Climate Change, Energy & Innovation: a UK historical perspective

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Why Explore Energy Histories?

"A lantern on the stern can help with navigation ahead."

- Studying a country's energy & environmental histories
- Helps appreciate
  - Energy's role in human development
  - Environmental & resource impacts & challenges
  - Innovation/penetration of fuels & technologies
  - 'Path dependency' & 'lock-in'
  - Roles of markets, institutions & policy
  - Past & potential 'Industrial Revolutions'

Background: Energy System Transitions

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Long collaboration with Roger Fouquet

Outputs: Long Run Estimates for Britain

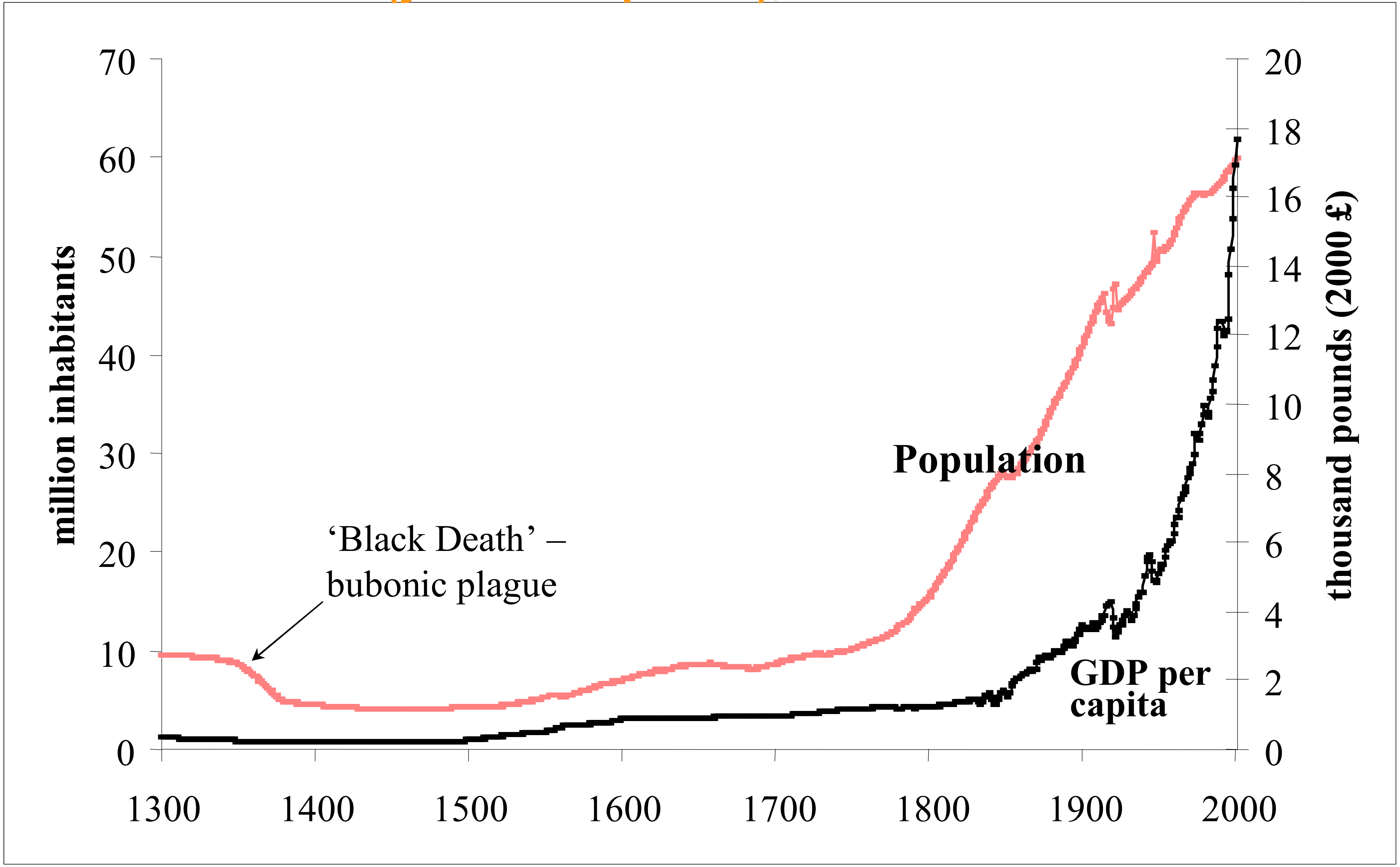
- Fuels/energy carriers (coal, gas, electricity, petroleum)
  - Prices; Consumption; Expenditure
- Energy services (today: lighting)
  - Energy conversion efficiency of devices
  - Cost/price of services
  - Consumption

[See journal papers & Fouquet's book - *Heat, Power and Light: Revolutions in Energy Services*, Edward Elgar (2008)]

Energy & Britain’s First ‘Industrial Revolution’

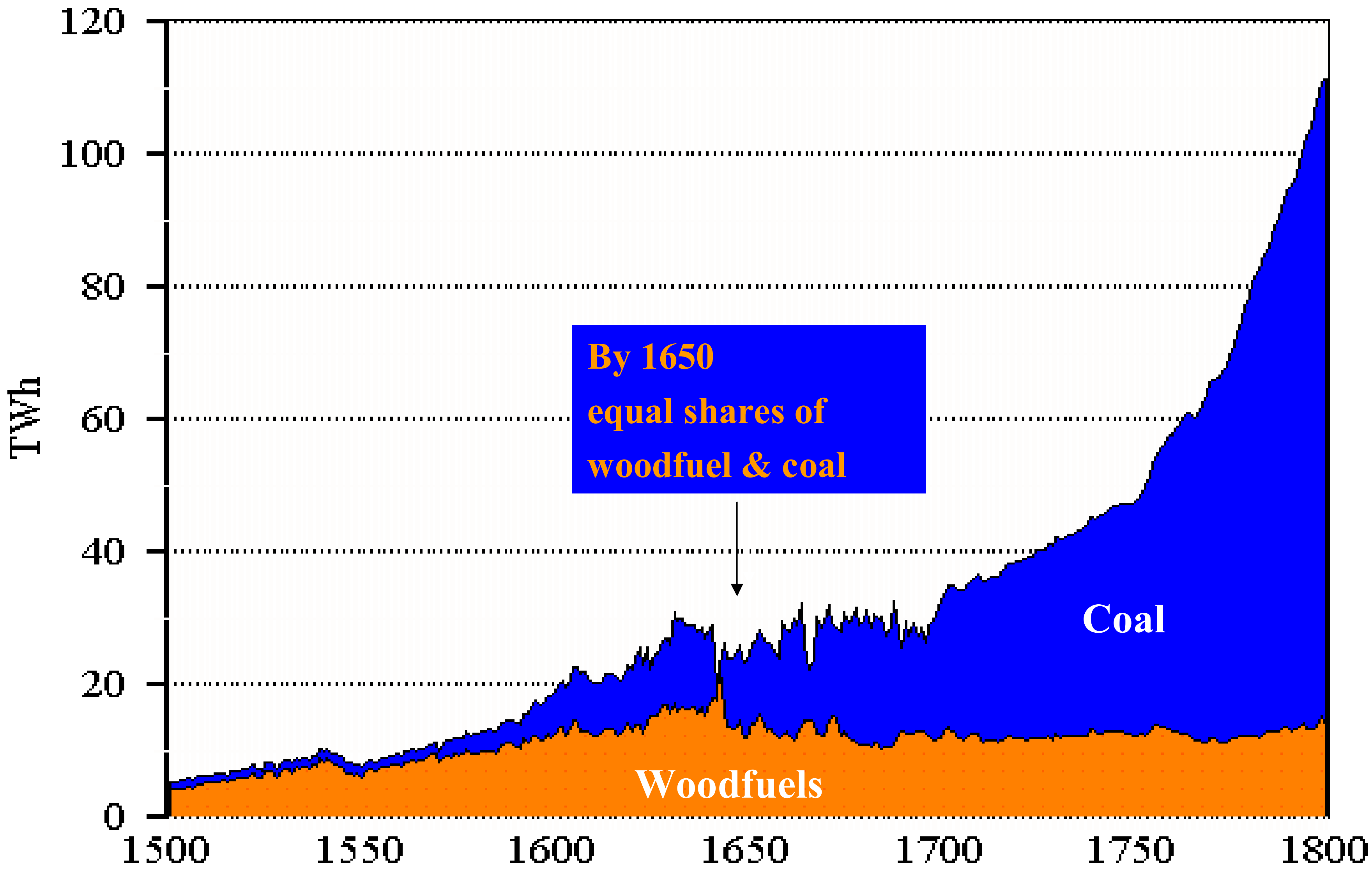
- C16th-19th transitions: traditional agricultural (‘organic’: Wrigley) economy, held back by limited
  - Productivity of scarce land &
  - **Flows** of energy for food, clothing, housing & **fuel**
- Moved to a new regime: growth & living standards transformed
  - By exploiting **stock** of fossil fuel (coal) for larger energy flows
  - Along with innovations
    - inc. steam engine
    - & other institutional, social & political innovations
- Coal & steam helped drive mechanisation, urbanisation & Britain’s ‘Industrial Revolution’

