Academic year 2023 – 2024

Research, Innovation and Global Trends

Knowledge and learning: Patterns of innovative activity

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Masters in Innovation and Research for Sustainability

A cognitive perspective

Dynamics of technology and industries

1. Knowledge

    types of knowledge

2. Learning

    types of learning

3. Technological change

    trajectories

4. Industrial dynamics

    patterns

Critical insight:

Understanding the knowledge and economic sectors.

- 1. Knowledge

1. The cognitive dimension

Economically relevant assets and activities

- **Knowledge** as a *stock* variable
- **Learning** as a *flow* variable

Many times we come accross these expressions:

- Know what;
- Know how;
- Know why;
- Know who...

1. The cognitive dimension

Codified knowledge

Tacit knowledge

1. The cognitive dimension

Codified knowledge
(*explicit*)

Knowledge that is, or can, be written or represented in a way that allows it to be understood by others and reproduced.

(like a chemical formula of a medicine)

Tacit knowledge
(*implicit*)

Knowledge that is a collection of judgments and trained intuitions acquired throughout processes that cannot codify or which translation is too difficult or expensive.

(like the refined habits of experienced professionals)

1. The cognitive dimension

Embodied knowledge

Disembodied knowledge

machines

R&D

- 2. Learning

2. Learning

Innovation as learning

- Learning a is a process of **knowledge accumulation**
- Economic analysis links to this to improvements in performance over time
- Learning takes place at the **individual and colective** levels

Learning and Knowledge in firms:

- **Resources** are tangible and intangible assets (like infrastructures or human capital)
- **Routines** are the regular operations procedures that contain knowledge
- **Competencies** (or capabilities) are combinations of routines that solve problems
- **Dynamic capabilities** is the ability to reconfigure capabilities in changing environments

2. Varieties of learning

Learning

- Not knowing
- Searching
- Doing
- Using
- Interacting

2. Varieties of learning

Learning without knowing

Somes things are not invented, they evolve. Serendipity plays a part.

Source Diamond, J. (1998), *Guns, Germs and Steel: A Short History of Everybody for the Last 13,000 Years*, London: Vintage.

2. Varieties of learning

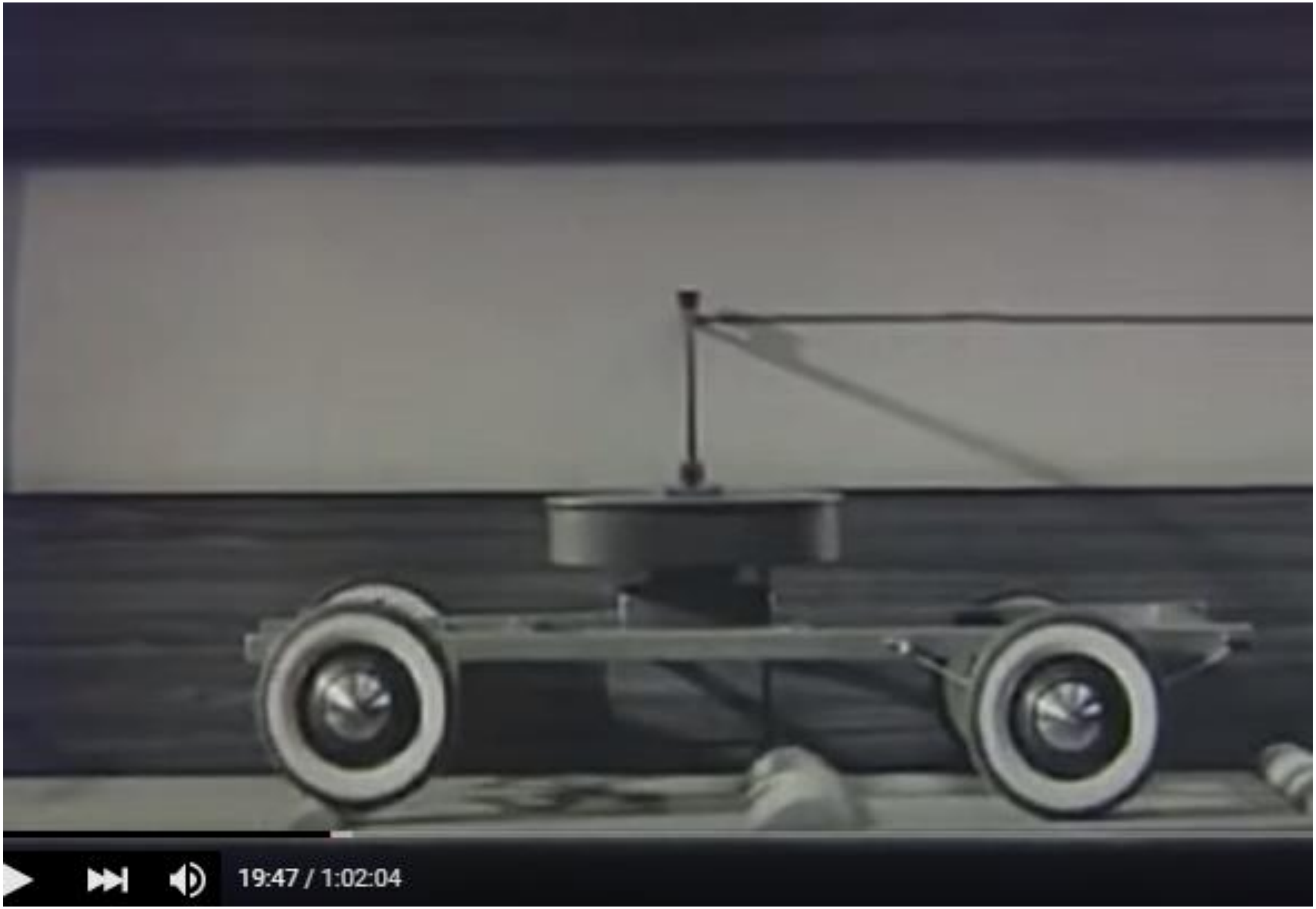
Learning-by-searching

R&D is a purposive and deliberative process, it is a formal and systematic activity

It is a rational investment in the search for new knowledge

Note 1: R&D and other forms of knowledge aquisition are complementary.

Note 2: Independent execution of R&D it is the best way to learn about what other learners are doing … so, imitation is expensive! It requires building absorbtive capacity



http://bit.ly/1raNs5x

2. Varieties of learning

Learning-by-doing

Cost declines and productive increases over time

Happens by *trial and error*.

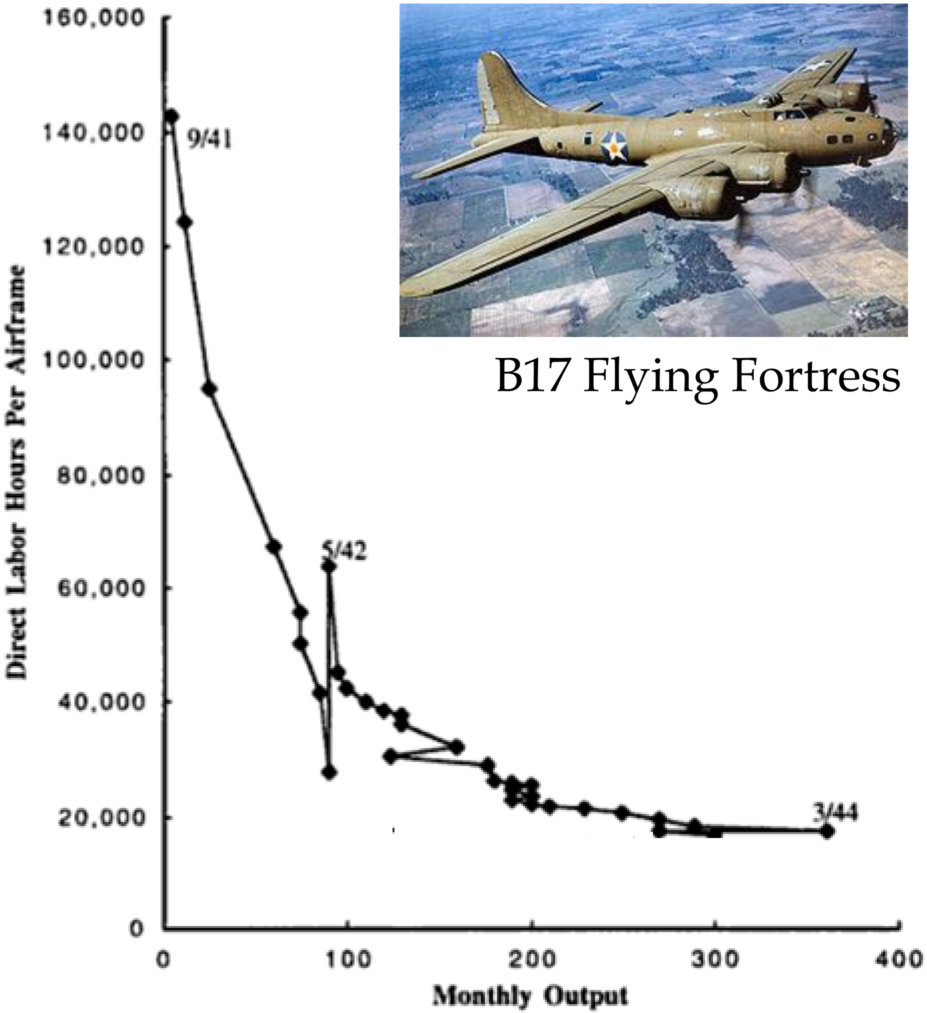
A *by-product* of production.

A sort of *informal* "R&D".

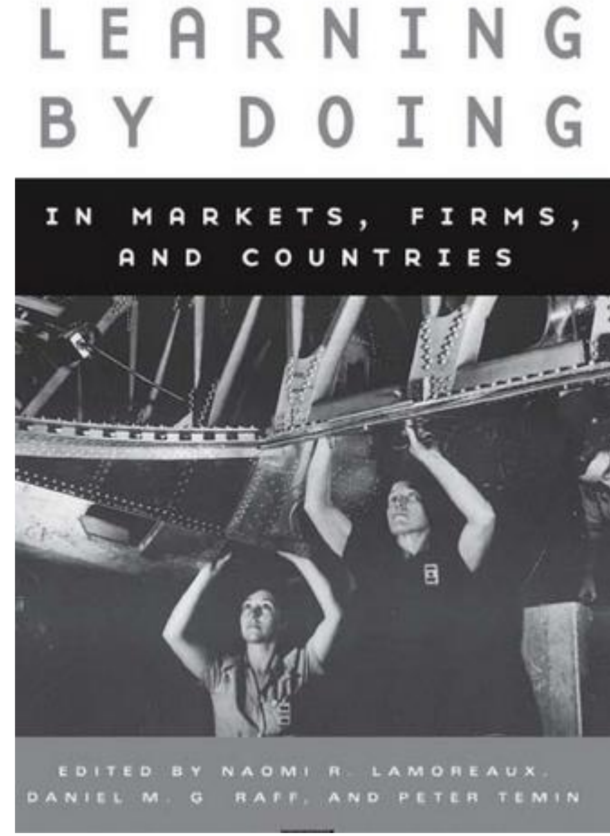
As a function of cumulative output, it is a source of <u>dynamic economics of scale</u>

Three aspects:

"Learning"	–	the process
"Experience"	–	the cause
"Progress"	–	the outcome



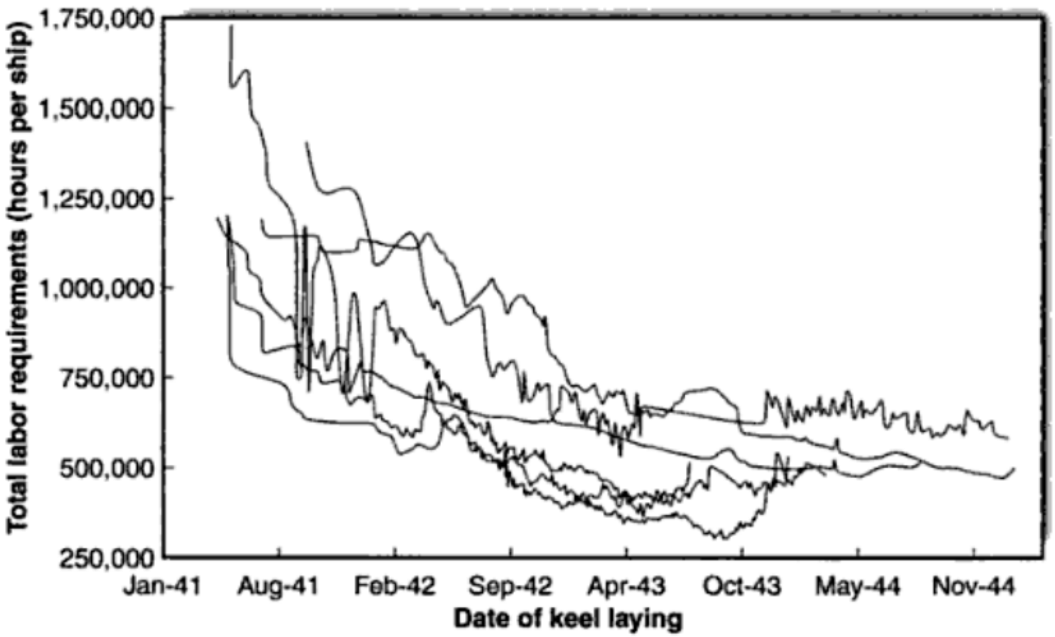
B17 Flying Fortress



Source: adapted from

Mishina, K. (1999), "Learning by new experiences: Revisiting the Flying Fortress learning curve", in N.R. Lamoreaux, D. Raff, and P. Temin (eds), *Learning by Doing in Markets, Firms, and Countries*, University of Chicago Press, pp. 145-84.

“Liberty Ships”,
produtividade dos estaleiros

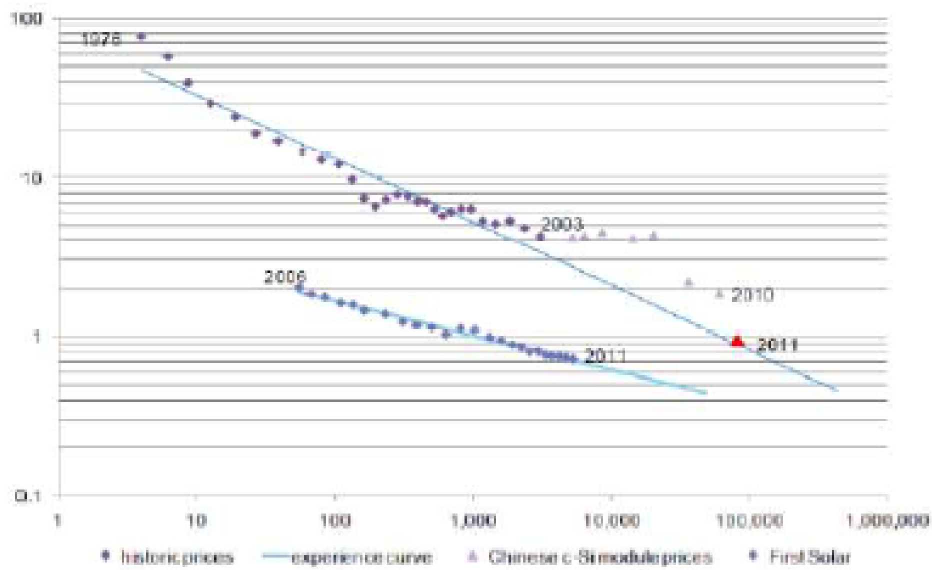


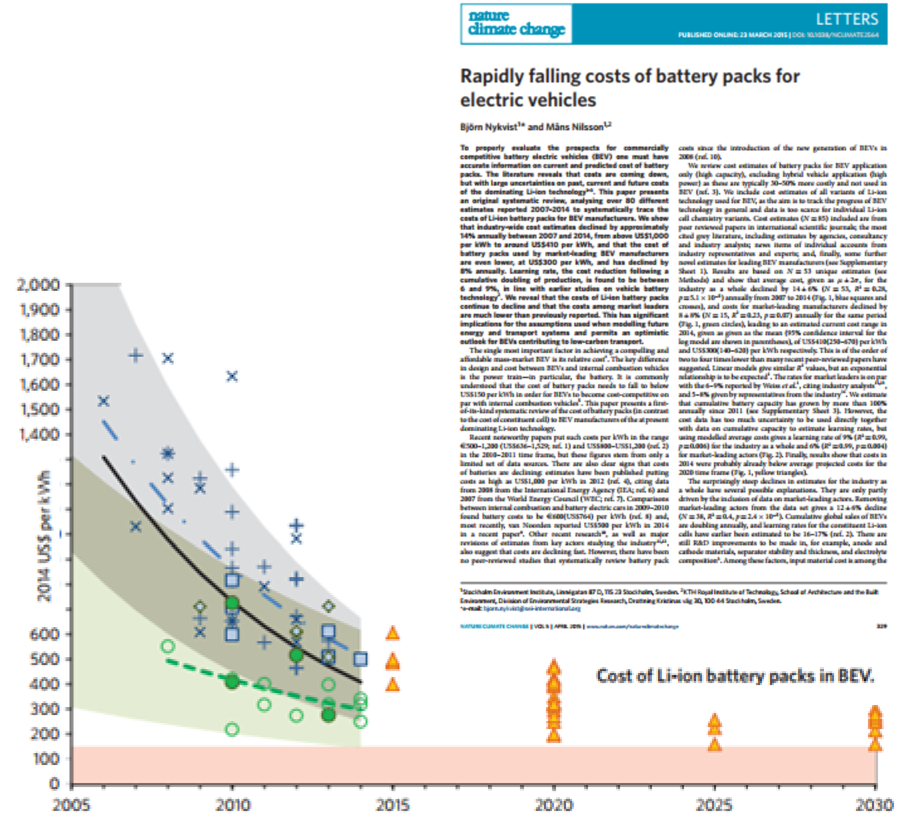
Standard Liberty ships labor productivity, six yards.

S.S. *Jeremiah O'Brien*

Source: Thompson, P. (2001), “How much did the Liberty shipbuilders learn? New evidence for an old case study”, in Daniel F. Spulber, (ed.), *Famous Fables of Economics*, Basil Blackwell, pp. 262-92.

Photovoltaic module experience curve, 1976-2011





Source: Mathews, J. (2013), "Greening of development strategies", *Seoul Journal of Economics*, Vol. 26, No.2, p. 154

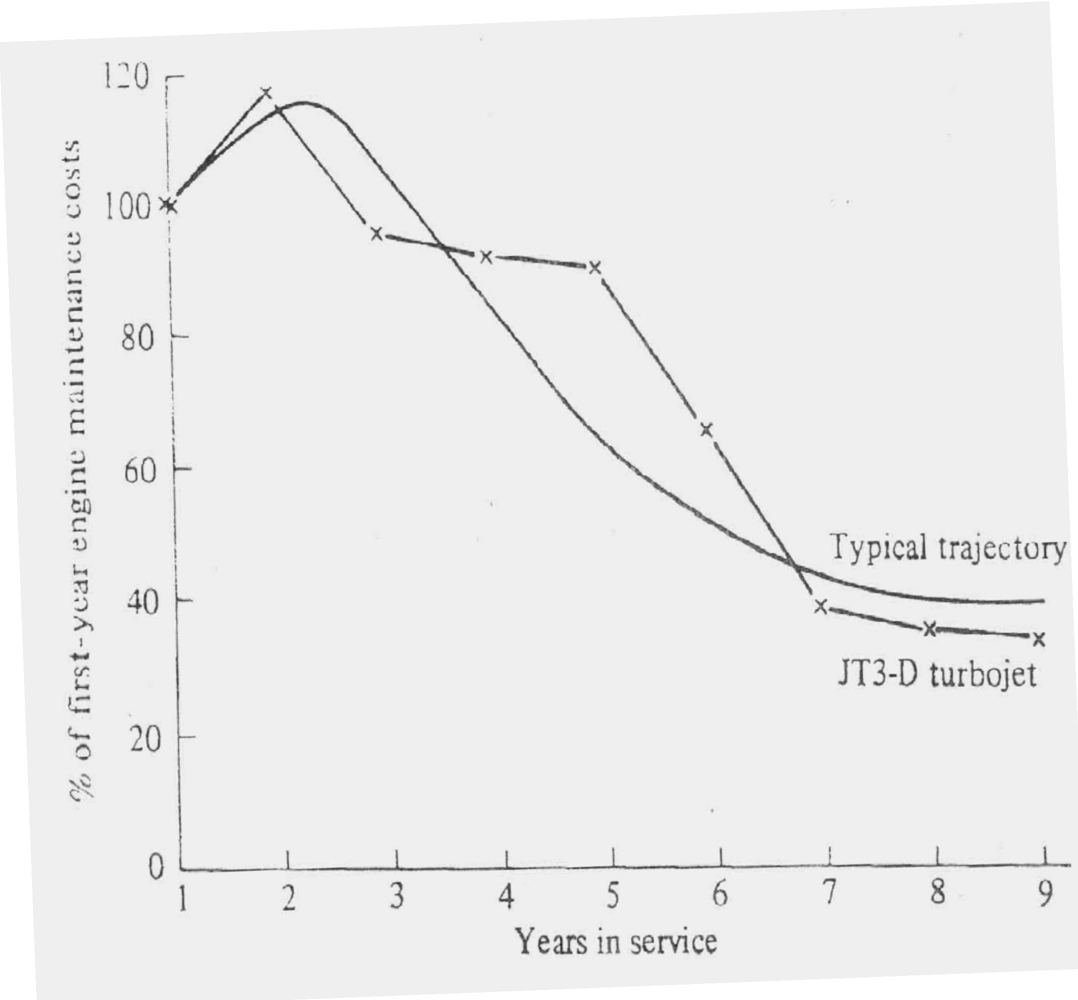
2. Varieties of learning

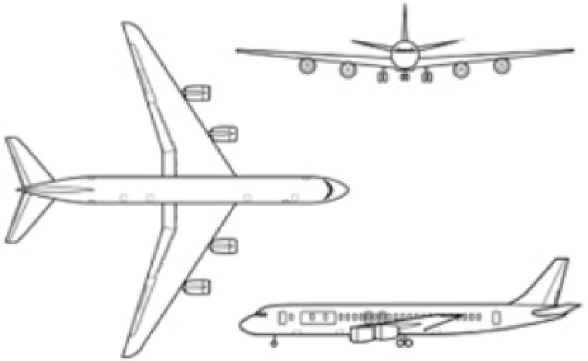
Learning-by-using

Learning-by-doing (l-b-d) starts while in production, i.e. after the formal learning in R&D

Learning-by-using (l-b-u) starts after production, i.e. when the equipaments are actually put to use

DC-8





Source: Rosenberg, N. (1982), *Inside the Black Box: Technology and Economics*, Cambridge University Press.

