Lecture 7
Technology II

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History of Economic Growth and Crises
31 January 2023

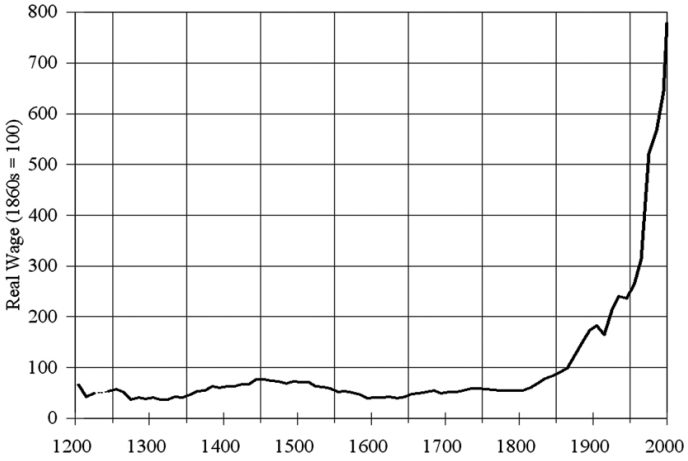
Outline of the course

1. The Malthusian Era
2. Fundamental causes of growth
3. Innovation and crises
    1. **Technology**
        1. Industrial revolution, 1750–1830
        2. Why 18th century Britain?
        3. (Later 19th century)
    2. Finance
4. Unleashing talent

Coalbrookdale by Night, Philip James de Loutherbourg, 1801

Real wages of English building workers

(Clark 2005)



Mokyr (1990, 81): "In two centuries daily life changed more than it had in the 7,000 years before. The destablising agent in this dizzying tale was technology, and Western technology alone. Of course, technological progress did not start in 1750, and the difference between the period after 1750 and the period before it was one of degree; but degree was everything"

Industrial Revolution, 1750–1830

Mokyr (1990, Ch 5)

- The Industrial Revolution
  - typically dated between 1750–1830
  - and located in Britain (though other European countries and, later, the United States also were sources of innovations)
- Was it a "revolution"?
  - per capita income did not improve much initially
  - but production technologies changed dramatically

Industrial Revolution, 1750–1830

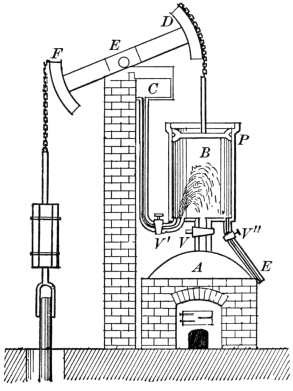
Mokyr (1990, Ch 5)

- Huge technological progress in some industries
  - power, metallurgy, textiles, high-precision machinery tools...
- Little progress in in other industries
  - service, construction, food processing, apparel making
- Innovation was not particularly scientific
  - though *scientists* made many important innovations
  - Mokyr: "A typical innovator in those years was a dextoreous and mechanically inclined person who became aware of a technical problem to be solved and guessed approximately how to go about solving it"

Power technology

Mokyr (1990, Ch 5)

Newcomen's engine



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Power technology

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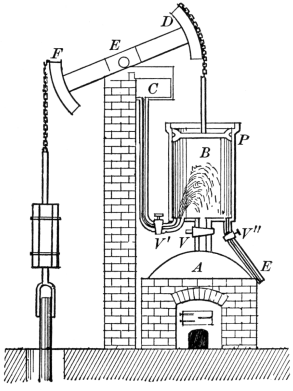

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- Steam engine's "scientific" background
  - realization that an atmosphere exists
  - thermodynamics developed much later (started in 1824 with Sadi Carnot's work that explained why steam engines work)
- Newcomen's engine first economically succesful one (installed in a coal mine in 1712)

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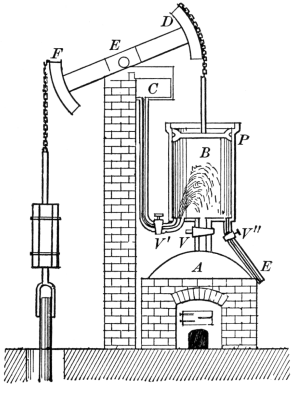