Figure 1. UK population & real GDP per capita (year 2000 prices), 1300-2000



Source: Snooks (1994) and others; see Fouquet and Pearson (1998) for details

Fig. 2: UK final energy consumption 1500-1800 (TWh)



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Coal & new steam technologies in C18

- Engines pumped water from coal & copper mines
    - 1698: Savery's patent
    - By 1733 110 Newcomen 'atmospheric engines' in 7 countries
    - 1769-1800: Watt's separate condenser patent
        - raised efficiency & royalties
- Rotary steam engine
    - Could drive machines: Watt (1782) & others
- But by 1800, only 2200 steam engines in mining & manufacturing
    - High steam & water power price differential

Steam: development & diffusion

- Steam/water power price differential gradually overcome
  - By mobility advantage
  - & increased engine efficiency
    - Higher pressure boilers (1840s)
    - Corliss valves (1860s)
- Steam let production move from water & wind power sites
  - Helped develop the factory system
  - Especially textiles: Manchester - ‘Cottonopolis’
- Railways & then ships

Fig. 3: UK Coal consumption by economic sectors, 1800-2000 (TWh)

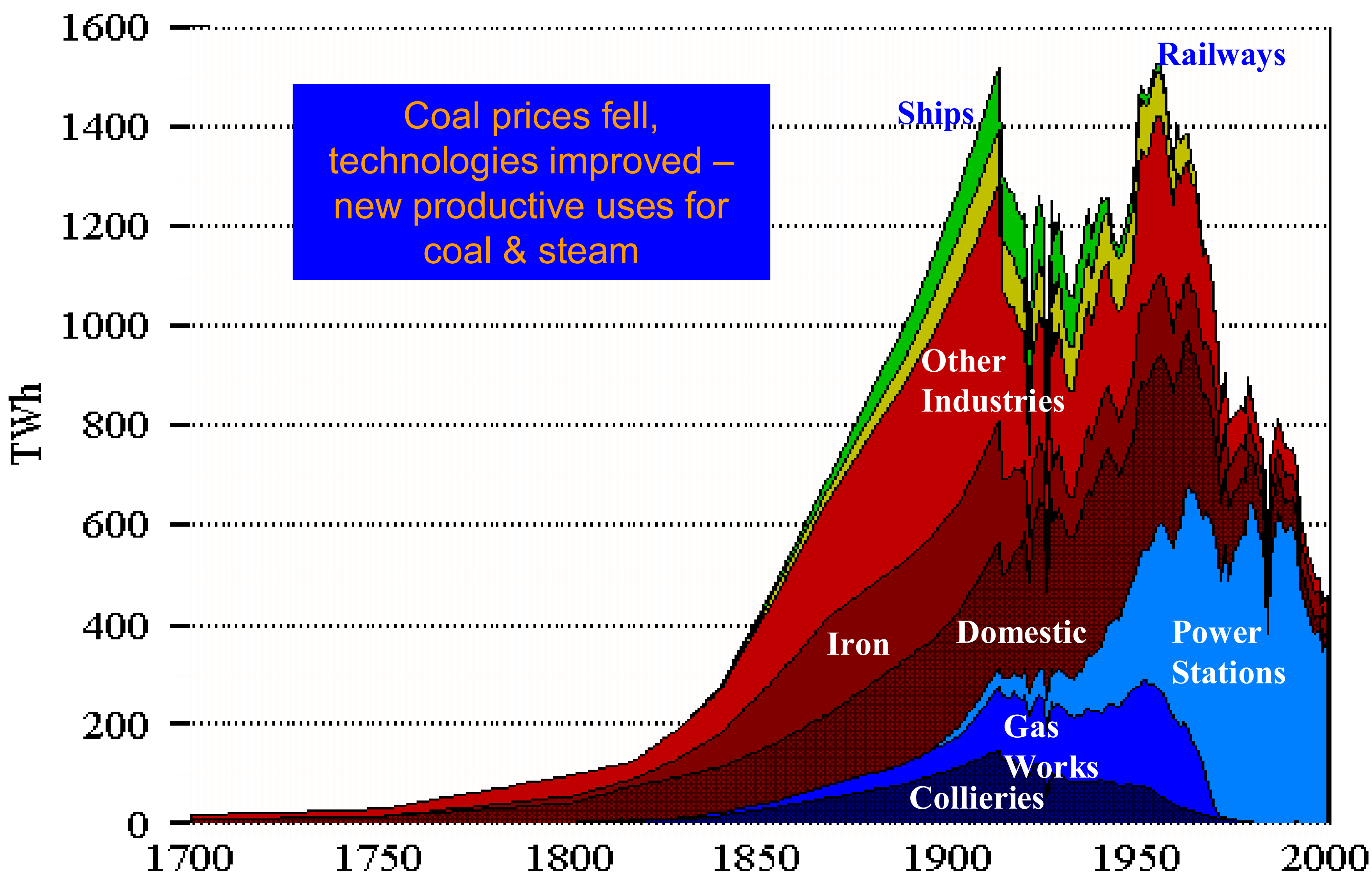

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Fig. 4: UK final energy consumption, 1800-2000 (TWh)