Wash & Go

What? Engine Water Wash
Invented by? KLM
When? 2000

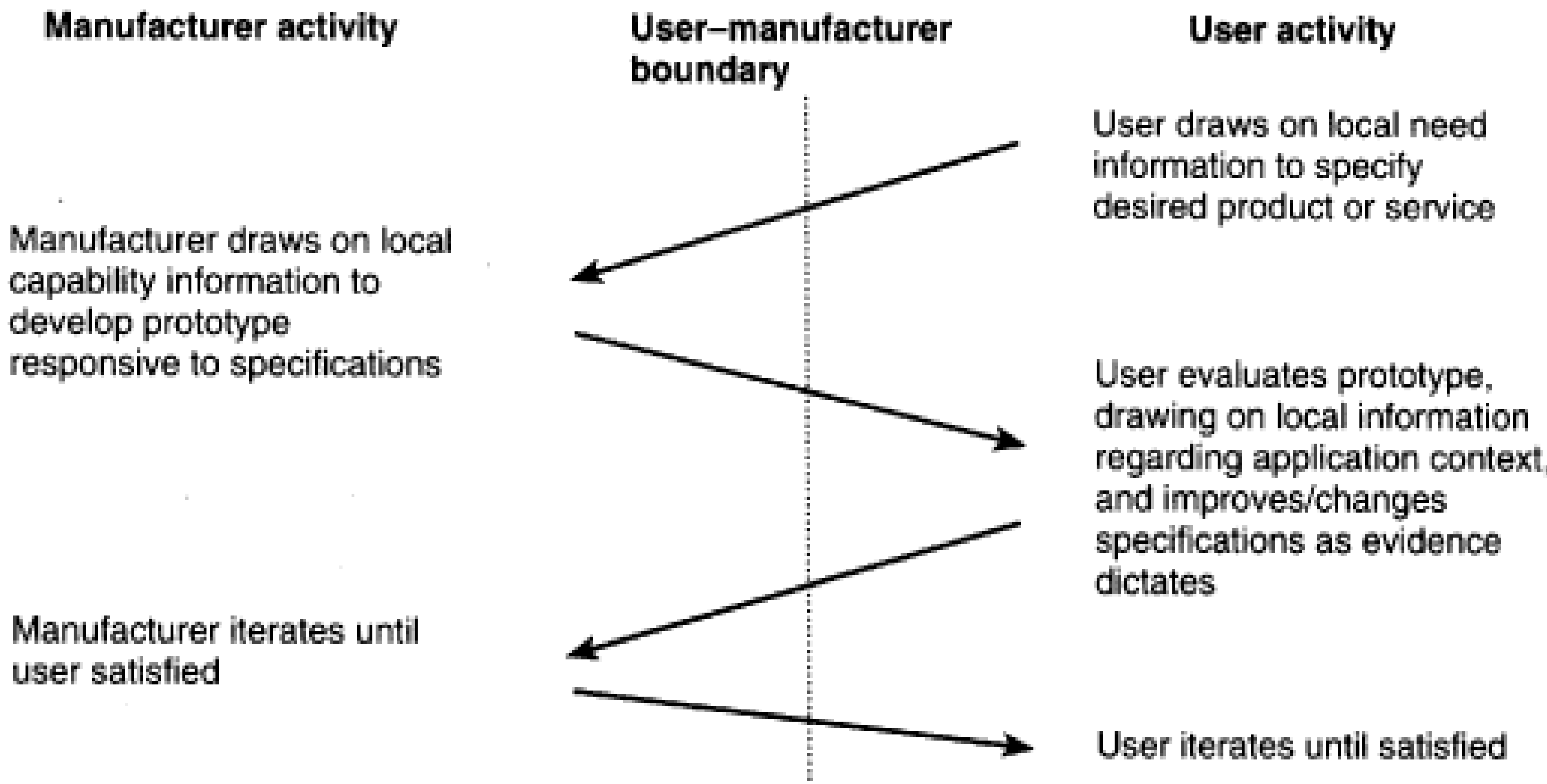
KLM, as many operators, used to clean the plane engines outside the hangar; there was no room and system to collect the dirty water indoors. It took a lot of additional time, personnel and equipment to move the planes. A special KLM work group decided to adjust the existing water wash system of British company AT Juniper. The fleet can now stay indoors, as the dirty water is collected in long tubes and used for recycling. This saves additional fuel, engine power and time, and reduces CO2 emissions.

2. Varieties of learning

Interactive learning

- Producers learn
- Users learn
- They *co-adjust* in real time but also establish enduring *relationships*
- Learning is continuous and cumulative, iterative and interactive process

Exchanges and linkaged between users and producers



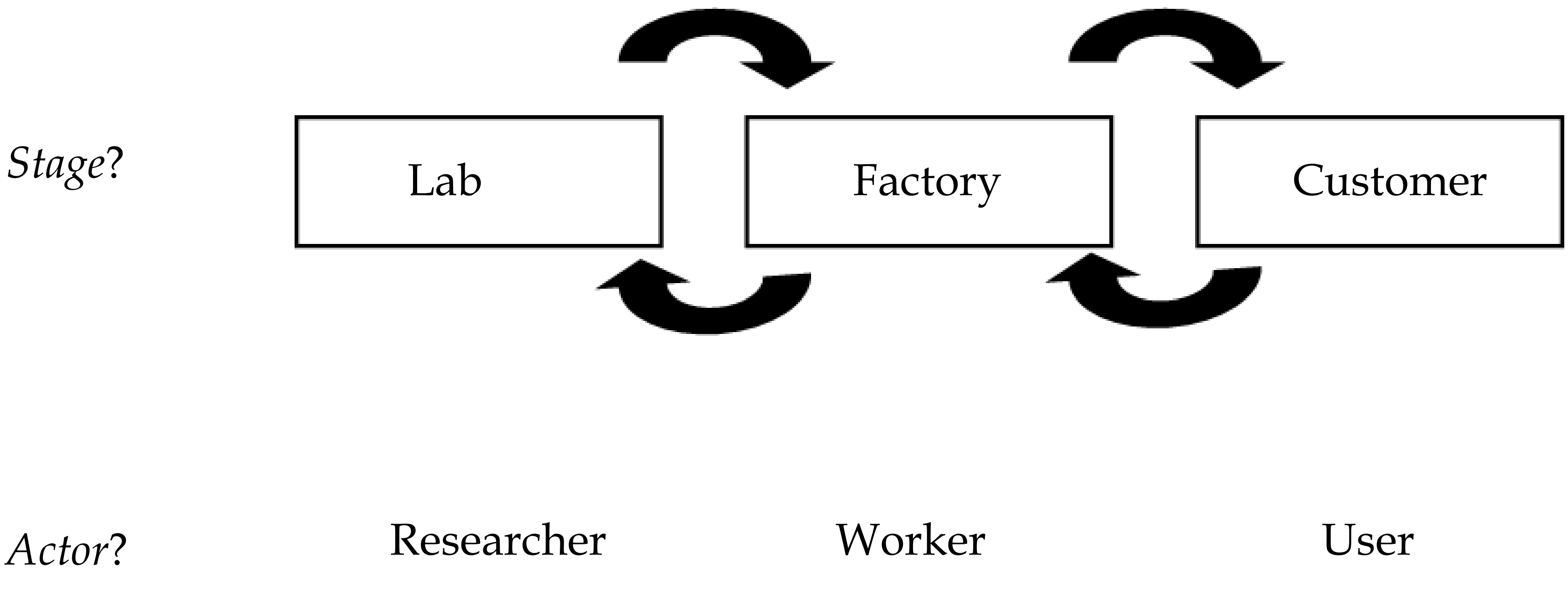
Inter-actor tecno-economic problem solving

Fonte: von Hippel, E. (1998), "'Sticky information' and the locus of problem solving: implications for innovation", in A.D. Chandler, Jr., P. Hagström and Ö. Sölvell (eds), *The Dynamic Firm: The Role of Technology, Strategy, Organization and Regions*, New York: OUP, pp. 60-79.

So…

“STI” (science, technology and innovation) vs “DUI” (doing, using, interaction)

Learning is a mix of learning modes



- 3. Pathways of innovation

3. Pathways of innovation

Forces governing the evolution of innovation

A debate: *Technology Push* Vs *Demand Pull*

- Technological developments occur first and determine the process of economic development ***or*** market demand is the driver an technology adapts to socio-economic conditions?
- That is to say, does innovation depars from the R&D lab ***or*** from the marketing department?

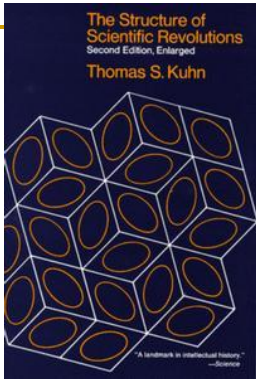
Na verdade trata-se de:

- Abstract intelectual stimulus Vs Users needing solution … Jacob Schmookler

- Combining the two ideias… Nathan Rosenberg, Giovanni Dosi

3. Pathways of innovation

Analogy to Kuhn



Patterns of innovation

- "…a '**technological paradigm**' [is a] 'model' and a 'pattern' of solution of *selected* technological problems, based on *selected* principles derived from natural sciences and on *selected* material technologies" (Dosi, 1982)

- "A **technological paradigm** is both an *exemplar* – an artifact that is to be developed and improved (such a car, an integrated circuit, a lathe, each with particular techno-economic characteristics) – and a *set of heuristics*…" (Dosi, 1988)

See Dosi (1982): https://www.sciencedirect.com/science/article/abs/pii/0048733382900166

3. Pathways of innovation

Heuristics

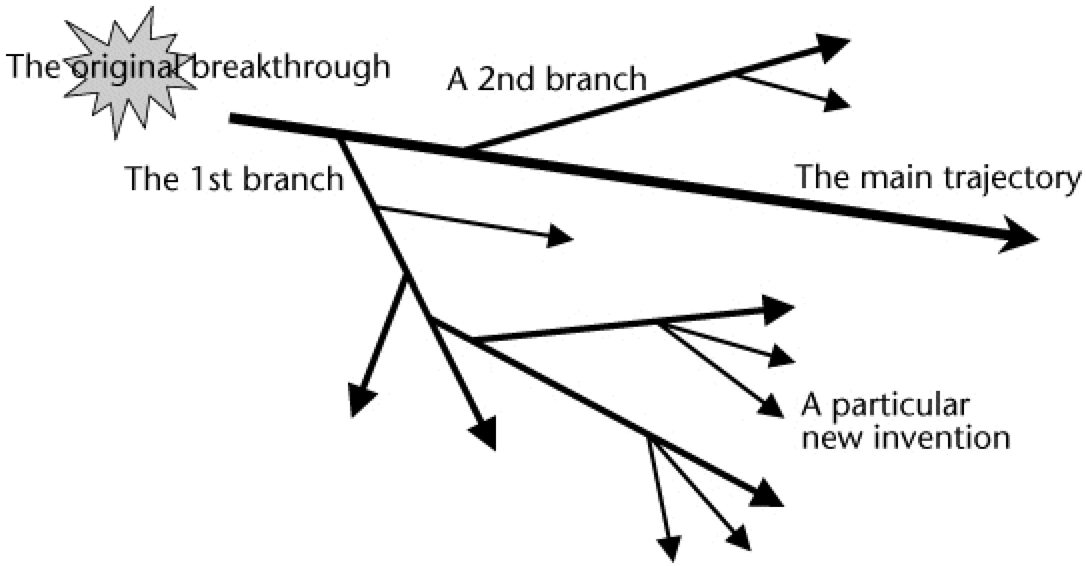
- "More precisely, if the hypothesis of technological paradigm is to be of some use, one must be able to assess also in the field of technology the existence of something similar to a "positive heuristic" and a "negative heuristic". In other words a technological paradigm embodies strong PRESCRIPTIONS ON THE DIRECTIONS OF TECHNOLOGICAL CHANGE TO PURSUE AND THOSE TO NEGLECT. " (Dosi, 1982)