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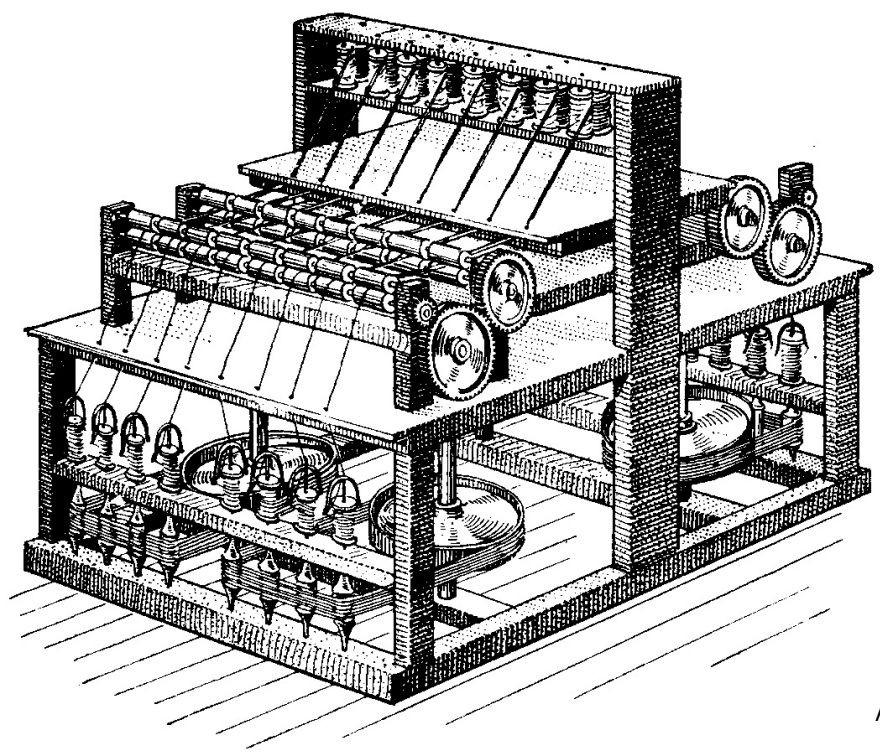
- Newcomen's engine first economically succesful one (installed in a coal mine in 1712)
- Watt designed important improvements that greatly increased efficiency
  - "his mind ran upon making engines *cheap* as well as *good*" (autobiography)
- Trevithick: high-pressure machine, 1802
  - smaller and more economical
  - fitted boats and horseless carriages
- Waterpower: breast wheel, turbine