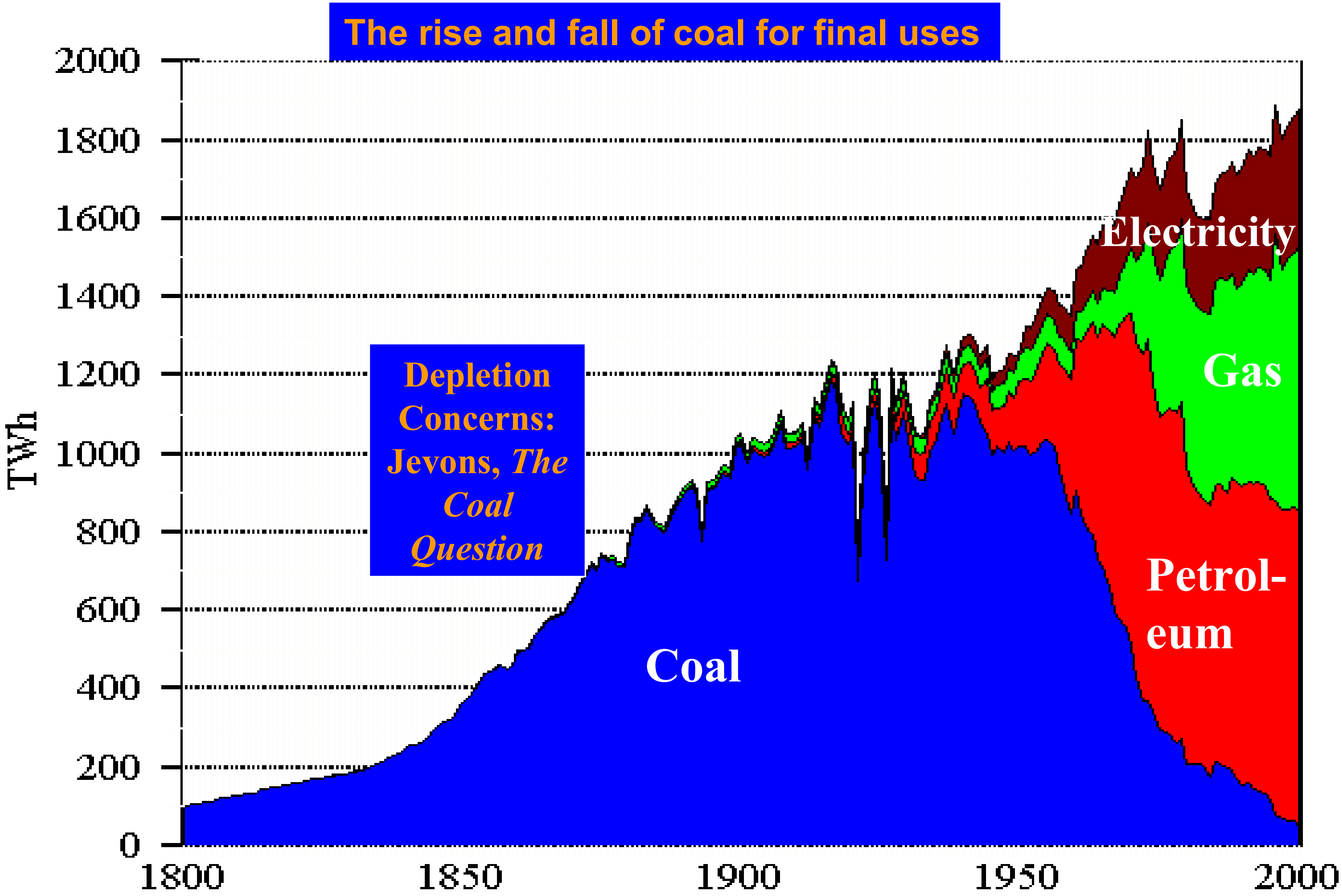

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Fig. 5: Real consumer fuel prices, 1500-1800 (p/kWh)

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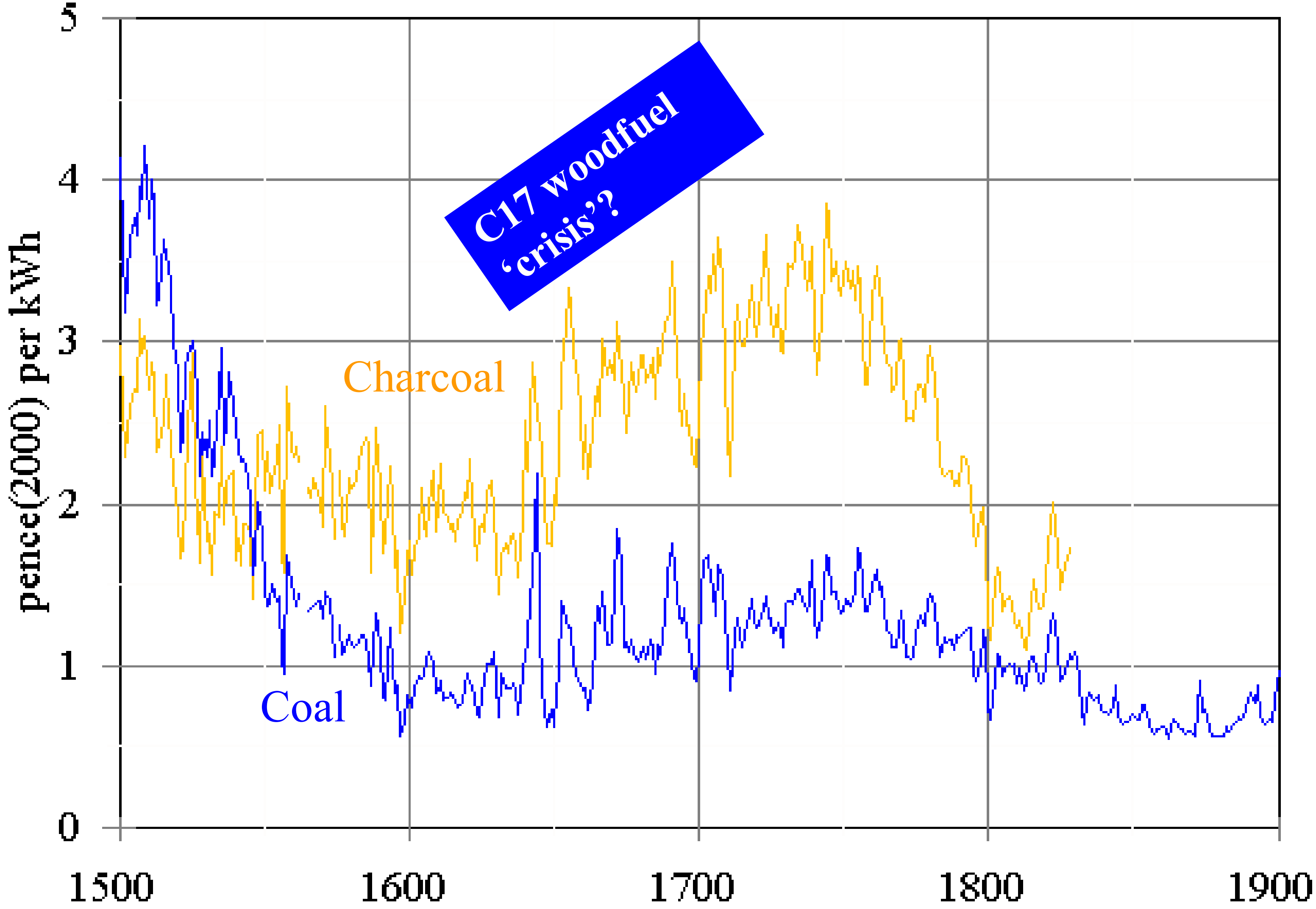

