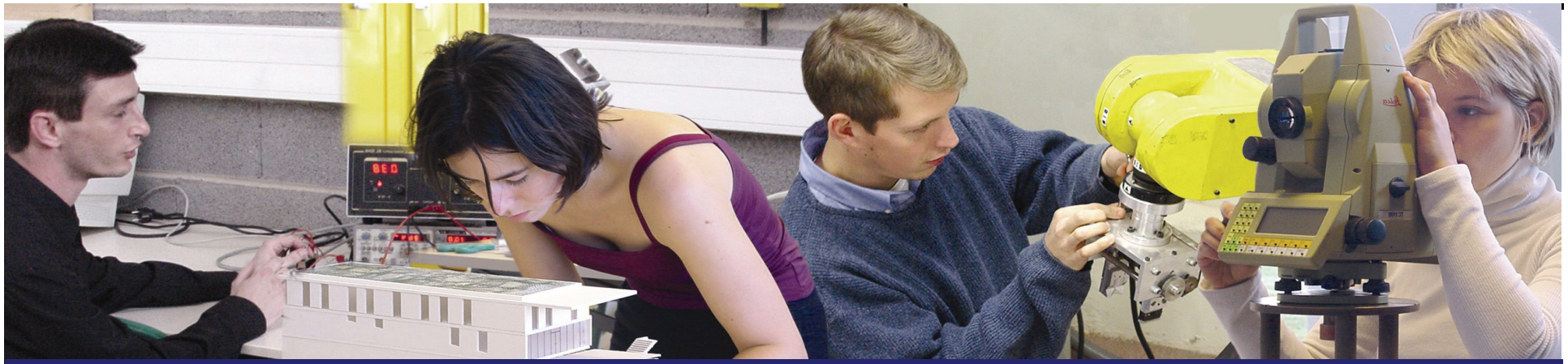

INSA STRASBOURG GRADUATE SCHOOL OF SCIENCE AND TECHNOLOGY

ARCHITECTS + ENGINEERS

LGECO INSA STRASBOURG

Application of S-shaped curve

Dmitry KUCHARAVY, dmitry.kucharavy@insa-strasbourg.fr
Roland DE GUIO, roland.deguio@insa-strasbourg.fr

LGECO - Design Engineering Laboratory
INSA Strasbourg - Graduate School of Science and Technology
24 bd de la Victoire, 67084 STRASBOURG, France

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CONTENT

Q1: What does S-curve mean?

Q2: Why does it work?

Q3: Where is it applied and why?

Q4: Qualitative or quantitative?

Q5: So what?

Q6: What would we do with it?

Q1: What does S-curve mean?

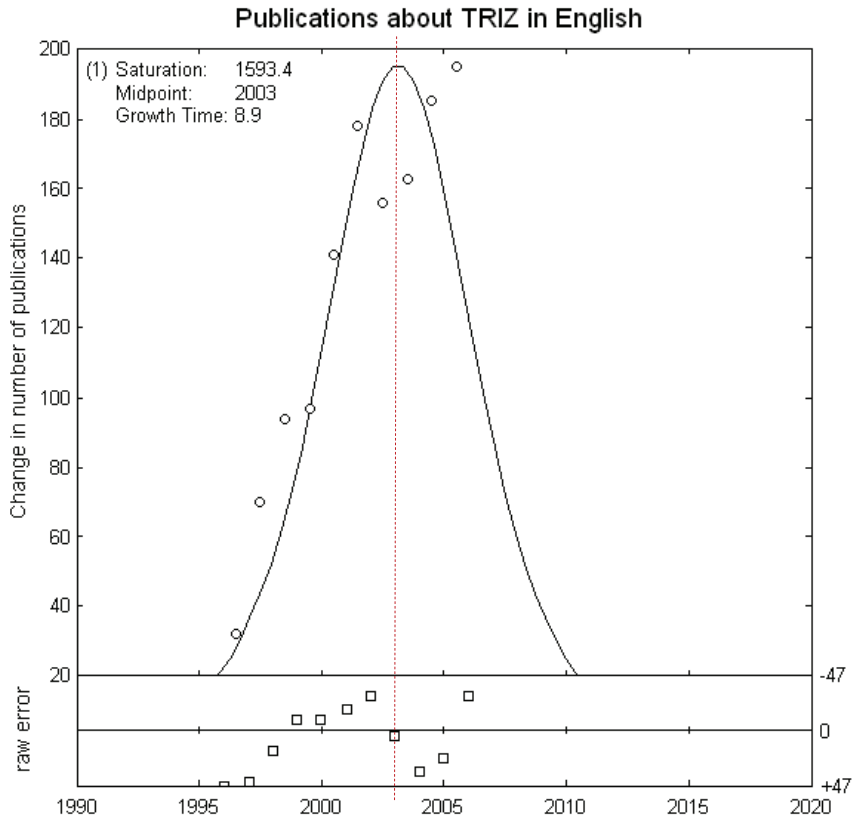
[model of growth in competition through time]

