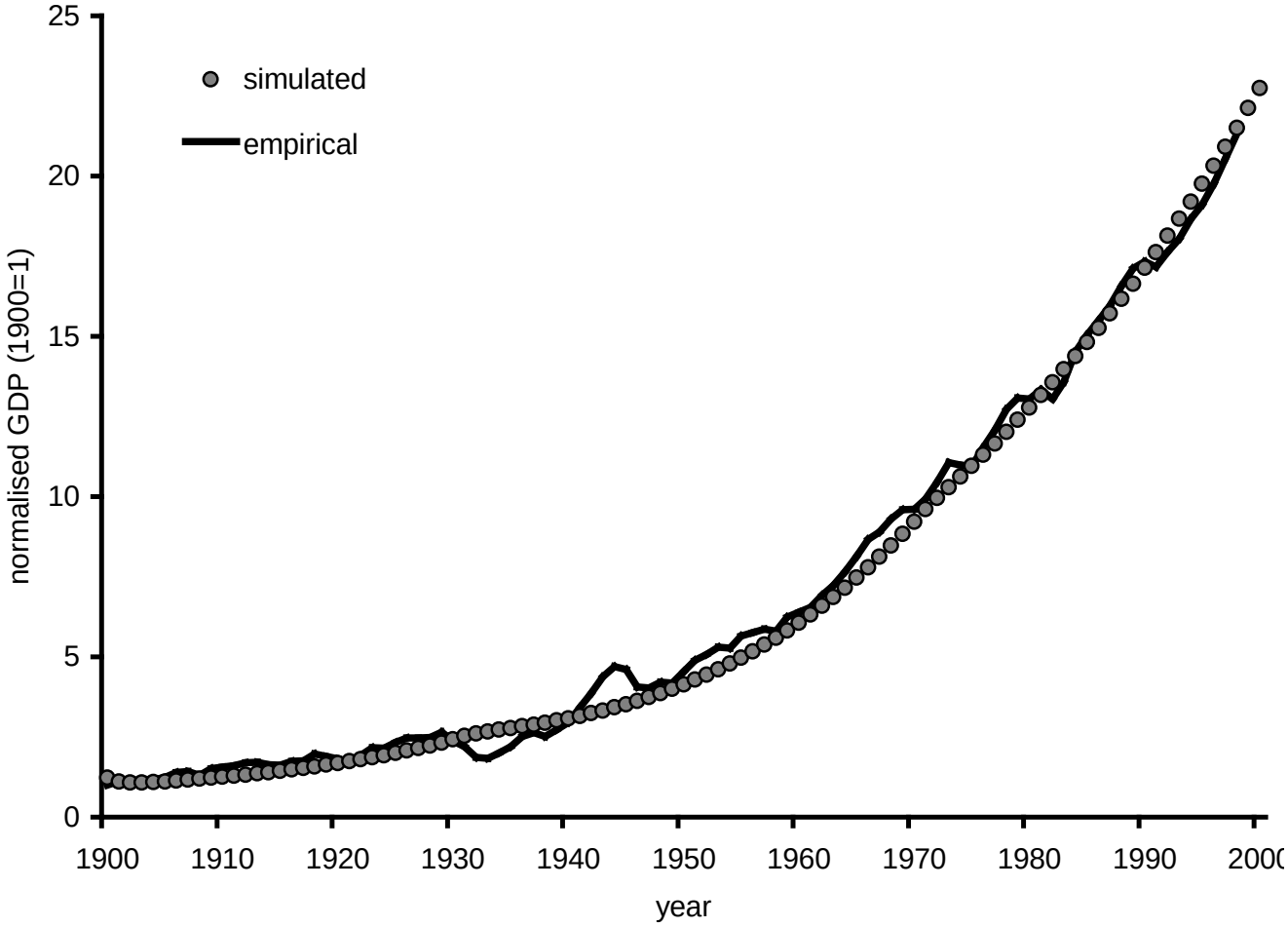

# Useful work Intensity of GDP – is this a quality indicator