Technological trajectories

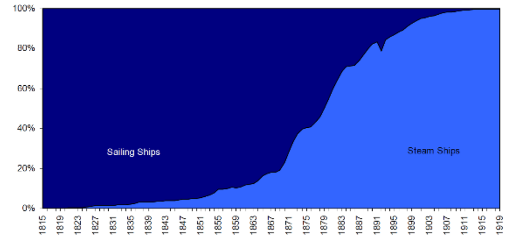
- "We will define a technological trajectory as the pattern of 'normal' problem solving activity on the ground of a technological paradigm." (Dosi, 1982)

- "A technological trajectory… can be represented by the movement of multi-dimensional trade-offs among the technological variables which the paradigm defines as relevant. Progress can be defined as the improvement of these trade-offs." (Dosi, 1982)

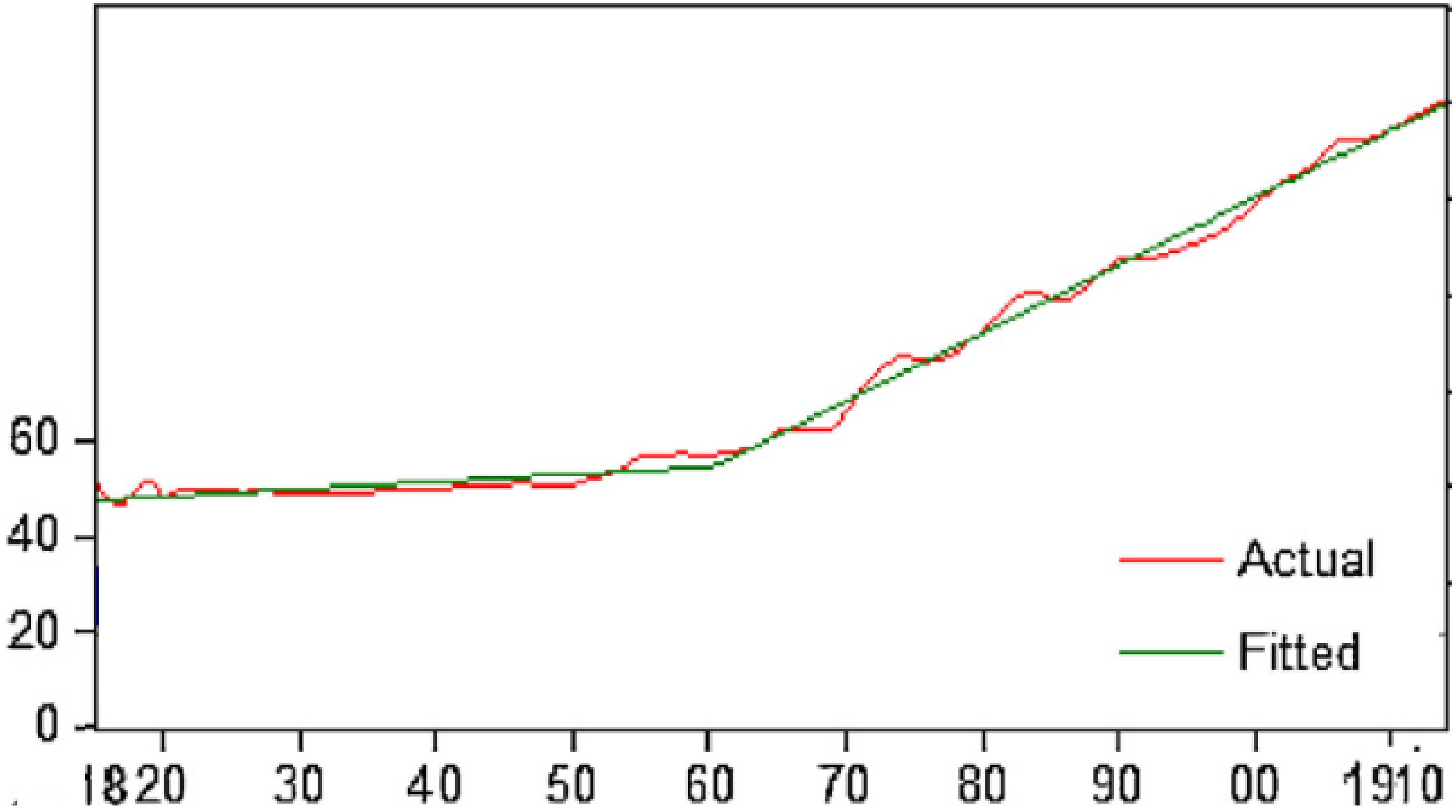
Evolutionary drift



This is very nice BUT… Show us an example!!



Average tonnage
Sail vs Steam
(1814-1914)



Source: Mendonça (2013)

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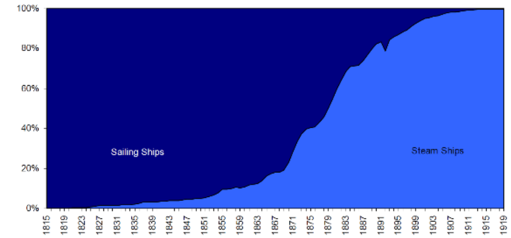

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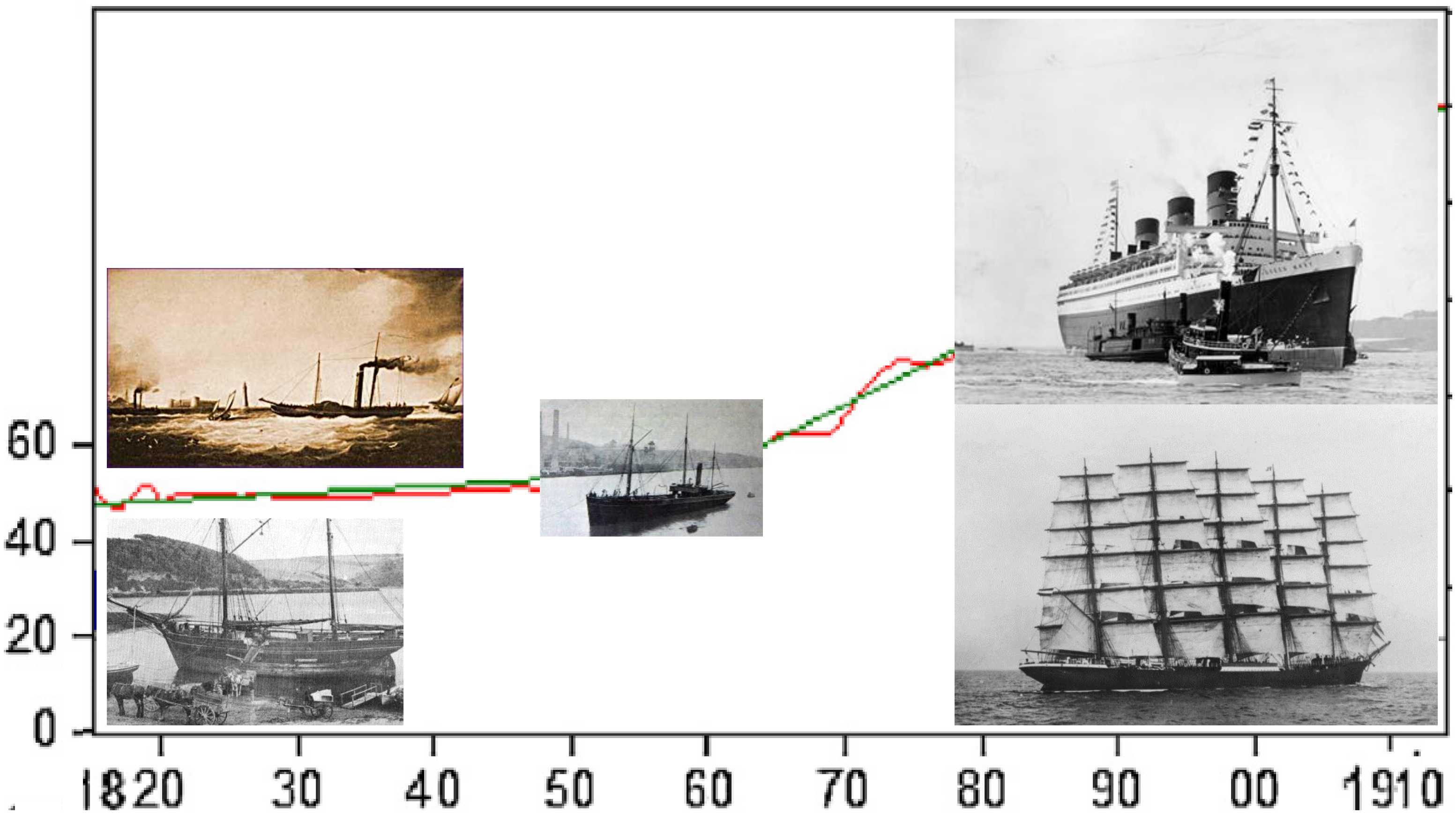

Source: Mendonça (2013)