Metallurgy

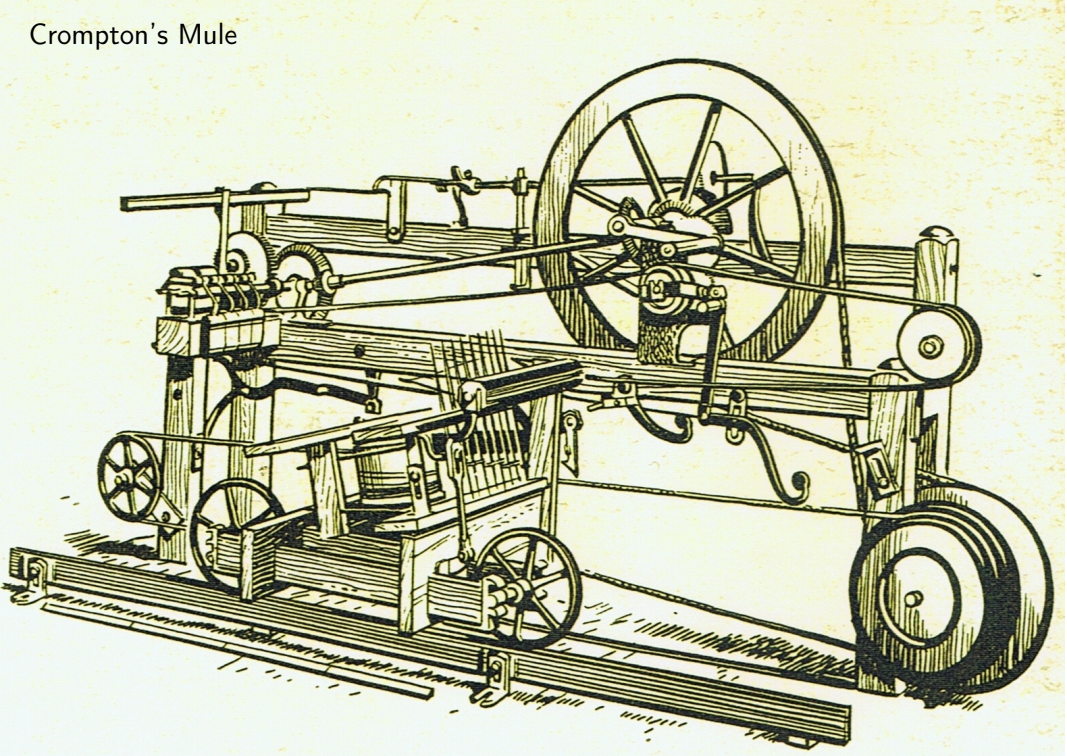
Mokyr (1990, Ch 5)

- 1760–1790: coke replaced charcoal in iron smelting
  - allowed to build bigger and more efficient blast furnaces
- 1784: Cort's puddling furnance
  - improved the process of turnig pig iron (intermediate product from the blast furnaces) into wrought iron ("pured iron")
- 1829: Hot blast
  - reduced fuel requirements by factor of three by using blast furnance's own gases to preheat the air
- These innovations led to high quality and cheap wrough iron
  - almost literally the building block of the Industrial Revolution



Arkwright's Water Frame

Crompton's Mule



Textiles

Mokyr (1990, Ch 5)

- Spinning: the central technical problem in textiles
  - for millenias, human fingers were the operating part
- 1738: Lewis Paul's patents a mechanical spinner
  - using rollers to replace fingers in cotton spinning
- 1769: Richard Arkwright patents the water frame
  - "water frame" because used water power
  - used two pairs of rollers $\rightarrow$ actually worked
  - Arkwright often credited as creating the modern factory system
- 1770: James Hargreaves patents the spinning jenny
- 1779: Samuel Crompton invents the *mule*
  - produced cotton yarn that was cheap, fine, strong
  - made all-cotton clothing possible

Textiles

Mokyr (1990, Ch 5)

- Innovations for preparing raw cotton for spinning
  - 1742: carding machine
  - 1793: cotton gin
- Other textile innovations
  - 1783: metal printing cylinders
  - 1784: bleacing using chlorine
  - 1785: first power loom (a working one around 1815)
- Summary of textiles
  - between 1760–1800 "a feverish wave of inventions focused on the manufactuing of cotton"
  - cotton industry grew in unprecedented pace
  - regarded as the quintessential growth industry of the early stages of the Industrial Revolution

Other innovations

Mokyr (1990, Ch 5)

- High-precision machine tools (UK)
  - vital ingredients for the other innovations
- Chemical industry
  - chlorine bleaching (France, 1789)
  - Leblanc soda (France, 1791)
- Gas lighting: Machester, London in 1807
  (based on earlier inventions made in Germany and France)
- Ceramics and glass: many inventions in the Continent
- Papermaking: continuous sheet machine (France, 1798)
- Flying: Montgolfier brothers' balloon (France, 1783)
  - no impact on production, but huge symbolic importance;
    see e.g Holmes' wonderful "The Age of Wonder" for the story

Why 18th century Britain?