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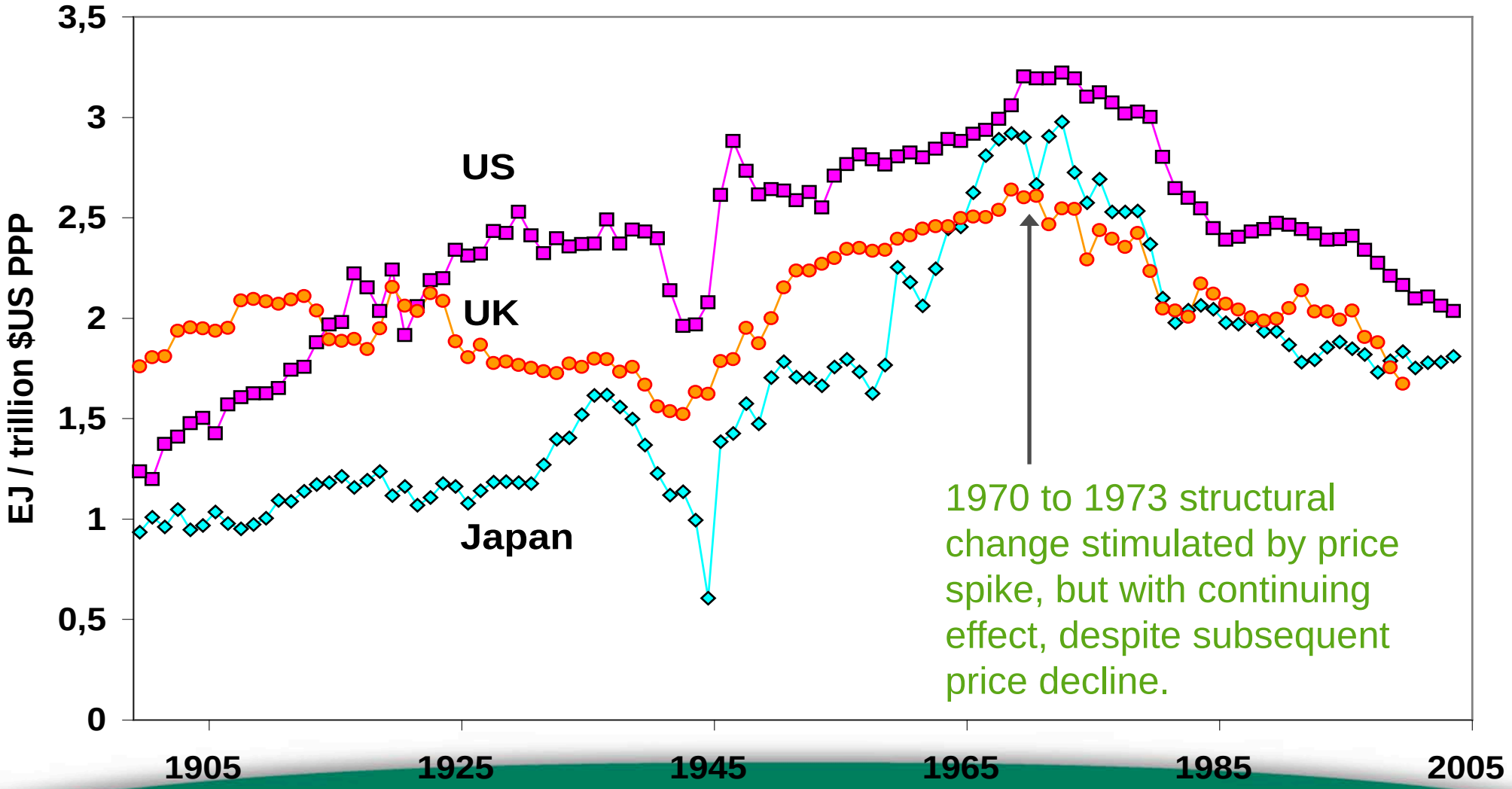