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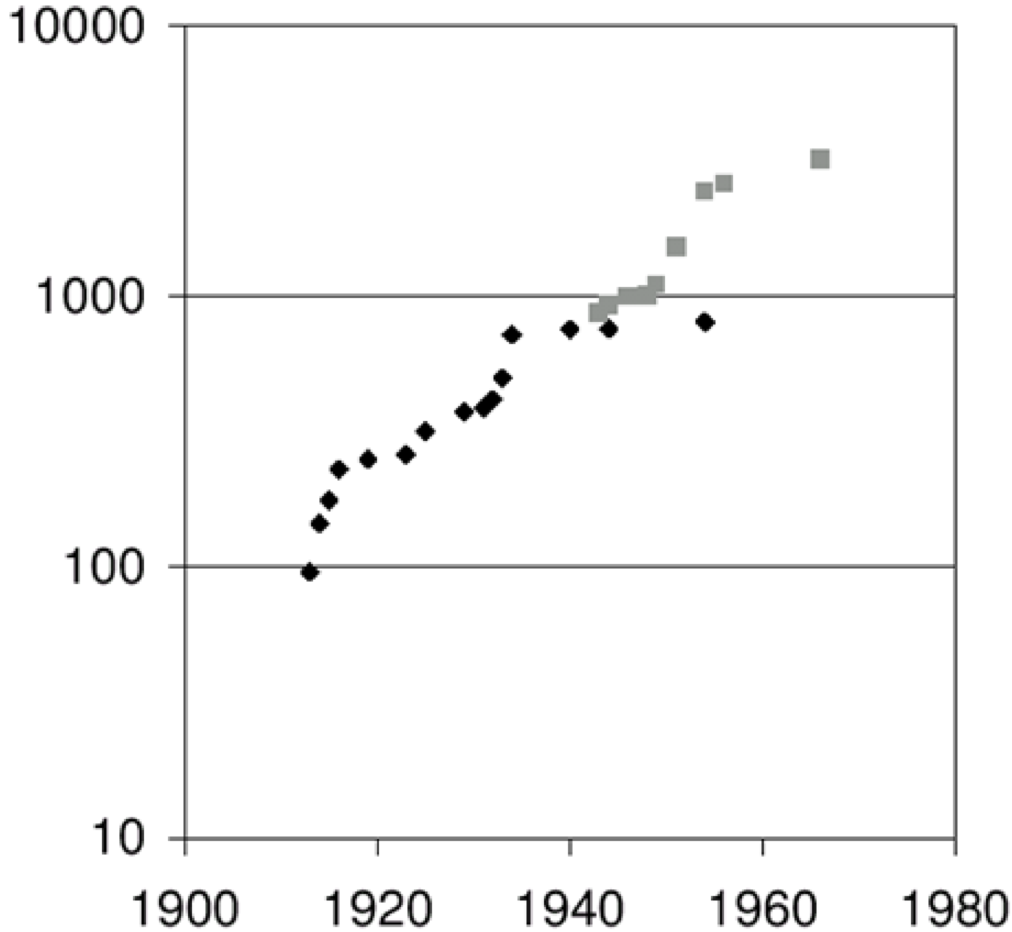
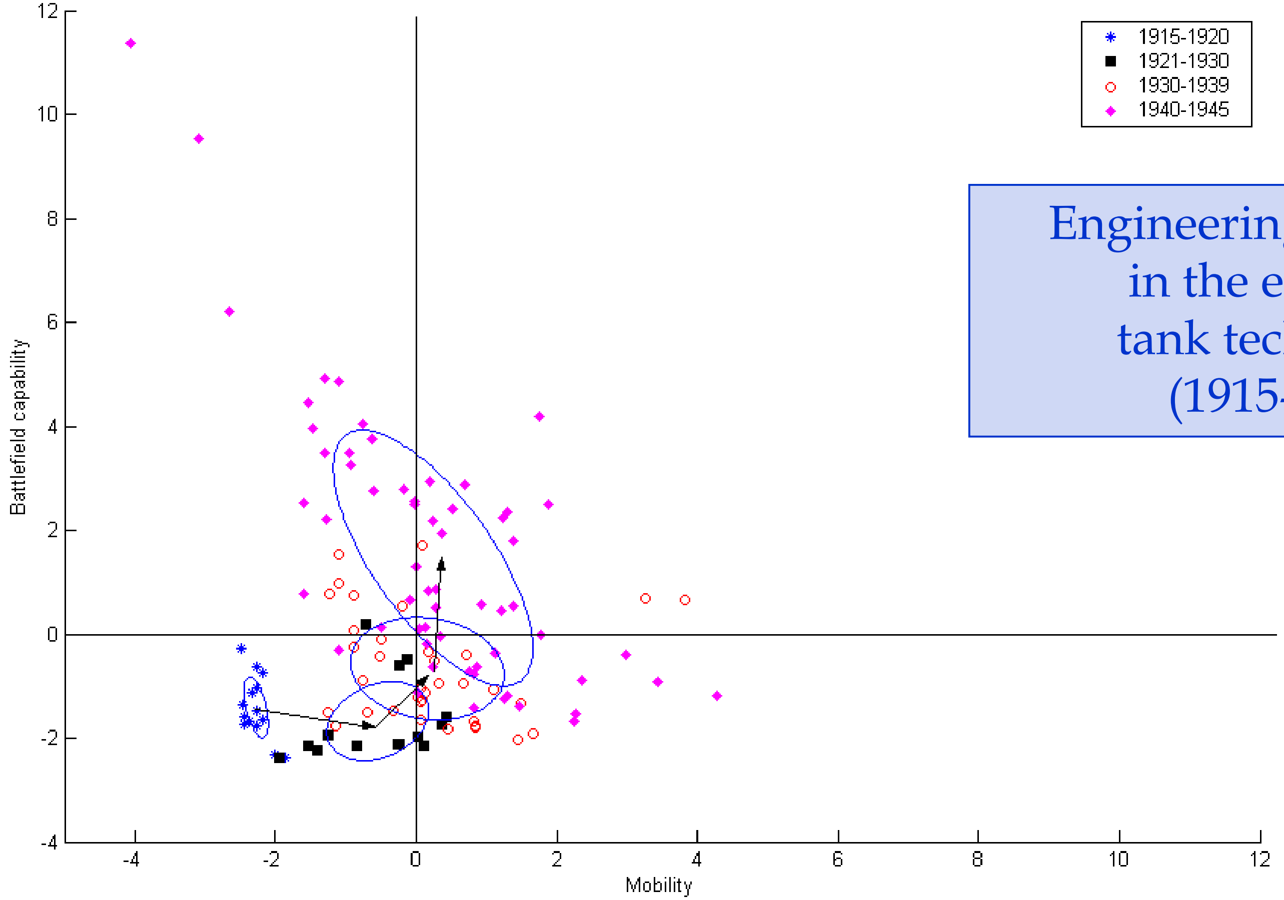


Maximum speed in km/h of propeller aircraft (diamonds) and jet aircraft (squares).

Source: Frenken (2005)

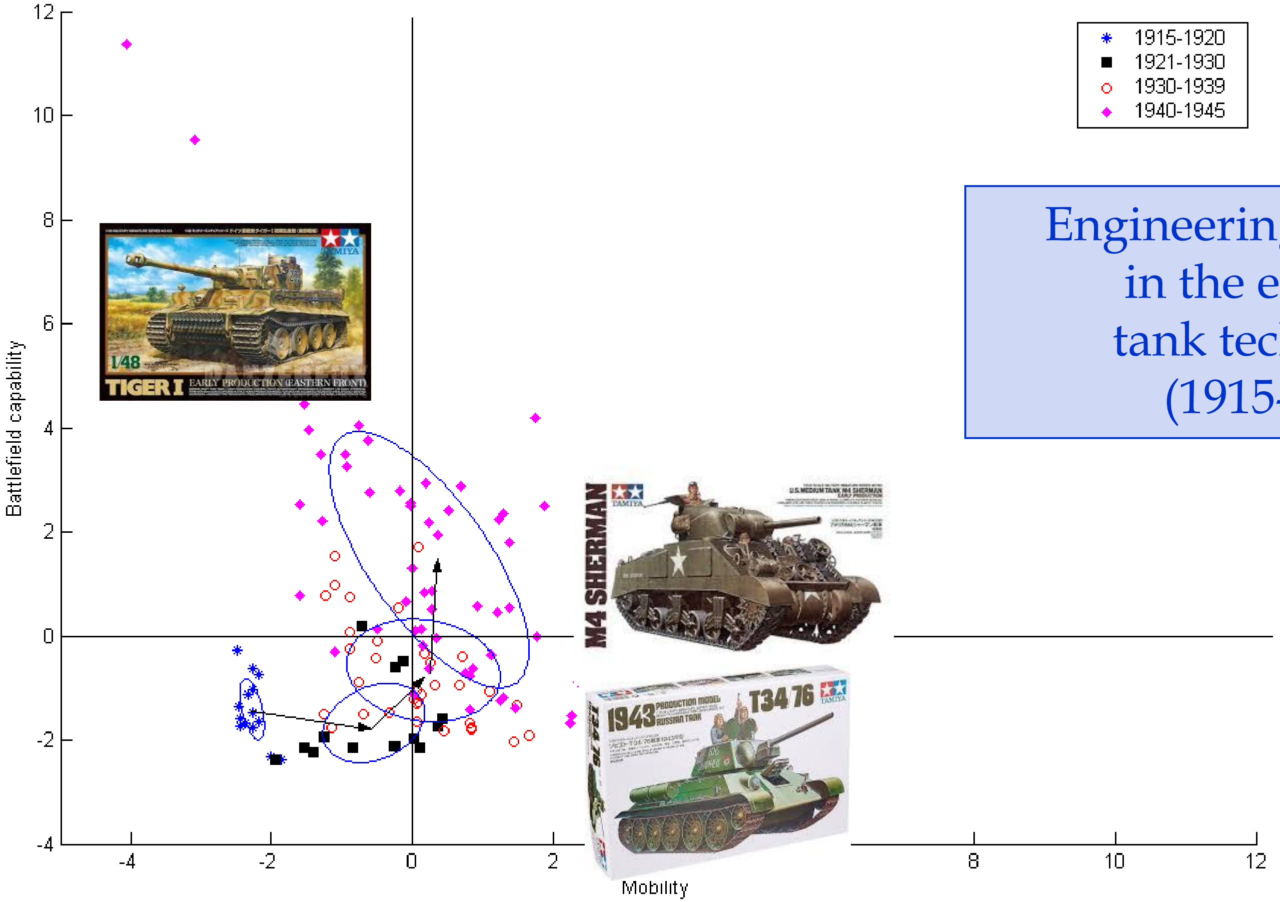
This is very nice BUT… Show us an example!!



Engineering trade-offs in the evolution of tank technology (1915-1945)

Source: Castaldi et al. (2005)

This is very nice BUT… Show us an example!!



Engineering trade-offs in the evolution of tank technology (1915-1945)

Source: Castaldi et al. (2005)

3. Pathways of innovation

Properties of technological trajectories

- Locality: variations on existing directions
- Cumulativity: progress depends of previous attainments
- Irreversibility: a given trajectory tends to overwhelm alternatives

…

Trajectories are driven by “autonomous drifts” and “compulsive sequences”: the internal logic of the technology (“solving the “inbalances”)

Trajectories do run into dead ends, and paradigm-shifts do happen

- 4. Industry structures

4. Industrial dynamics

From technological trajectories to industrial dynamics

There is persistent and significant intra- and inter-sectoral diversity in the organization of markets and in the behaviour and performance of agents.

Analytical frameworks to understand "stylised facts" (i.e. empirical regularities):

- Industry lifecycles
- Technology regimes

4. Industrial dynamics

Where is economic initiative comming from?

Entrepreneurs

- Those people who try (not always succeed) to generate value through the creation or expansion of economic activity, through the identification and exploration of new proposals and businesses

Intrapreneurs

- Launching attempts from within, sometimes comiting voluntary "cannibalism" or diverting attention from the organization's official agenda.

Source: OCDE (2009), *Measuring Entrepreneurship A Collection of Indicators*, 2009 Edition, OECD-Eurostat Entrepreneurship Indicators Programme, p. 6

4. Industrial dynamics

Product life-cycle and market change: example

0. Pre-initiative
– R&D, marketing plan, investiment

1. Product launch
– high production costs, few firms

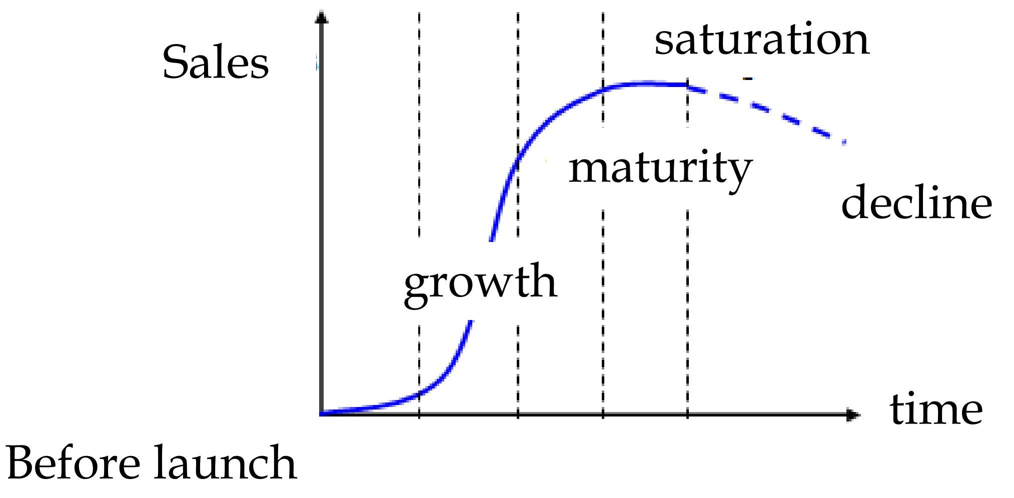
2. Going exponential
– price declines with (average) production cost, competition increases