- One of the key questions in economic history
  - why didn't these breakthroughs occur earlier?
  - and why did they take place in Europe, particularly Britain?
- The field remains very active, recent books include:
  - Robert C. Allen's *The British Industrial Revolution in Global Perspective* (2009), Gregory Clark's *A Farewell to Alms: A Brief Economic History of the World* (2007), Jan de Vries's *The Industrious Revolution: Consumer Demand and the Household Economy, 1650 to the Present* (2008), Deirdre McCloskey's *Bourgeois Dignity: Why Economics Can't Explain the Modern World* (2010), Joel Mokyr's *The Enlightened Economy: An Economic History of Britain 1700–1850* (2010), Jan Luiten van Zanden's *The Long Road to the Industrial Revolution* (2009), E. A. Wrigley's *Energy and the English Industrial Revolution* (2010)
- A broad categorization of the explanations:
  1. Ideas (macro-inventions, science, culture)
  2. Incentives (institutions, prices)

Ideas 1: Genius and luck

- Hypothesis
  - radical new ideas (macroinventions) appear "from nowhere"
  - Mokyr (1990): "[macro-inventions] do not seem to obey obvious laws, do not necessarily respond to incentives, and defy most attempts to relate them to exogenous economic variables. Many of them resulted from strokes of genius, luck or serendipity"

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- Criticism
  - why would 18th century Britain have more genius and/or luck than other countries and time-periods?
    - but: maybe Britain just was particularly lucky
  - a substantial R&D period typical for the big inventions
  - many of the inventors appear to have been motivated by profit

Ideas 2: Science

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- Criticism
  - little sign of productivity advance between 1540–1760
    - but: who knows how long it "should" take
  - little evidence of the inventors drawing from scientific results

Ideas 3: Scientific culture

- Hypothesis: "Industrial Enlightenment"
  - scientific, experimental *methods* applied to technology
  - belief that the universe could be apprehended by science
  - idea that science and technology would improve human life
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- Criticism
  - Enlightenment was not a particularly British movement
  - ... and it started about a century "too early"
    - but again: how could we know how long it "should" take
  - inventors were craftsmen with limited formal education

Natural selection

- Hypothesis (Clark 2007, *A Farewell to Alms*)
  - the rich had more children than the poor
  - downward mobility spread "middle-class" culture
  - "[societies were] becoming increasingly *middle class* in their orientations. Thrift, prudence, negotiation, and hard work were becoming values for communities that previously had been spendthrift, impulsive, violent, and leisure loving. A plausible source of this apparent evolution of human preferences is the survival of the richest."

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- Criticism (Allen 2008, *review of Clark 2007 in JEL*)
  - Clark's proposed causal chain is not consistent with the facts
  - established alternative explanations exist for all changes that Clark attributes to natural selection
  - "Instead of being good business managers, the English knights were the most rapacious warriors in Europe"

Incentives 1: Institutions

- Hypothesis
  - the institutional structure following the Glorious Revolution of 1688 made the Industrial Revolution possible
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- Criticism
  - timing: the Glorious Revolution took place eight decades before the start of the Industrial Revolution
    - yet again: we really don't know how long it should take
  - insecurity of property prior to 1688 contestable
  - ... and many other countries also had secure property rights
  - patents were costly, sometimes had counterproductive effects

Institutions: a closer look

- 16th and 17th century Britain characterized by
  - power strugle between the Monarch and the Parliament
  - monopolies (granted to the supporters of the Crown)
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- Another example (from Mokyr, 1990)
  - machine breaking and riots during the Industrial Revolution
  - 1769: machine breaking made capital crime
  - 1811–13: 12,000 men deployed to suppress the Luddite riots
  - i.e. the institutional response had changed dramatically

Incentives 2: Prices

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- Next: a closer look at stylized facts:
  - British wages were higher than those of its competitors
  - high wages translated into higher living standards
  - wages were high relative to capital prices
  - ... and relative to energy prices (in some British areas)

Data

Allen (2006, 2009)

- Database combining hundreds of price histories
  - typically based on the archives of an institution that lasted for hundres of years (e.g. colleges, hospitals)
  - records of quantities and prices of everything bought or sold
  - typical items: agricultural and food stuffs, cloth, fuel, candles, building materials, implements, wages, salaries
- Tables of the annual averages available now for many cities
  - while many gaps remain, these data make international comparisons possible and redefine our understanding of economic history (see a data archieve here)