# The Underlying Theory

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## Standard Theory

- Driven by an external process called Technological Progress (all tech is equal)
- Growth in perpetual equilibrium along 'optimal path'
- Origins of physical production remain unexplained
- Closed system of abstract flows ($)
- Growth drives energy consumption

## Ayres-Warr Model

- Driven by endogenous Technological progress in energy supply & efficiency
- No equilibrium, no optimality, rather constraints from technological lock-in
- Linked to bio-physical reality
- Open system of exergy (& information) (J) and $
- Bi-directional relationship between energy & growth

# What might the future hold? Alternative efficiency scenarios.

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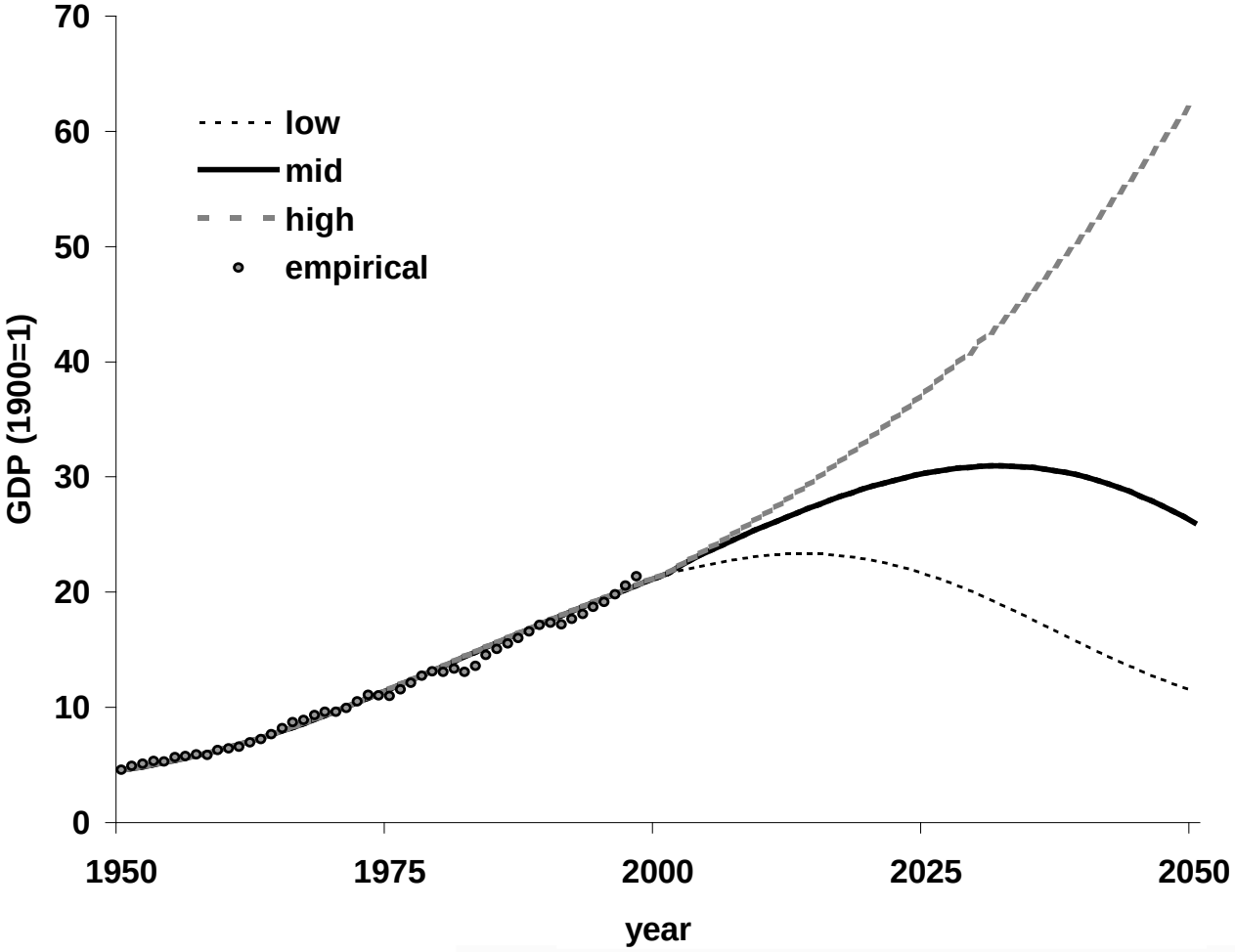


Maintaining historical (1900-2000) average rates of efficiency improvement (~1% per annum), with no constraint on energy supply (and demand at historical rates) allows maintenance of historical rates of growth.