3. Maturity
– competitive pressures intensify, mergers & acquisitions

4. Saturation
– total sales stagnate, competition drops

5. Decline
– exits, consolidation, few players

4. Industrial dynamics

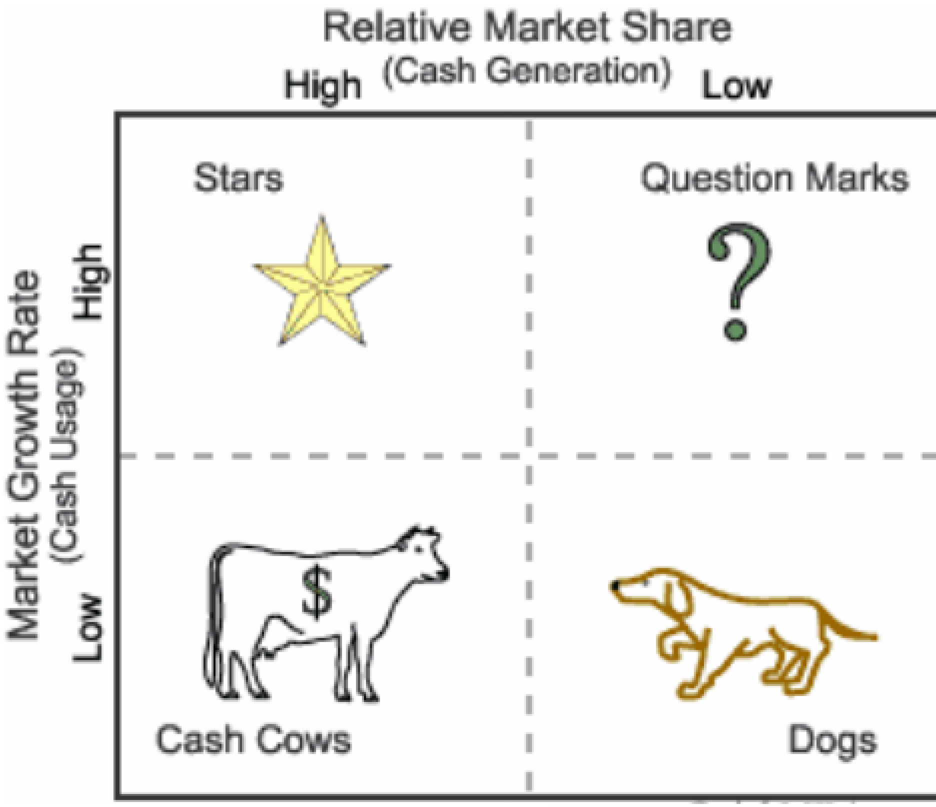


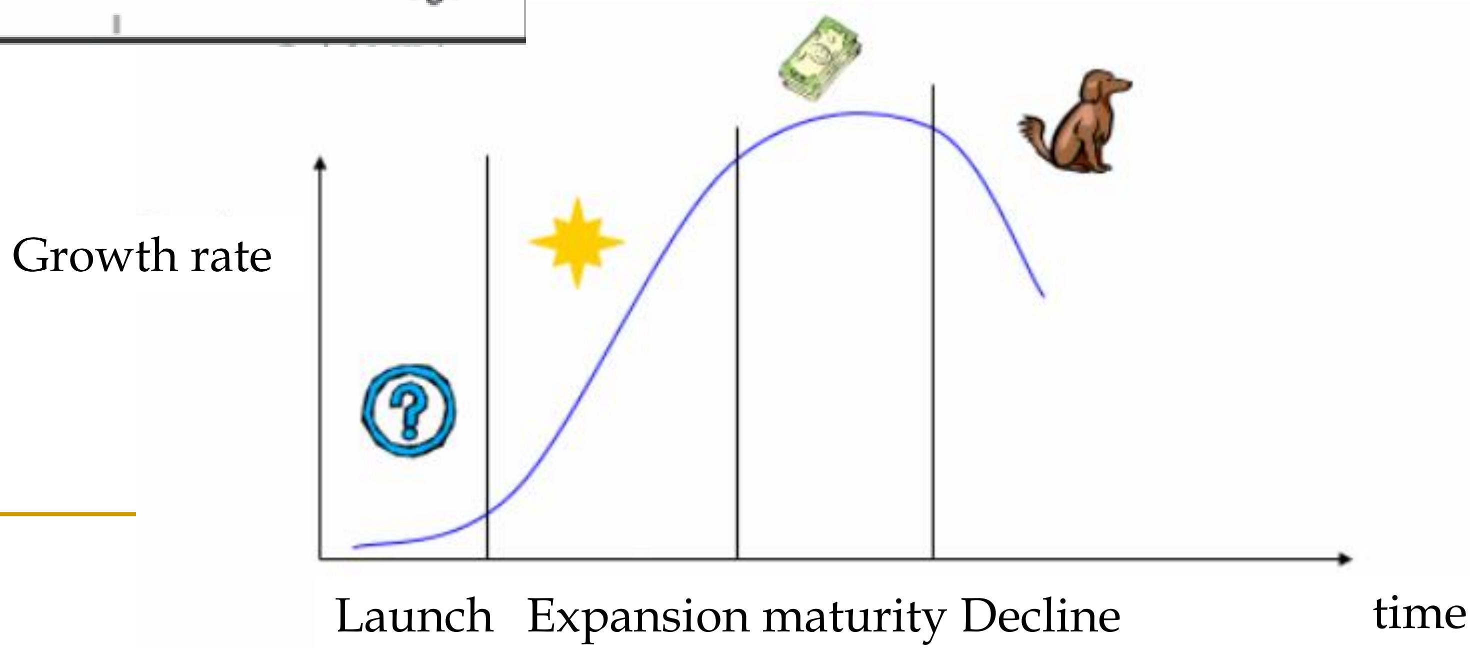
Note that the product life-cycle is **not the same** as industry lifecycle. An industry sees much entry and exits of products and firms.

The importance of the pre-market phase

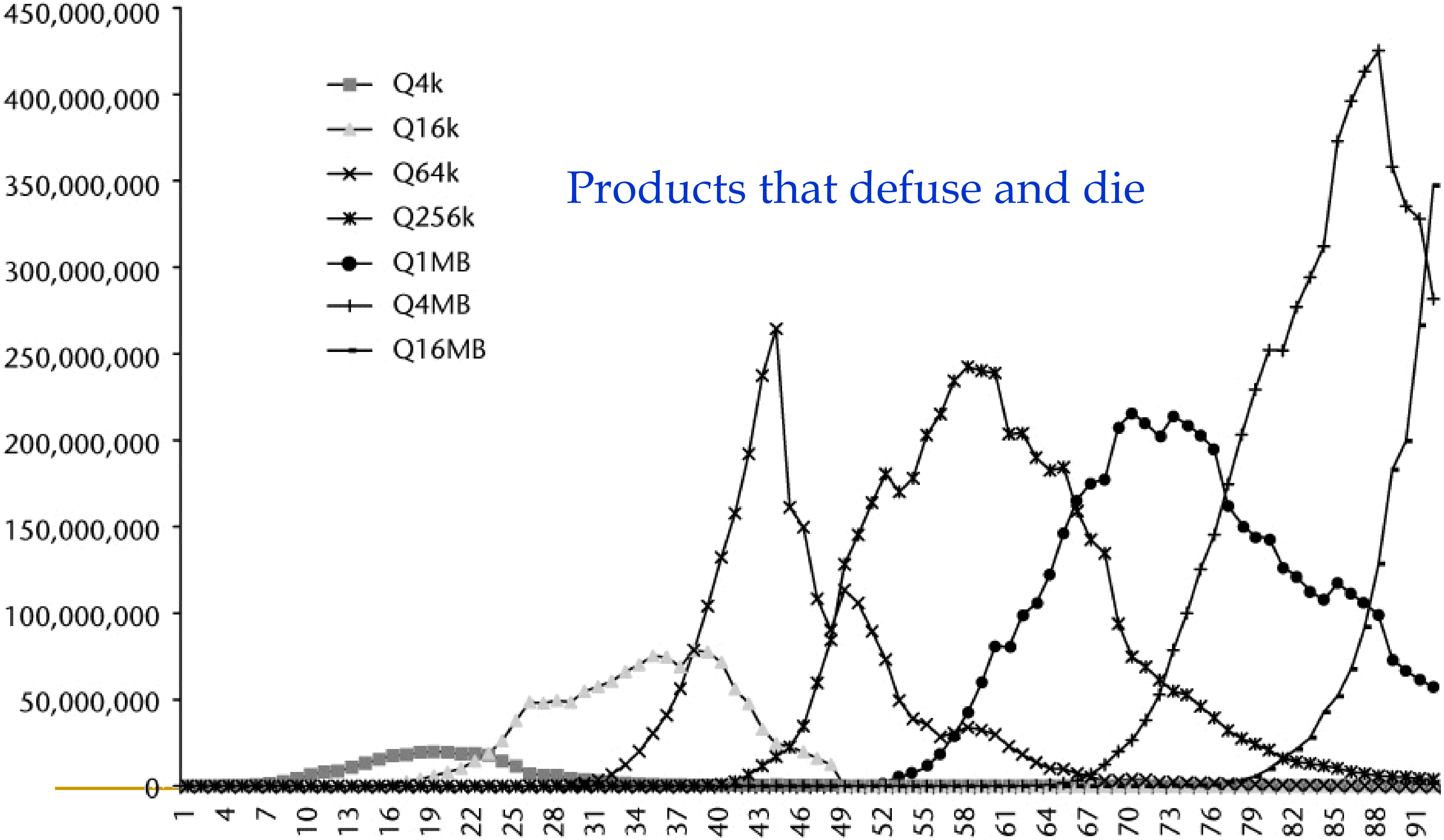
Mature markets have dynamics

Later-day destruction over creativity


Relative Market Share
High (Cash Generation) Low
Market Growth Rate
(Cash Usage)
High
Low
Stars
Question Marks
Cash Cows
Dogs

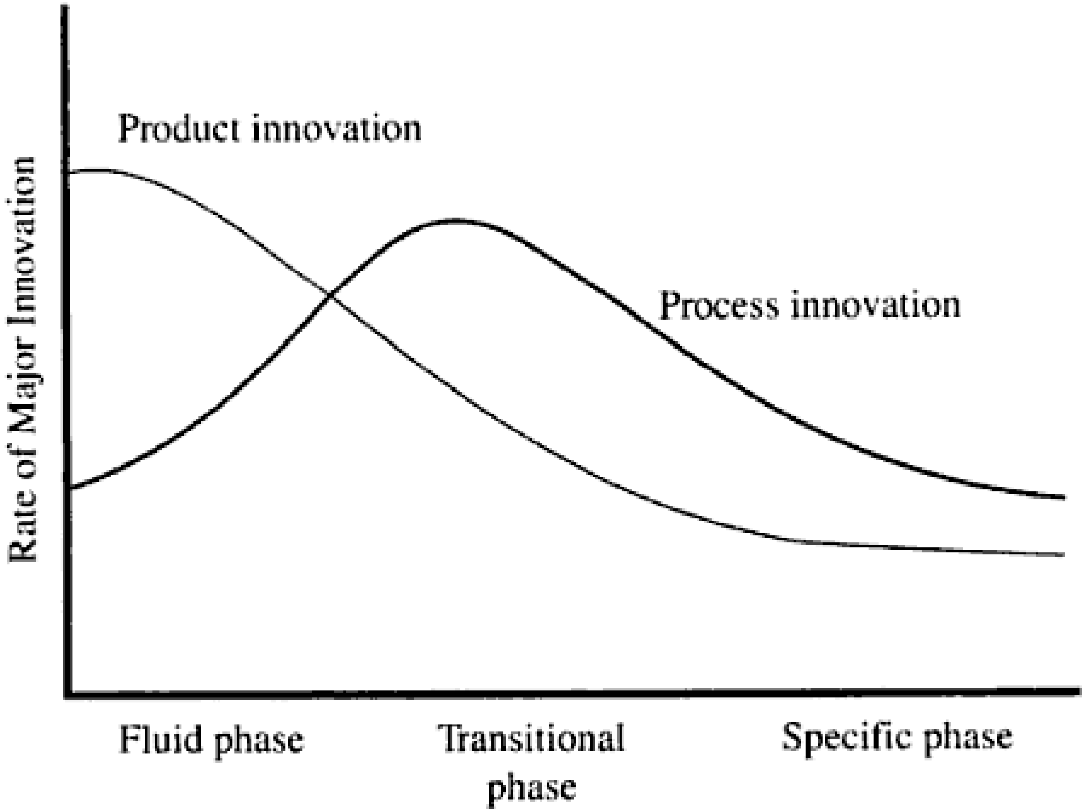

Growth rate
Launch
Expansion
maturity
Decline
time

Successive generations of semiconductors



Source: Geroski (2003)

Product lifecycle and type of innovation



Source: Utterback, J.M. (1996), *Mastering the Dynamics of Innovation*, Harvard: Harvard Business Press.