- Model of *natural growth* of autonomous systems *in competition* might be described by logistic equation and logistic S-curve.
- Natural growth is defined as ability of a '*species*' to multiply inside finite *'niche capacity*' through *time period*.
- For socio-technical systems the three-parameter S-shaped logistic growth model is applied for describing continuous "trajectories" of growth or decline through time.

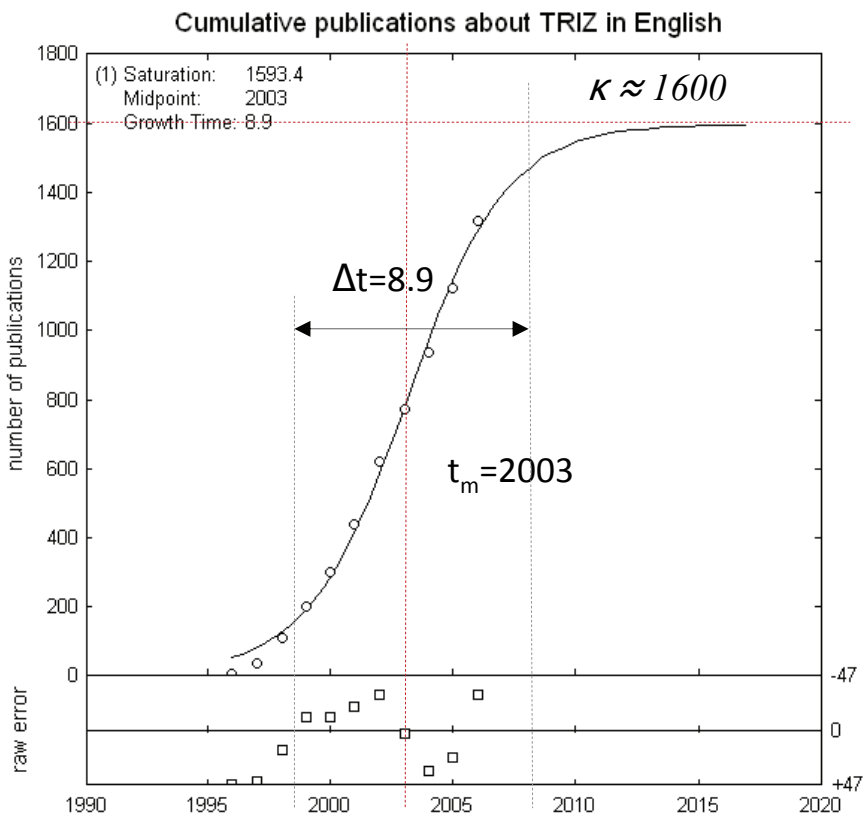
$$N(t) = \frac{K}{1 + e^{-\alpha t - \beta}}$$

Q1: What does S-curve mean?

[introduction: rate of growth, cumulative growth]



Bell-shaped ("normal" distribution)



Simple logistic (symmetric) S-curve

Data sources: The TRIZ Journal (1996-2006), proceedings of the TRIZCON (1999-2006), proceedings of the ETRIA TFC (2001-2006). The same articles from different sources where taken into account just once.