# What effect efforts to reduce energy intensity of GDP?

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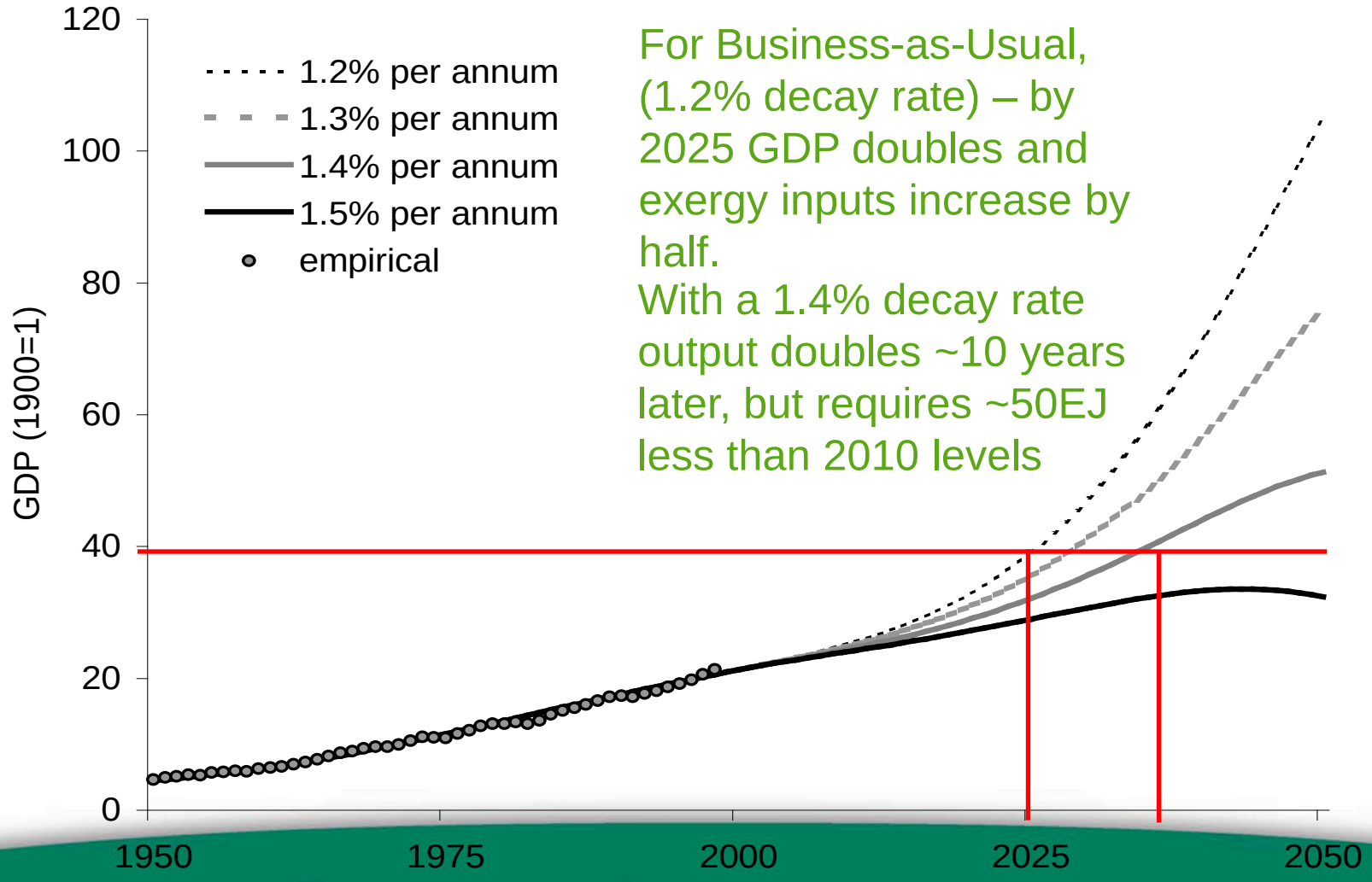