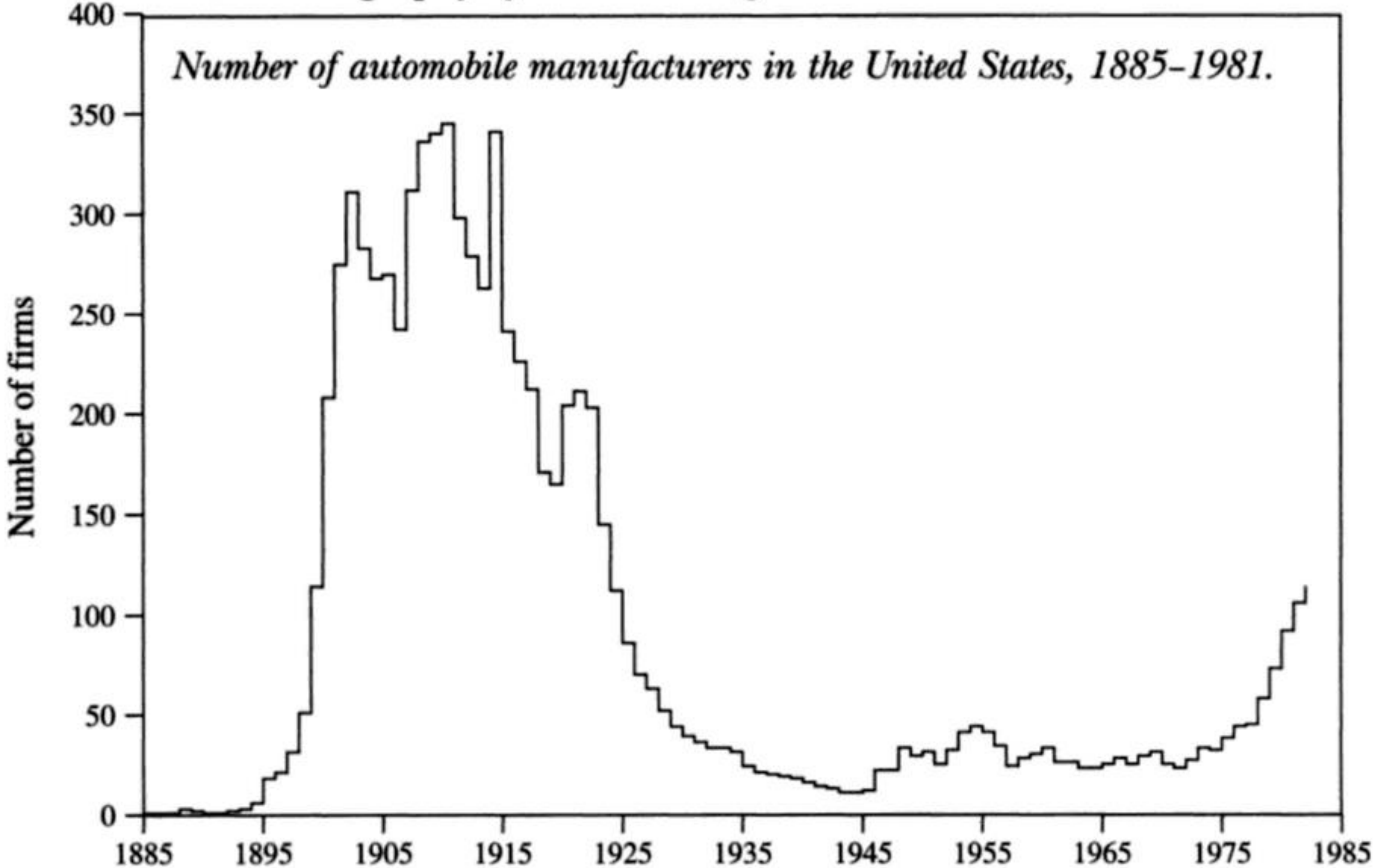
4. Industrial dynamics

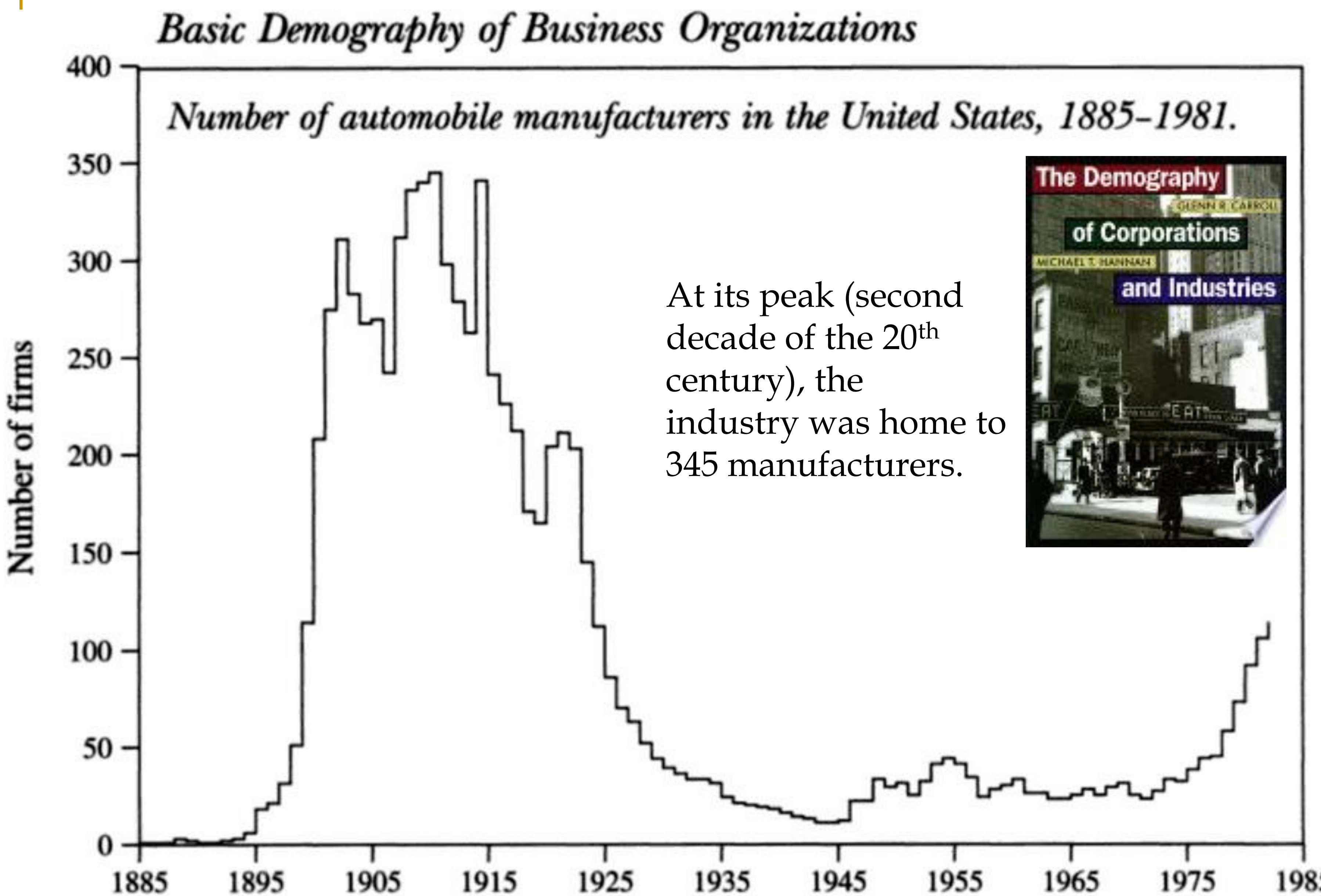
Industry lifecycle

"Three stages of evolution are distinguished. In the initial **exploratory** or embryonic stage, market volume is low, uncertainty is high, the products design is primitive, and unspecialized machinery is used to manufacture the product. Many firms enter and competition based on product innovation is intense. In the second, intermediate or growth stage, output growth is high, the design of the product begins to stabilize, product innovation declines, and the production process becomes more refined as specialized machinery is substituted for labour. Entry slows and a **shakeout** of producers occurs. Stage three, the **mature** stage, corresponds to a mature market. Output growth slows, entry declines further, market shares stabilize, innovation are less significant, and management, marketing and manufacturing techniques become more refined. Evidence on first mover advantages [. . .] and the link between market shares and profitability [. . .] suggests that the firms that ultimately capture the greater share of the market and earn the greatest returns on investment tend to be those that enter earliest." (Klepper, 1997, p. 148)

Source: Klepper, S. (1997), 'Industry life cycles', *Industrial and Corporate Change*, Vol. 6, No. 1, pp. 145-81.

Basic Demography of Business Organizations



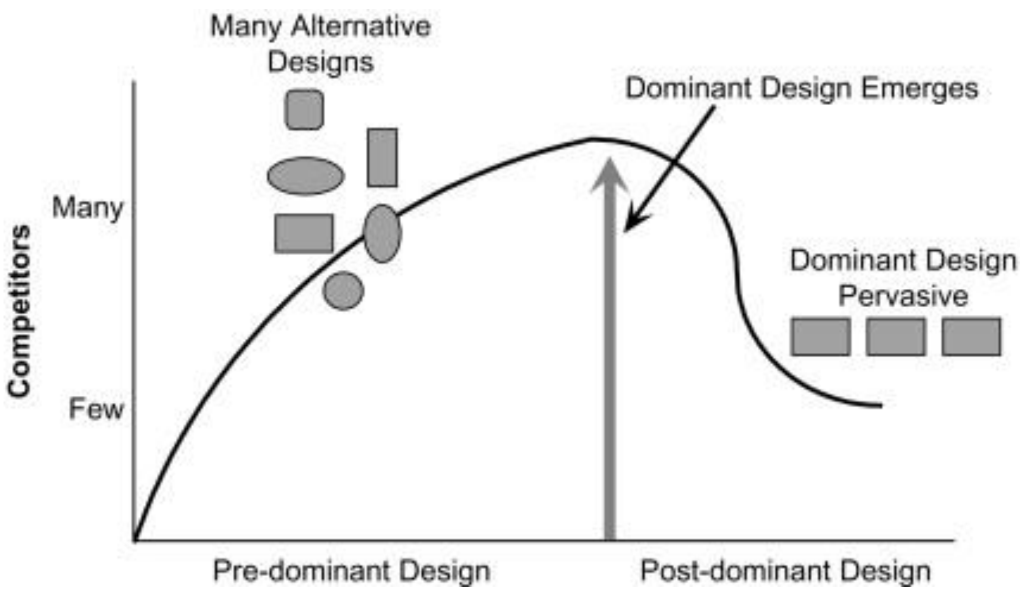


At its peak (second decade of the 20th century), the industry was home to 345 manufacturers.