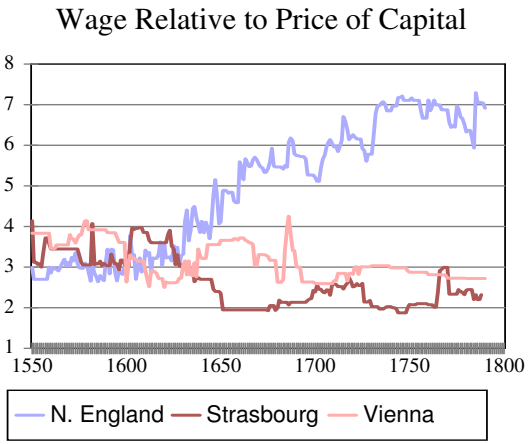
Nominal wages

Allen (2006, 2009)

Nominal wages for building workers were very similar in the European cities during the Middle Ages. In 1550– 1620, wages in eastern Europe remained stagnant, while they rose in western Europe. Thereafter, there was a three way split with silver wages falling in southern Europe, levelling out in the Low Countries, and continuing to rise in London.

Price of labor vs. capital

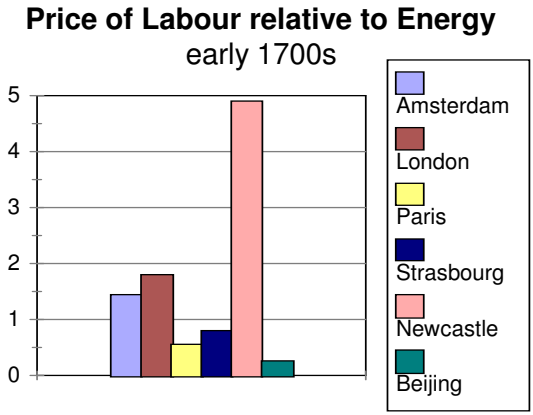
Allen (2006, 2009)



The ratio of a building labourer's daily wage relative to an index of the rental price of capital (average of price indices for iron, nonferrous metals, wood, and brick multiplied by an interest rate plus a depreciation rate). Strasbourg and Vienna chosen since long data series are available, and their data look comparable to those of most of Europe apart from the Low Countries. The series are 'PPP adjusted' so that we can compare across space as well as over time.

Price of labor vs. energy

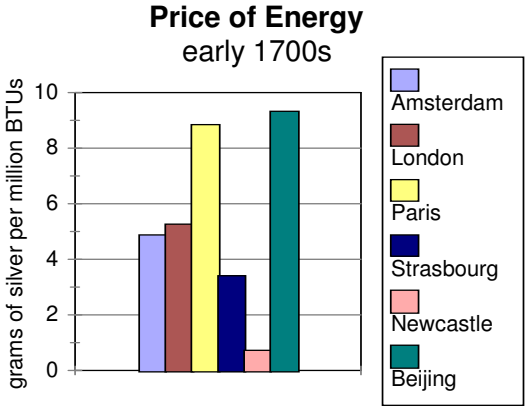
Allen (2006, 2009)



Ratio of the building wage rate to the price of energy in the early eighteenth century in important cities in Europe and Asia. In this ratio, the price of a kilogram of fuel was divided by its energy content, so energy prices are expressed as grams of silver per million BTUs. The ratio is calculated for the cheapest fuel available in each city–coal in London and Newcastle, peat in Amsterdam, charcoal or fire wood in the other cities.

Energy prices

Allen (2006, 2009)



London did not have particularly cheap fuel at that time; Newcastle, however, did. The difference in the energy price between the two cities equals the cost of shipping the coal from the Tyne to the Thames. Coal prices at other cities in northern and western Britain were similar to those in Newcastle–at least once canal improvements brought down internal shipping costs. Except perhaps for southern Belgium, no region anywhere in the world had the same combination of large population and cheap energy. Belgian coal output, however, was only 3% of Britain's in 1800.