For Business-as-Usual, (1.2% decay rate) – by 2025 GDP doubles and exergy inputs increase by half.

With a 1.4% decay rate output doubles ~10 years later, but requires ~50EJ less than 2010 levels

# Growth, Causality, Decoupling-Rebound Energy Productivity: Evidence

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*Note that there are very few studies in developing world; few long-term studies, big differences in measures used.*

**GROWTH:** Most indicate positive relationship

**CAUSALITY:** Variable, due to short time series, low resolution data, but many indicate some form of bi-directionality

**DECOUPLING-REBOUND:** depends on saturation of demand + relationship to new technologies; (*in standard model they were never coupled.*)

**EFFECTS on EMPLOYMENT:** some find that efficiency decreases employment at firm level, but others find that overall productivity increases stimulate employment elsewhere. (There is no labour shortage).

**I would ask you to consider the alternative –**
**lets constrain supply & get less efficient and see where that takes us?**

# 2 implications for employment

## What is the meaning of labour productivity (Y/L) ?

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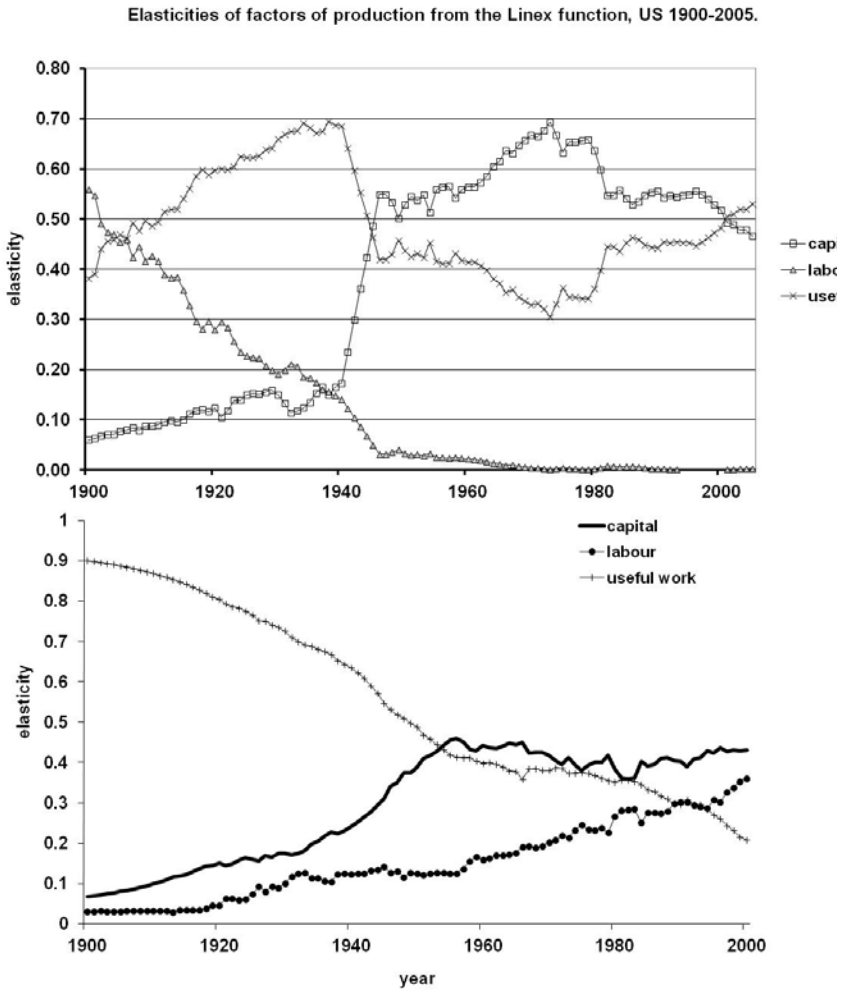
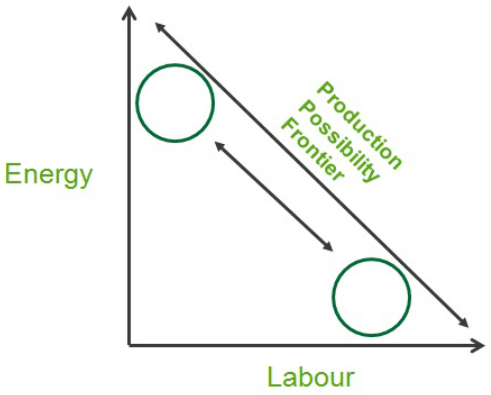
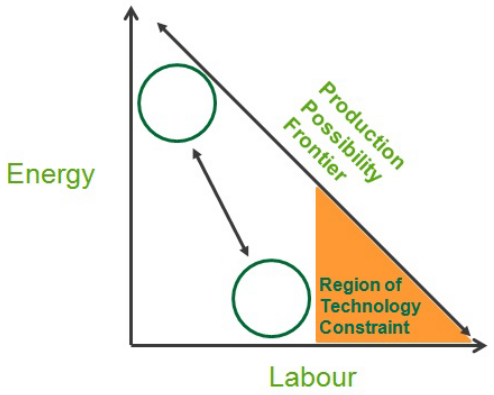