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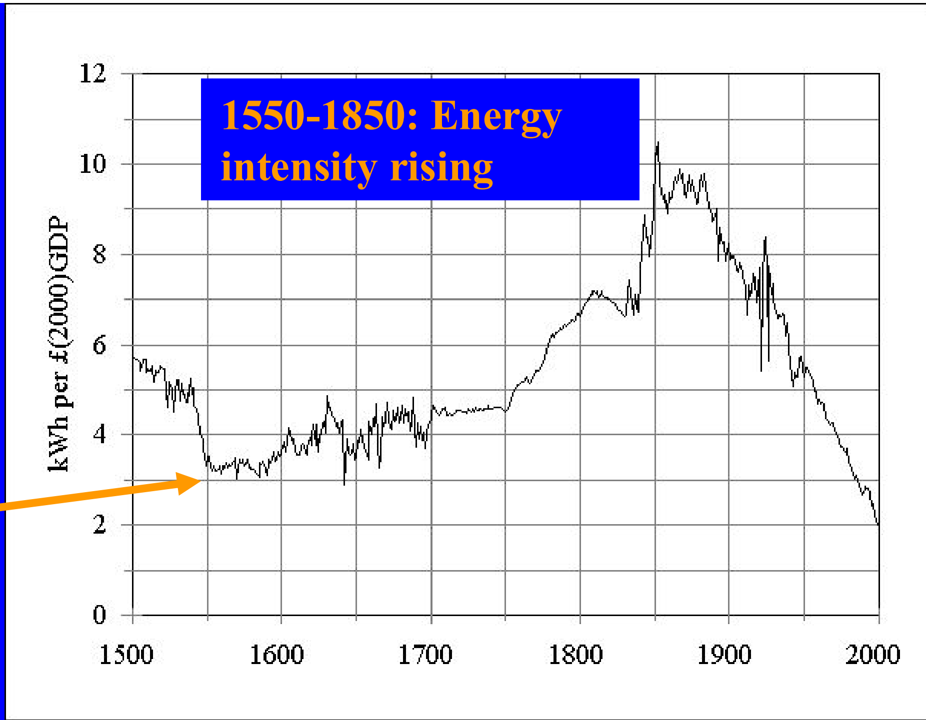
Fig. 6

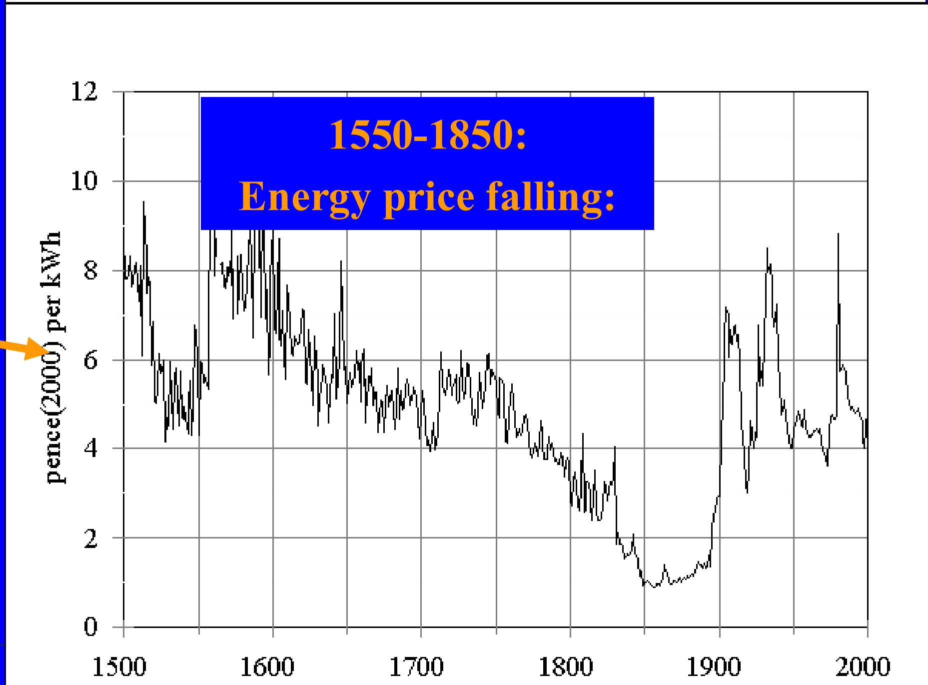
Inverse relationship between:

Energy intensity (E/GDP)

and

Real energy prices





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Long-Run Perspective

- But new technology diffusion **took time**
  - Major productivity effects of steam engines, locomotives & ships only observable after 1850
  - A few steam-intensive industries
    - Mining, textiles & metal manufactures
    - Accounted for >50% of industrial steam power, 1800-1900
- Not just steam: electric light slow to dominate gas (40 years: 1880-1920)

UK Environmental Issues: Air Pollution & Climate

- Growing 19th UK concerns - little action:
  - Alexis de Tocqueville - Manchester (1835):
    - 'A sort of black smoke covers the city. Under this half daylight 300,000 human beings are ceaselessly at work…'
  - Little serious action until C20
- London's long air pollution history
  - 1952 'Great London Smog': est. 3500-4000 premature deaths
  - 1956 Clean Air Act
- Then small particles & acid deposition
- Now climate change & GHGs, including CO_2

Perspective on Energy System Transitions

- Transitions mean interactions between
  - Fuels & energy converting technologies
  - Infrastructures (transport networks, pipes & wires…)
  - Institutions (markets, companies, finance…)
  - Policy regimes (institutions, regulations…)
  - Economic variables (prices, income/output…)
  - Environment
  - & people…
- Complex, *evolving systems*
  - Must focus on much more than fuels & technologies

Innovation & Energy Services: UK lighting

- What's the energy for? Energy services:
  - *illumination*, transportation, hot food, comfortable temperatures…
- Evidence: innovation's extraordinary potential to
  - Lower costs, raise service quality & welfare
- UK lighting services innovation
  - Mostly after 1800
    - In fuels, technologies, infrastructures & production
  - Lower lighting costs & rising incomes
  - Meant 'revolutions' in light use & quality

Figure 7. UK Consumption of Lighting from Tallow Candles & Whale Oil (billion lumen-hours, 1711-1900)