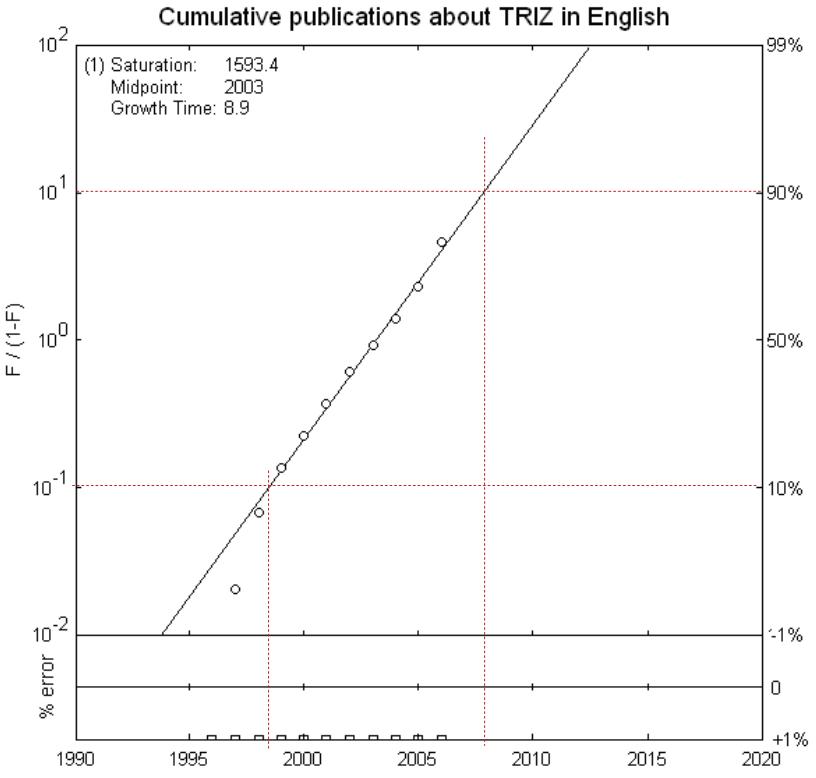
* S-curve fit on data by Loglet Lab Version 1.1.4

Q1: What does S-curve mean?

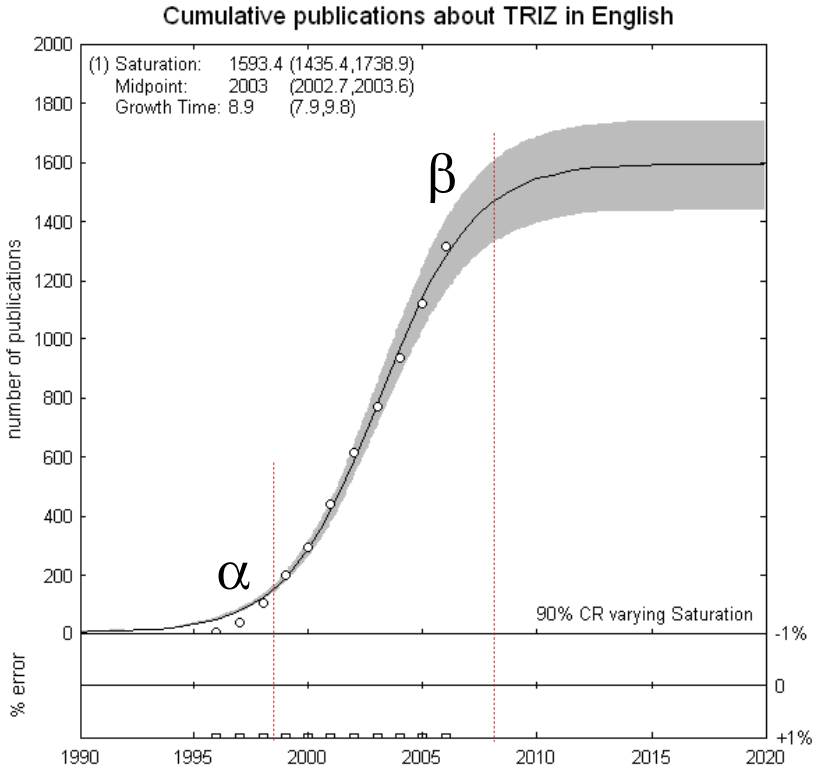
[introduction: rate of growth, cumulative growth]

Fisher-Pry transform

$$FP(t) = \left(\frac{F(t)}{1 - F(t)}\right) \quad \text{where} \quad F(t) = \frac{N(t)}{\kappa}$$



Forecast with confidence intervals



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* S-curve fit on data by Loglet Lab Version 1.1.4

Q2: Why does it work?

[Why does it possess forecasting power?]

Logistic S-curve describes evolution of system under limitation of resources through time.

Strength:

- Properly established logistic growth reflects the action of a natural law.
- Relatively easy to apply. Clear concept and working mechanism.
- Can be applied for systems where the growth mechanisms are understood and where the mechanisms are hidden.