Source: Carrol and Hannalh (2004, p. 21)

Dominant design

After trial and error among different configurations of attributes there is the emergence of a "dominant design" in the product or technology space, i.e. some core template of core and peripheral attributes that generates consensus. It does not mean that all players adopt it (there can be niches) or that this is indeed a superior technology (and it can stick).



Source: Tiwana (2014)

Dominant design

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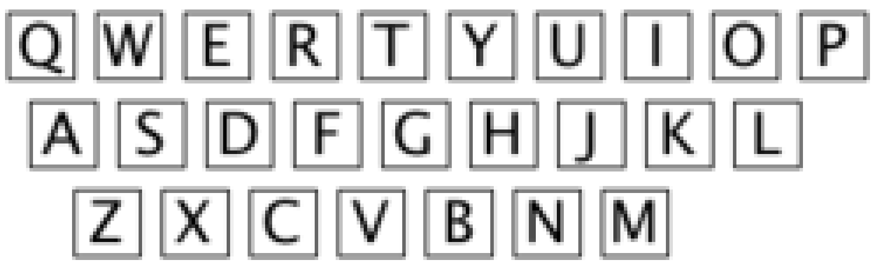
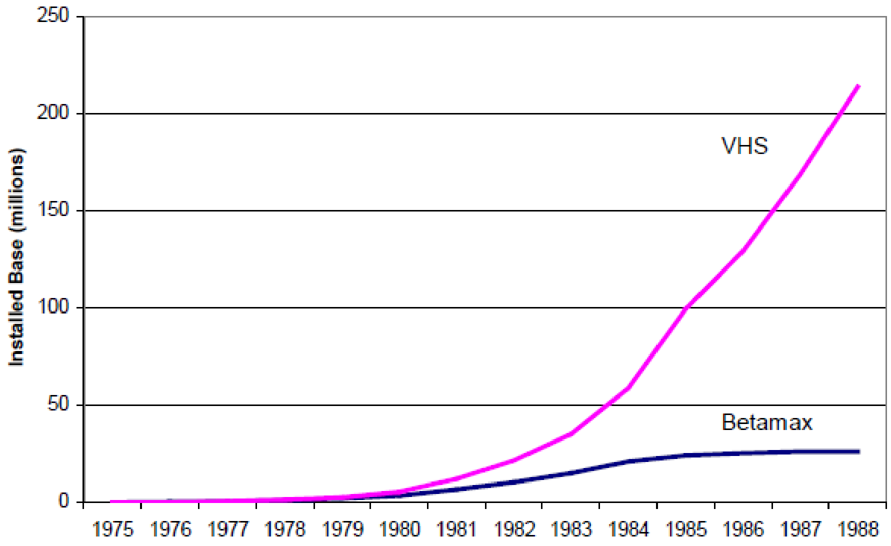
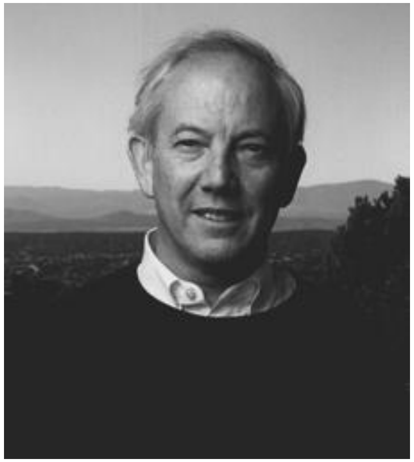


Paul David
and “path dependence”

Dominant design

After trial and error among different configurations of attributes there is the emergence of a “dominant design” in the product or technology space, i.e. some core template of core and peripheral attributes that generates consensus. It does not mean that all players adopt it (there can be niches) or that this is indeed a superior technology (and it can stick).





Brian Arthur
and “lock-in”

4. Industrial dynamics

Technological regimes

Schumpeter Mark I (1911): **Creative destruction** (Schumepter)

“**Entrepreneurial regime**” (*widening* pattern of innovation)
New business protagonists (entrepreneurs) launch new business projects that incorporate new concepts that challenge agents already established in the market and continually call into question the ways of producing, organizing and distributing

Schumpeter Mark II (1942): **Creative accumulation** (Pavitt)

“**Routine regime**” (*deepeming* pattern of innovation)
Established organizations are central to economic action and have large internal resources (installed capacity, R&D, etc.) that create high barriers to the entry of new companies.

Sources: Malerba, F. & L. Orsenigo (1995), “Schumpeterian patterns of innovation”, *Cambridge Journal of Economics*, Vol. 19, No. 1, pp. 47-66; Malerba, F. & L. Orsenigo (1996), “Schumpeterian patterns of innovation are technology specific”, *Research Policy*, vol. 25, pp. 451–78.

4. Industrial dynamics

Indications of Schumpeterian regimes of innovation

	Players	Concentration	Entry/Exit	Profits
Mark I	Many	Low	High	Low
Mark II	Few	High	Low	High

Regimes are different combinations of fundamental features of technology:

1. **Opportunity** conditions (i.e. 'how easy' is to innovate given the resource invested)
2. **Appropriability** conditions (i.e. how economic rents can be extracted from innovation)
3. **Cumulativeness** conditions (i.e. how today's innovators are likely to innovate again in the future)
4. Nature of the **knowledge base** (i.e. what type of knowledge is required to innovate)

So, …

- If high Opp, low App, low Cum and high relevance of science

  ➔ Mark I (e.g. Biotech)

- If low Opp, high App, high Cum and high relevance of engineering
- ➔ Mark II (e.g. Pharma)

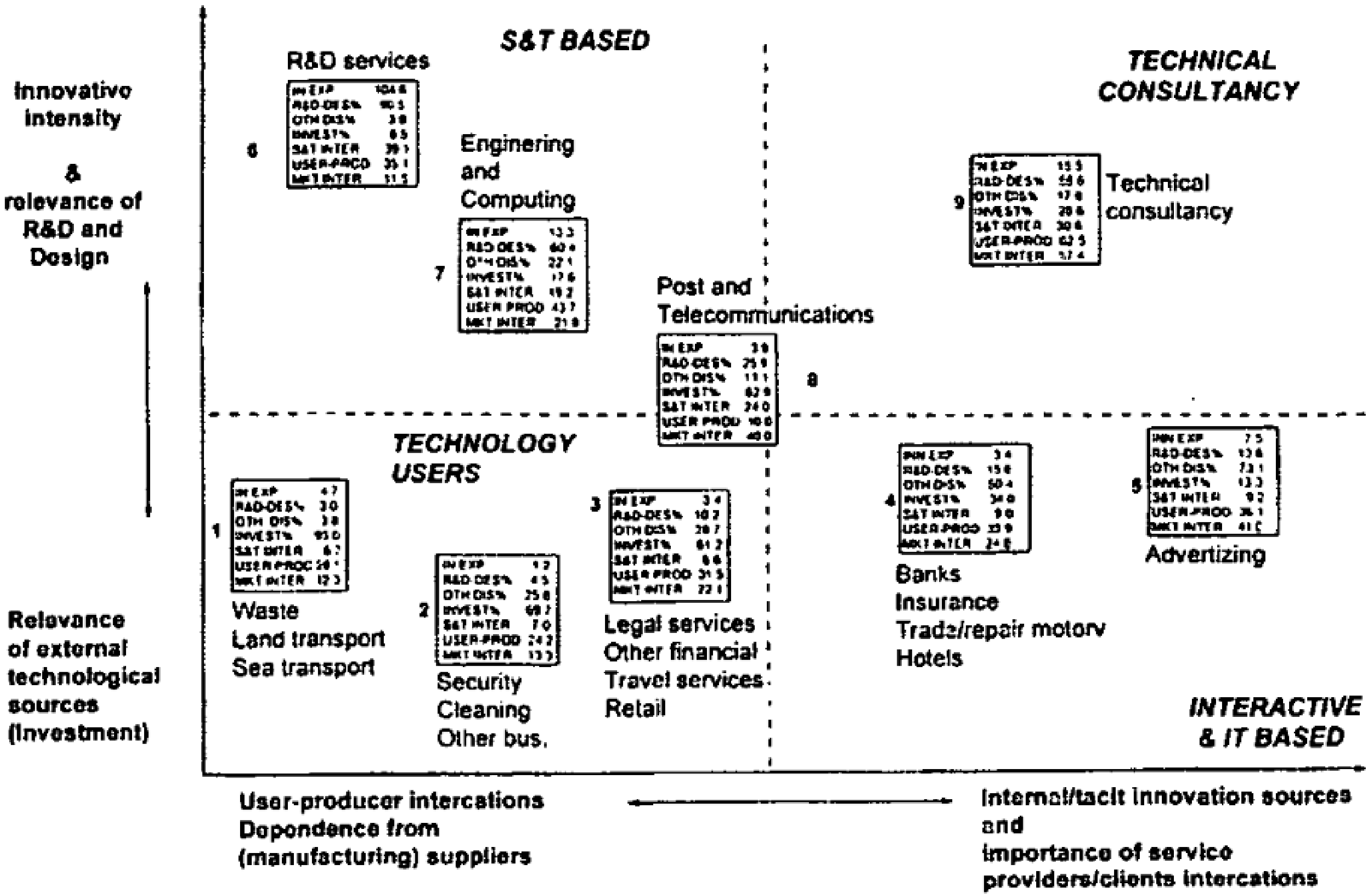
But then we have also to explain transitions from Mark I to Mark II

Sectoral patterns of innovation: the Pavitt taxonomy

	Supplier dominated	Scale intensive	Specialized suppliers	Science based	Information intensive
Core sectors	Agriculture, food, wood based, textiles, rubber & plastics	Automotive, transport equipment	Fabricated metals, machinery, instruments, electrical, electronics	pharmaceuticals, drugs, chemicals, microelectronics	All services
Firm size	Small	Large & Medium	Small	Medium & Large	Small
Type of innovation	Process	Process	Product	Product & Process	Product & Process
Strategy	Cost affectivity	Either cost affectivity (price) or Differentiation (quality)	Differentiation (quality, performance, customization)	Differentiation, Focus strategy (innovation, quality)	Differentiation (quality, quick delivery, customization)
External sources of innovation (cooperation)	Suppliers and users	Suppliers and users	Universities and users	Universities and users	Users

Fonte: adaptado de Pavitt (1984) e Tidd *et al*. (2001)

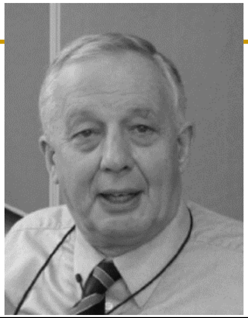
Profiles of innovation in services



Source: Evangelista (2000)

Schumpeterian patterns in history

Long waves (Chris Freeman) & *sectoral patterns* (Keith Pavitt)



Period	Techno-economic paradigm	Industrial organisation	Industrial drivers	Pavitt taxonomy
1780-1815	Mecanisation, canals, factory	Small firms	Textiles	*Supplier-dominated*
1815-1873	Steam, railways, steam navigation, telegraphy	Capital good industries	Steel, coal, machine-tools	*Specialised suppliers*
1873-1918	Applied scientific research	Giant industrial companies, trusts, financial markets	Chemicals, dynamo	*Science-based*
1918-1973	Fordism	Oligoplolies, multinationals, big banks	Oil and derivatives, cars, electrification	*Scale-intensive*
1973- …	Micro-electronics and digital connectivity	Global value chains, venture capital, platforms	Semicondutors, personal computers, smartphones, e-commerce, cloud, gatekeepers, AI	*Information-intensive*

- …

conclusions

Conclusions

- Types of knowledge and modes of learning
- Technological change and industrial dynamics