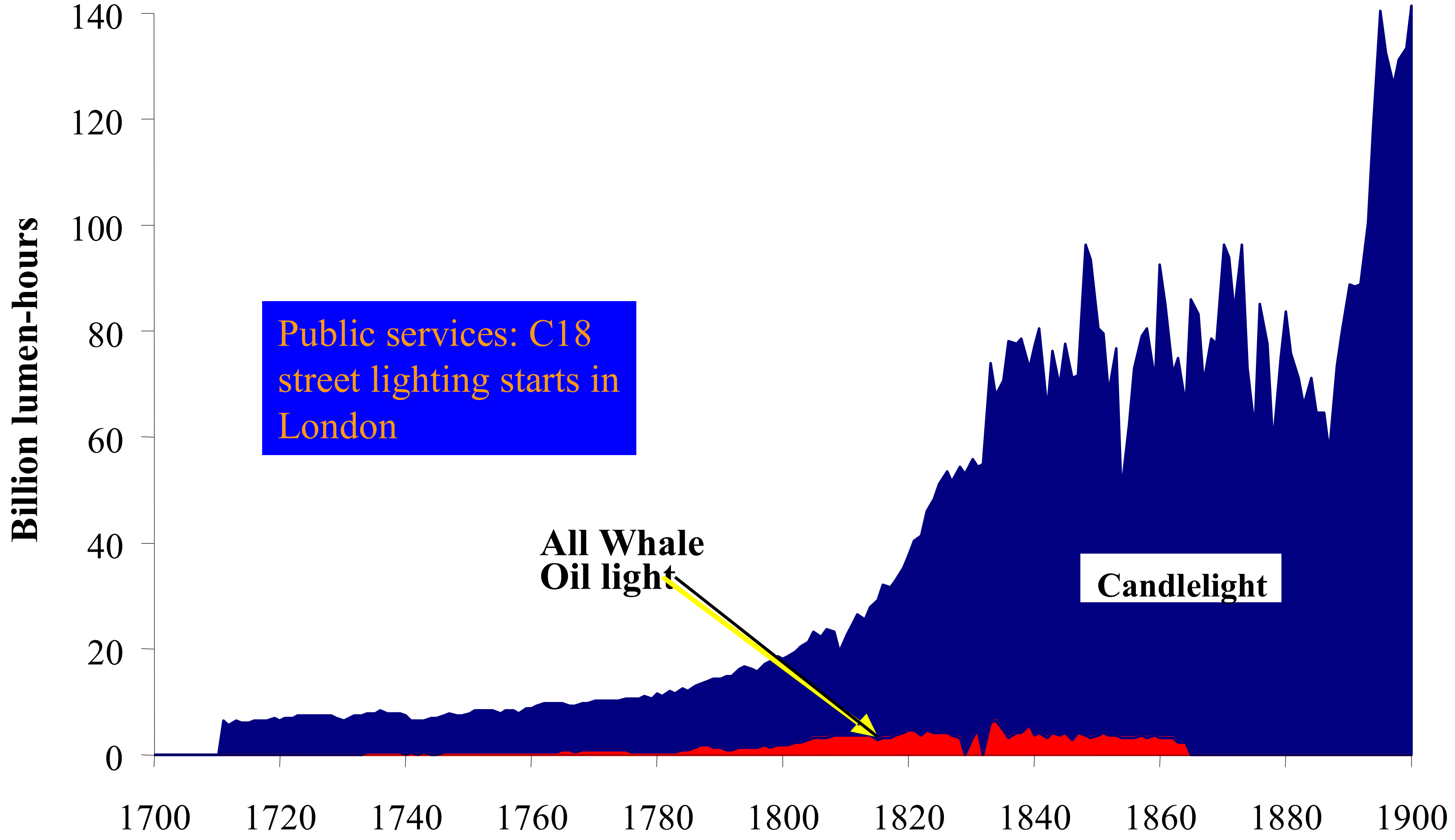

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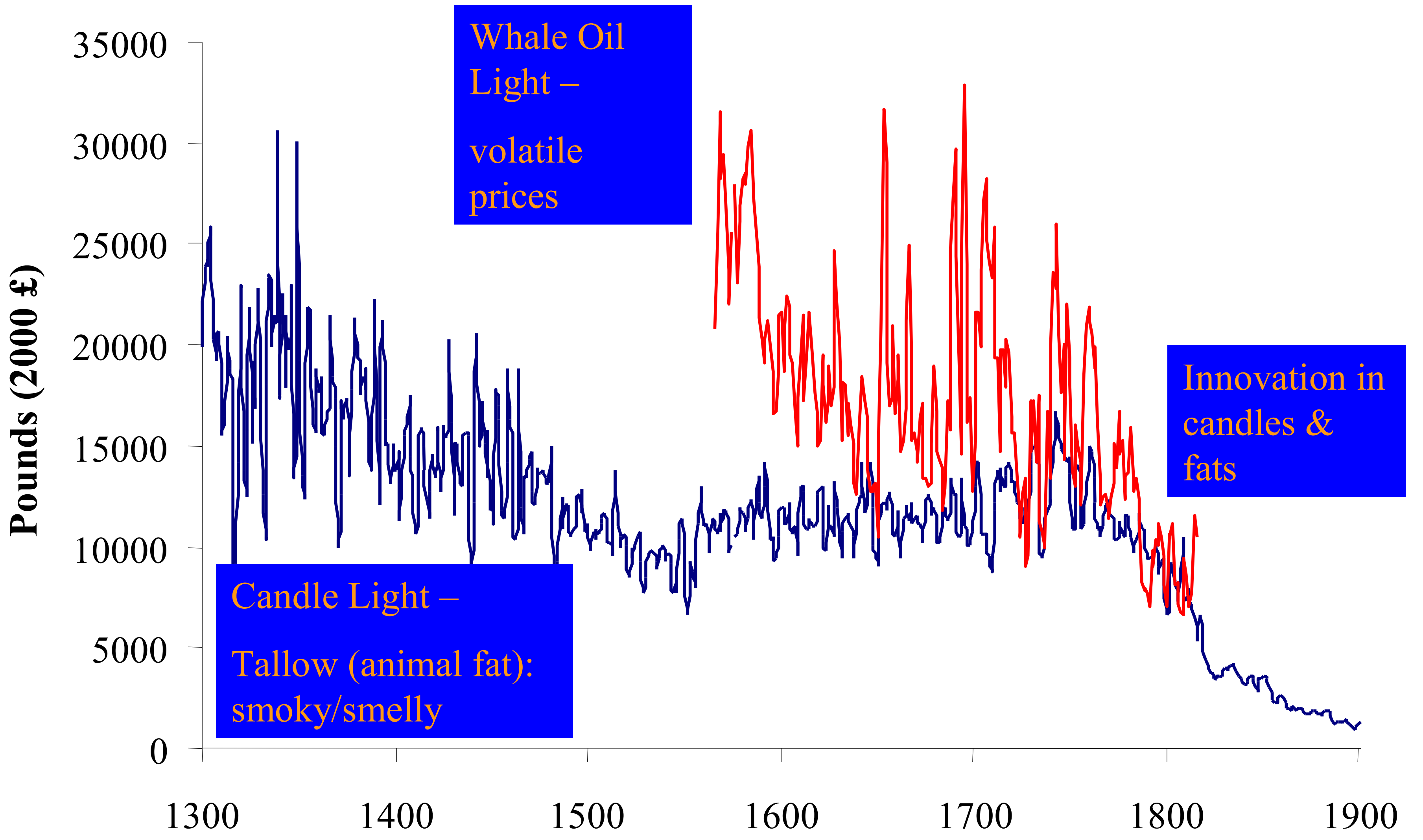
Figure 8. The Cost of Lighting from Tallow Candles & Whale Oil (£ per million lumen-hours, 1300-1900)



NB: ‘Cost’ is marginal (i.e. running) cost

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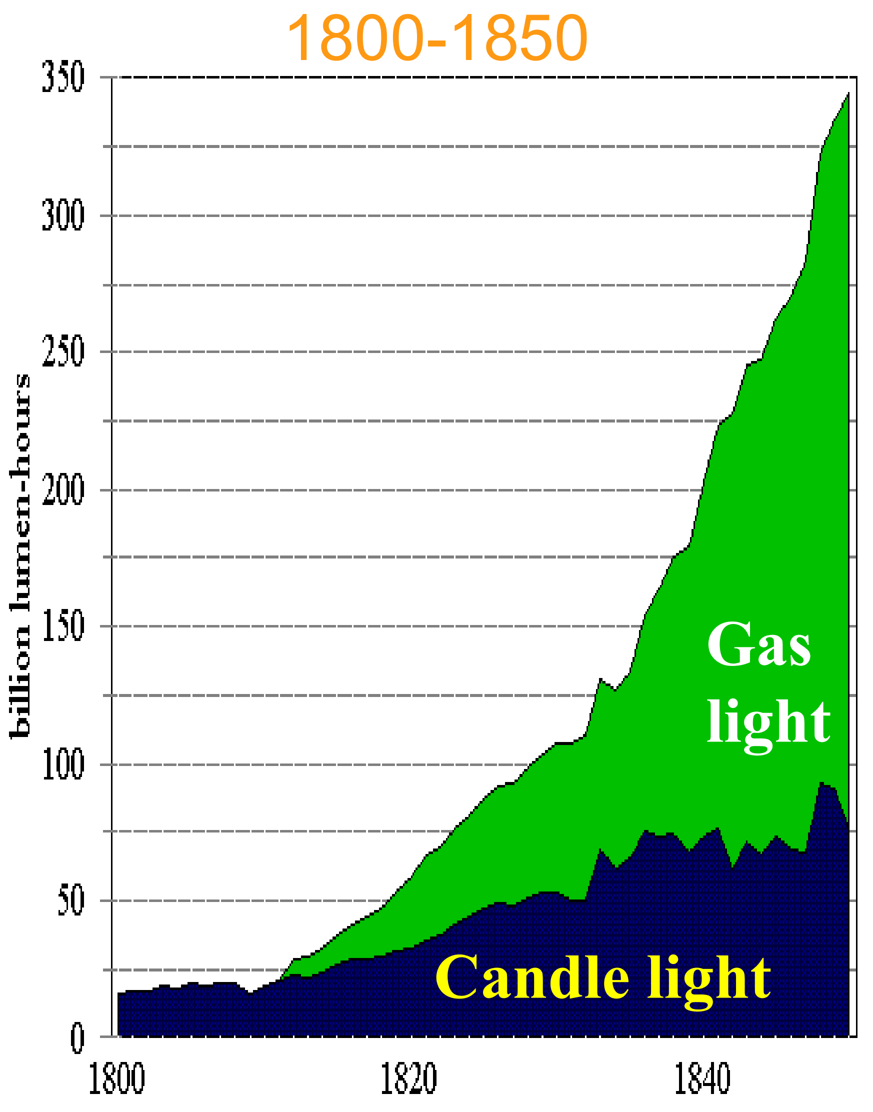
Fig. 9. UK Consumption of Gas, Kerosene & Candle Light (billion lumen-hours)