Why were British wages and prices unique?

Allen (2006, 2009)

- Geography
  - Britain had vast and readily worked coal deposits
  - inexpensive coal raised wage/energy price ratio
  - ... and reduced the price of capital (production of metals and bricks)

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- International trade
  - late 16th-century: 'new draperies' made in East Anglia and exported to the Mediterranean through London
  - 17th century onwards: imperialism
  - 1500–1800: population living in cities/town 7% $\rightarrow$ 29%, agriculture labor force share 75% $\rightarrow$ 35%

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- Interaction between geography and trade
  - 16th century: London's population exploded
    $\rightarrow$ demand for fuel increased
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  - the Duch cities were also growing, close to vast coal deposits
  - Duch peat initially used to meet growing energy demand
    $\rightarrow$ transport on the Ruhr not improved
  - once industry established in Newcastle, coal could be delivered as cheaply to Amsterdam and London

Why did international price differences matter?

Allen (2006, 2009)

- Product innovations
  - trade with Asia brought new products to Britain
    (cotton fabrics, Chinese porcelain, coffee, tea)
  - Britain's high wages $\rightarrow$ a broad market for these products
    $\rightarrow$ British manufacturers started to produce cotton, porcelain...
  - Industrial revolution was largely import substitution

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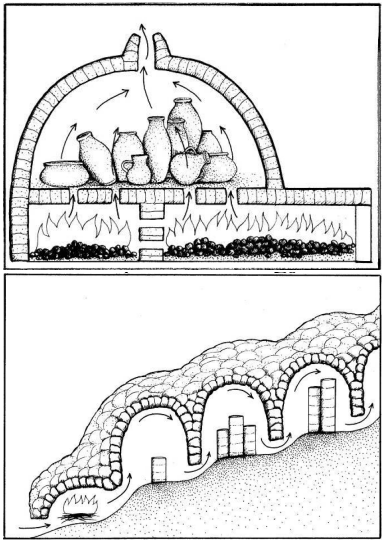
  - Industrial revolution was largely import substitution
- Process innovations
  - British inventions were labour saving, energy/capital intensive
  - thus these inventions were adopted in Britain and not on the (low wage, costly energy) continent
  - the necessary R&D behind the invention was profitable under British conditions but unprofitable elsewhere
  - new technology was being improved and once it was sufficiently effective, it spread across the continent

Example: English and Chinese kilns

Allen (2009)



In Britain, pottery was fired in round, up-draft kilns (top picture). These were cheap to build but did not use energy efficiently (much heat escaped from the holes in the top).

In China, kilns were designed to conserve energy. A common design was the 'down-draft climbing kiln' build in hill slopes (bottom picture).

That is, the Chinese *were* inventive, but they invented tecnologies that were optimal for their factor prices

Industrial Revolution: summary

- Technology shifted the supply curves
  - prices decreased (e.g. cotton price decline by 85% between 1780–1850)
  - completely new goods were created
  - the quality of many old goods greatly improved