## Technology Constraints on Substitutability of Factor Inputs




Standard Theory




Ayres-Warr Model

- **New measures**
- **Rethinking of long-held assumptions about factors and their relationships.**

# Wealth benefits beyond GDP

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1. **More output for less input –** v. important under constraint in supply (see Japan)
2. **Lower energy costs –** efficiency improvements are often negative costs; (value of marginal improvements often small)
3. **Efficiency → Productivity→ Competitiveness** at regional / global level
4. **Job creation & Poverty reduction *through growth***
5. **Energy supply & Price stability**
6. **Reduced FOREX import bill**
7. **Environmental sustainability**

# Barriers to investment & innovation

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1. **Education & Information Barriers:** received ideas, business-as-usual (is there such a thing?).
2. **Financial Barriers / Discounting / Hurdle rates / Wrong energy prices (subsidies/no externality costs):**

   Often not so much absence of funds rather misallocation of funds

   NB: energy investments and discount rates are intimately linked if energy* efficiency drives growth – we make our own future.
3. **Technological barriers:** lock-in, no systems overview, perceived risks, investment habits – see 2
4. **(Political) Short-termism, lack of imagination:** see 1, see 2
5. **Weak civil society & independent institutions**

# Critical Components

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(1) Incorporating **externalities** in costs

**(2) Education** & information

(3) Institutional **enabling environment** (marketing, finance, incentives, fine grained resolution, system-wide thinking, imaginative)

**(4) Social** technology

**(5) Business innovation**

National Innovation Systems – Stability, full costing, level playing fields
PAT Schemes – Perform , Achieve , Trade Schemes
Social Entrepreneurship – Underutilised Inventory – Aggregate – Incentivise

**Production as an open system;**
**Productivity as an integrated system**

# Final thoughts

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- We can measure the quality of energy use & its technological dependence
- Using energy price in models ignores real costs and real productivity effect of energy use
- Not all technologies are equal – those that impact energy and natural resource use efficiency have deep growth implications
- Assumptions about abstract perpetual technological progress means growth will be predicated on debt funded consumption
- Does it matter how efficient a renewable energy system if self-sustaining & negative environmental impacts are low, positive social impacts are high?
- Most social innovation technology is being driven by small, innovative start-ups, philanthropists. Not, or even despite governments.

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