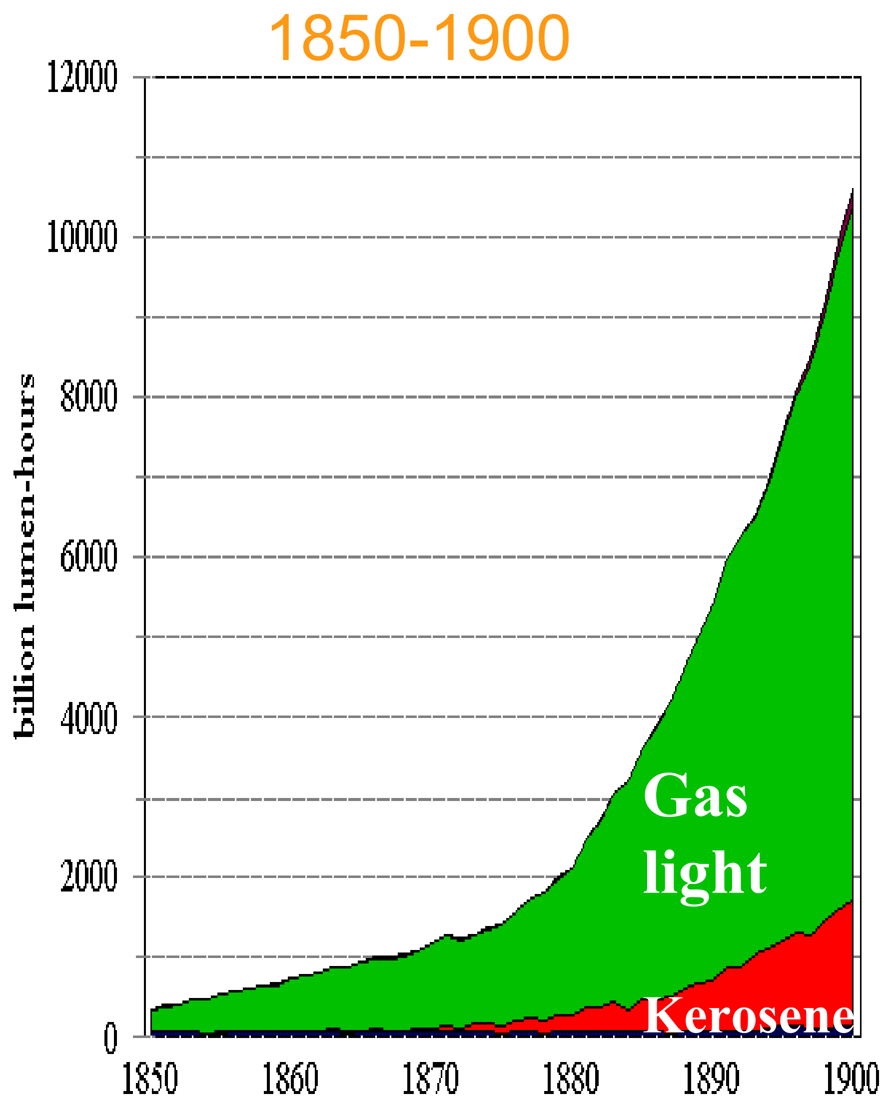


Fig. 10. UK Consumption of Kerosene, Gas & Electric Light, 1900-2000 (billion lumen-hours)