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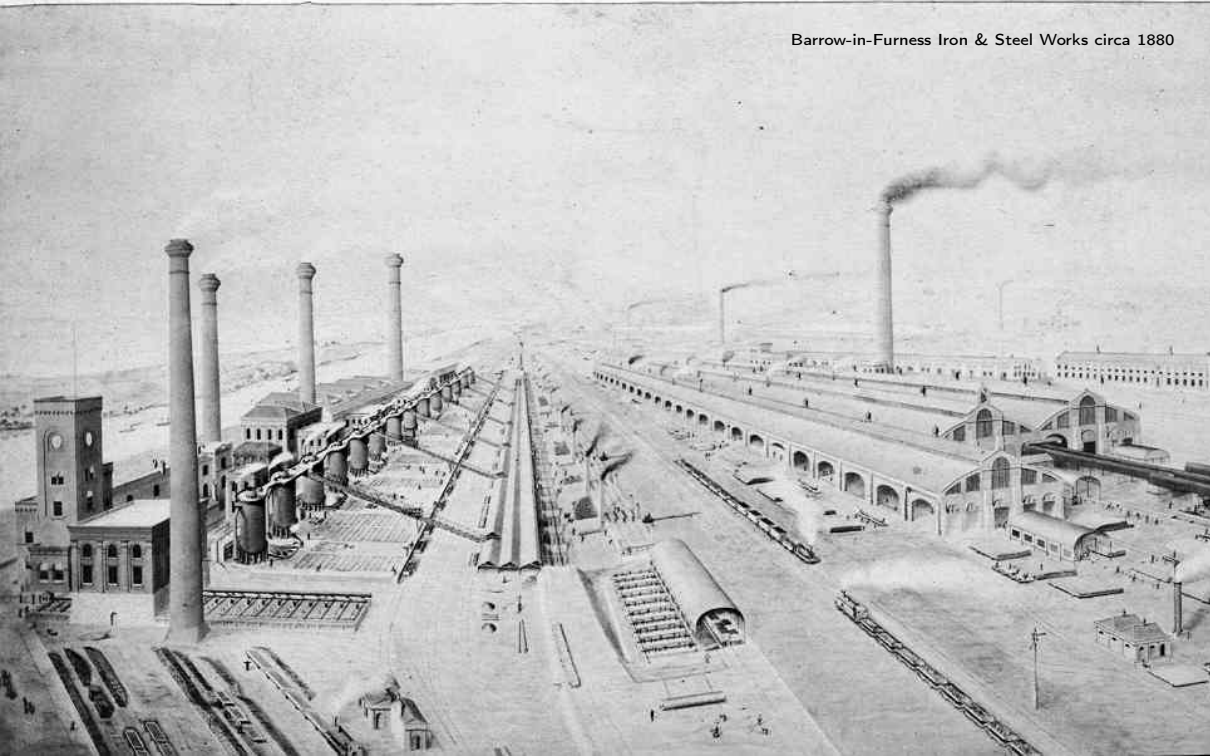
- Technology shifted the supply curves
  - prices decreased (e.g. cotton price decline by 85% between 1780–1850)
  - completely new goods were created
  - the quality of many old goods greatly improved
- Why did it happen in 18th century Britain?
  - many alternative explanations
  - not necessarily mutually exclusive
  - hard to test, but can examine consistency with data
- Next: very brief overview on the "Second Industrial Revolution"



Barrow-in-Furness Iron & Steel Works circa 1880

The "Second Industrial Revolution": 1830–1914

Mokyr (1990, Ch 6)

- The growth industries of the later 19th century
  - steel, chemicals, electricity, transportation
- Science starts to become more important for technology
  - purely empirical breaktroughs do not decline, only their share
- The factory system emerges
  - rare still in 1870, but then becomes more pronounced
  - fixed costs, spillovers, network technologies, interchangeble parts, new products (e.g. railroads, chemical industries) give rise to larger increasing returns

The "Second Industrial Revolution": 1830–1914

Mokyr (1990, Ch 6)

- Technological systems and networks
  - before 1850, technology largely isolated chunks of knowledge (apart from the need of high-quality components)
  - new innovations: railroads, electricity, telegraph, telephone, water supply systems, need to supply standardized spare parts
- Market create impressive sets of universal standard
  - but the world is also split into 110V vs. 220V electrical current, left-side and right-side drivers, narrow and broad gauge rails...
- So many facinating and important things to study, but we are hitting our time constaints...

Papers for essays

- Pascali (2017): The Wind of Change: Maritime Technology, Trade, and Economic Development. AER 107(9): 2821-54.
  - examines the impact of the introduction of the steamship on international trade. Finds a major impact on patterns of trade that benefited a small number of countries characterized by more inclusive institutions.
- Donaldson (2018): Railroads of the Raj: Estimating the Impact of Transportation Infrastructure. AER 108(4): 899-934
  - uses archival data from colonial India to investigate the impact of India's vast railroad network. Finds that railroads increased trade and real income.