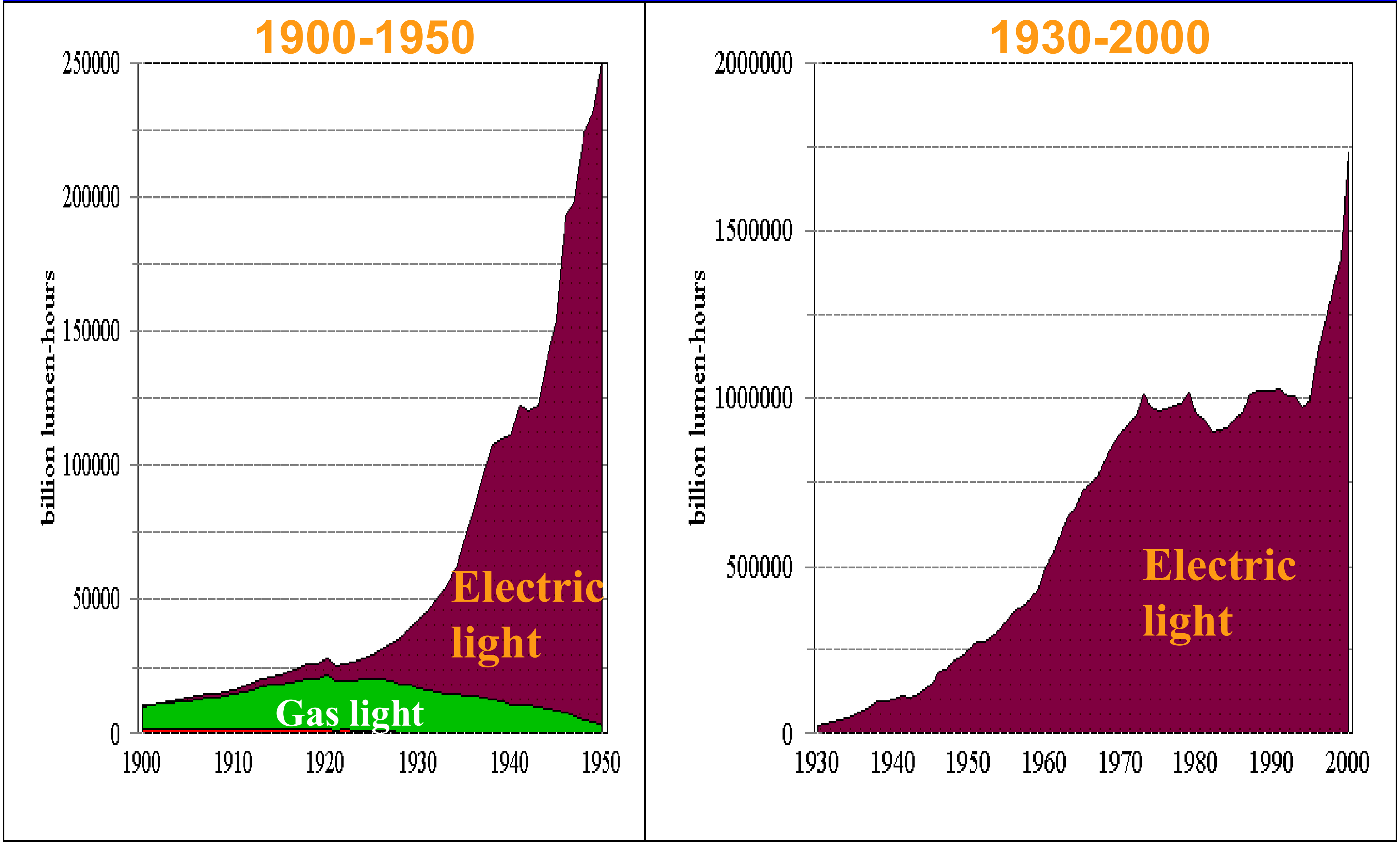


Fig. 11. UK Price Ratio of Lighting from Competing Energy Sources, 1820-1950

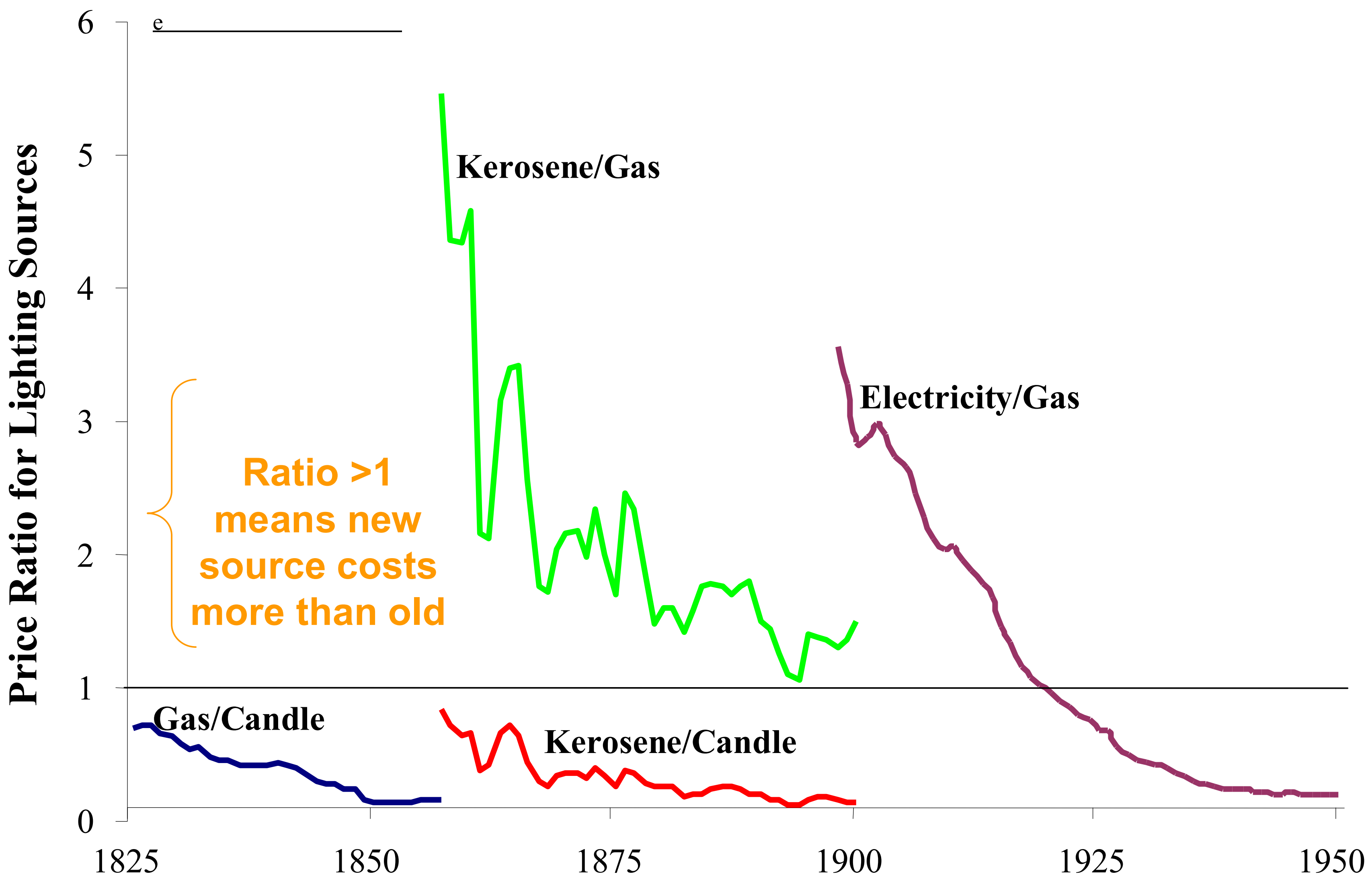


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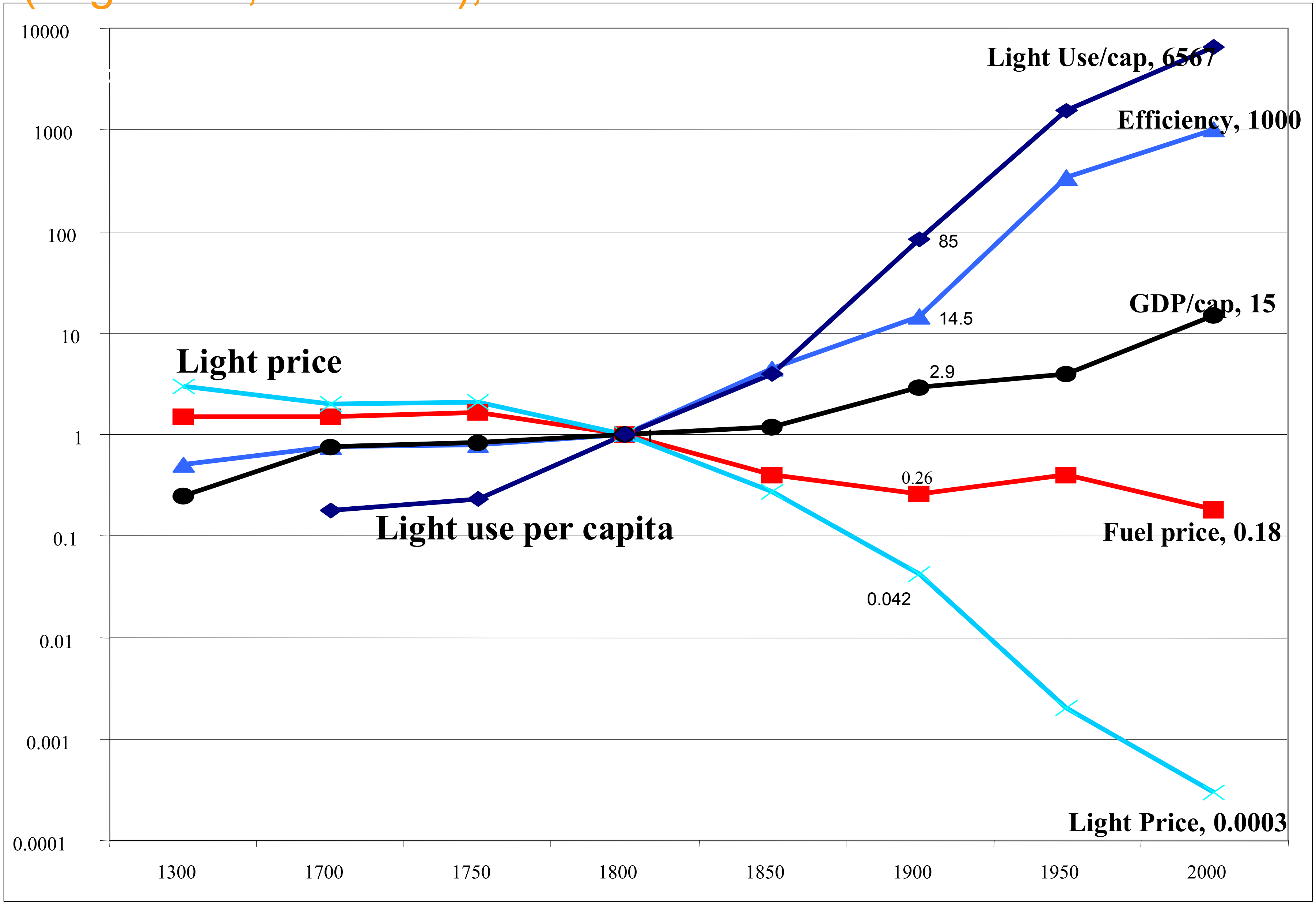
Fig. 12. Indices of Key Lighting Variables in the UK (Log Scale, 1800 = 1), 1300-2000



Source: authors' own estimates – see Section II

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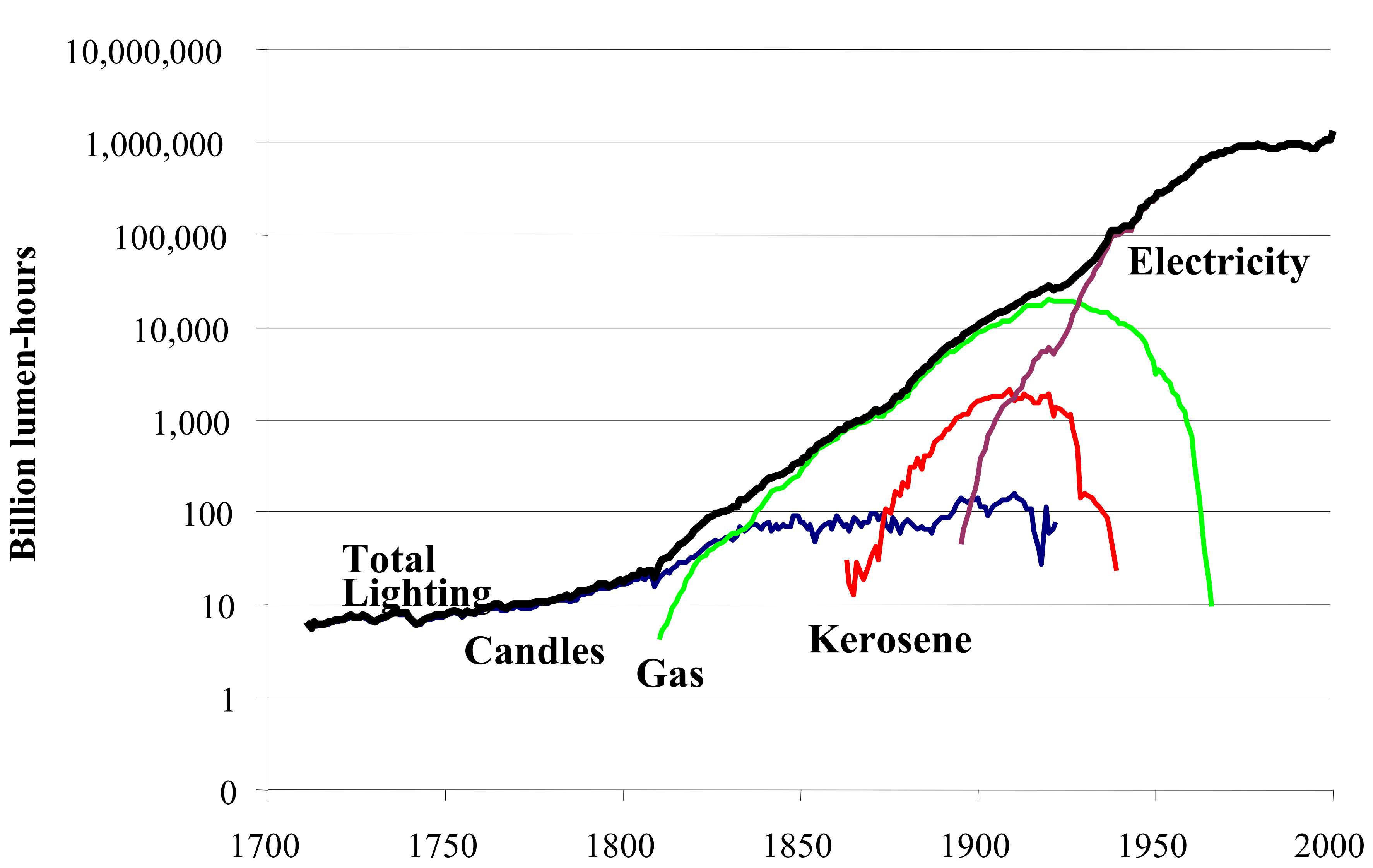
Fig. 13. UK Consumption of Lighting - Candles, Gas, Kerosene & Electricity (billion lumen-hours, 1700-2000)



Source: authors ' own estimates – see Sections II.2 and II.3

Billion: 10 [9] (i.e. one thousand million)

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Some Lessons from UK Experience of Energy transitions

- Energy innovations can have profound effects on human development & welfare
  - But takes time for new fuels, technologies, infrastructures & institutions to develop
  - There can be much inertia in our systems
- We were slow to recognise & address environmental impacts
- Government policy can make a difference

Turning over the capital stock takes time…

- Thompson's Atmospheric Engine
  - Ran for 127 years in coal mines (1791-1918)

- Bell Crank Engine
  - Ran 120 years (1810-1930)

- Both in Science Museum, London

•Path dependence? First mover advantage?

•UK mining & textile industries slow to adopt electricity

•Relative to chemicals & engineering, shipbuilding & vehicles

The Future for Low Carbon Technologies?

- Two previous Industrial Revolutions were about manufacturing
  - C18 revolution driven by textiles, iron & steam
  - end C19 2nd revolution: electricity, chemicals, petroleum & mass production
- Improved technology (energy & ICT) *might* help break link between energy services, fuel demands & emissions
  - *Could* enhance macro-level productivity
  - Energy & ICT as *General Purpose Technologies*
  - Steam engines, ICE, electrification & ICT raised productivity growth (but took decades)

Climate Change & Low Carbon Technologies

- Two key features of GPT's:
  - *Technological Dynamism:* continuous innovation in efficiency of the technology, so costs fall/quality rises over time
  - *Innovational Complementarities:* new technology users improve own technologies, find new uses
- How to get there from here?
  - Means more than substituting low carbon technologies into *existing* uses and institutions
  - Low carbon technologies need capacity:
    - For continuous innovation & cost reduction
    - To change what we do with them & how
    - To be proactively sustainable
- And so contribute to a 3rd 'Industrial Revolution'

In what ways might bioenergy & renewable raw materials meet these challenges?

- For example, are there routes from petrochemical complexes to sustainable biorefineries :
  - Are there prospects for synergystic co-evolution of energy & chemicals production
    - Around bio-based renewable raw materials?
  - Analogous to the ways in which petroleum & chemicals co-evolved in 2^{nd} half of C20?
  - Or might it be not synergy but antagonism?

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