…and Weakness:

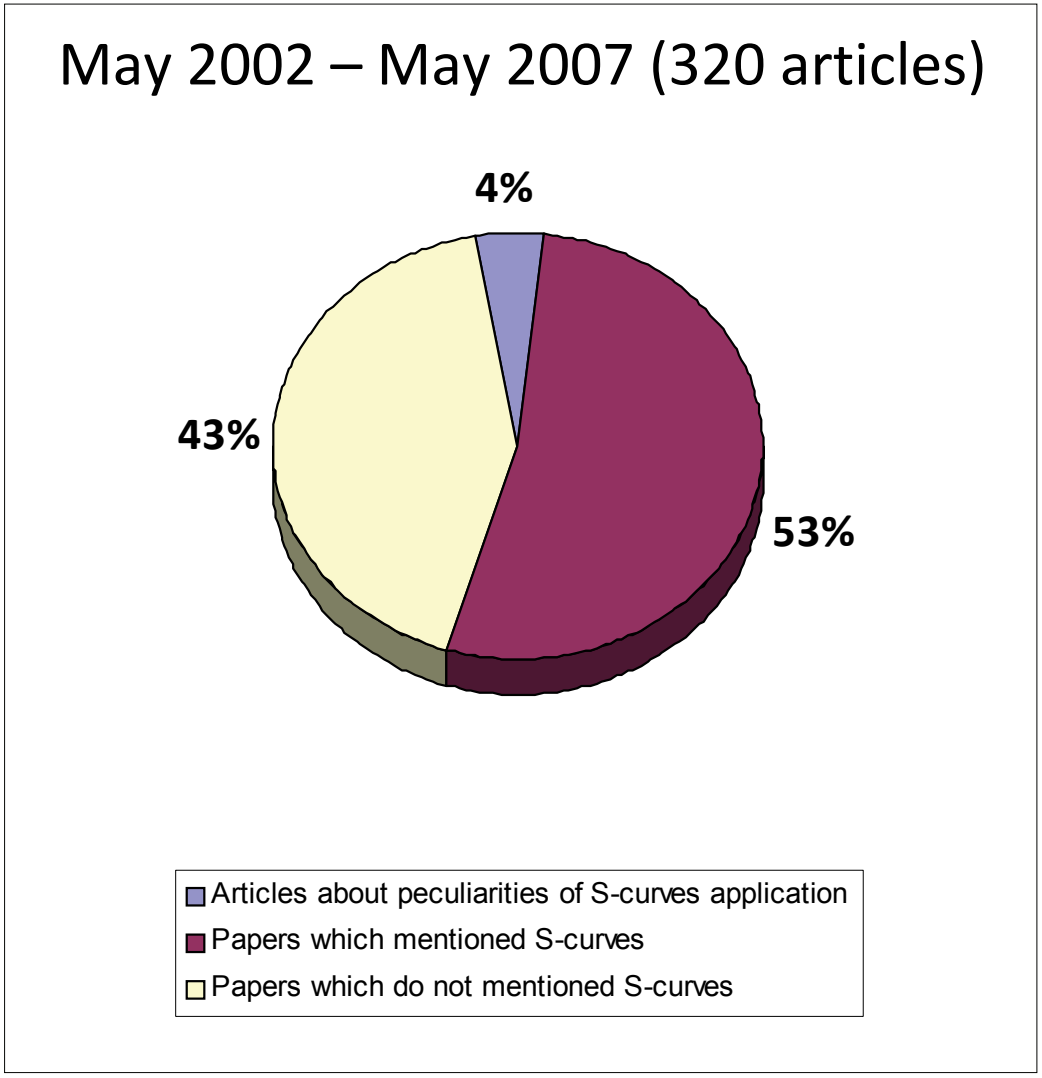
- *What is growing variable (species) and what is underlying competing mechanism in particular case? Lack of formal procedure to define.*
- *Bias towards low or high ceiling: 'no two people, working independently, will ever get EXACTLY the same answer for an S-curve fit'.*
- *Should we fit S-curve to the raw data or to cumulative number? Fitting technique errors and uncertainties.*

Q3: Where is it applied and why?

[forecasting of socio-technological systems]

The International Journal of Technological Forecasting and Social Change

http://www.elsevier.com/wps/find/journaldescription.cws_home/505740/description#description



Q3: Where is it applied and why?

[diffusion of innovations…]

Studies about technology maturity at the industry level:

- …Mensch (1978) – diffusion of basic innovations and new industries formation;
- Marchetti and Nakicenovic (1979) – energy dynamics;
- Constant (1980) – aircraft engines;
- Roussel (1984) – foam rubber;
- Foster (1986) - examples from a range of industries;
- Grübler (1987) – steel and coal industries;
- Modis and Debecker (1988) – computer industry;
- Van Wyk, Haour, and Japp (1991) – permanent magnets;
- Christensen (1992) – disk drive industry;
- Ausubel and Marchetti (2001) – transport systems;
- Modis (2005) – Internet growth…

Q3: Where is it applied and why?

[…and revealing of trends]

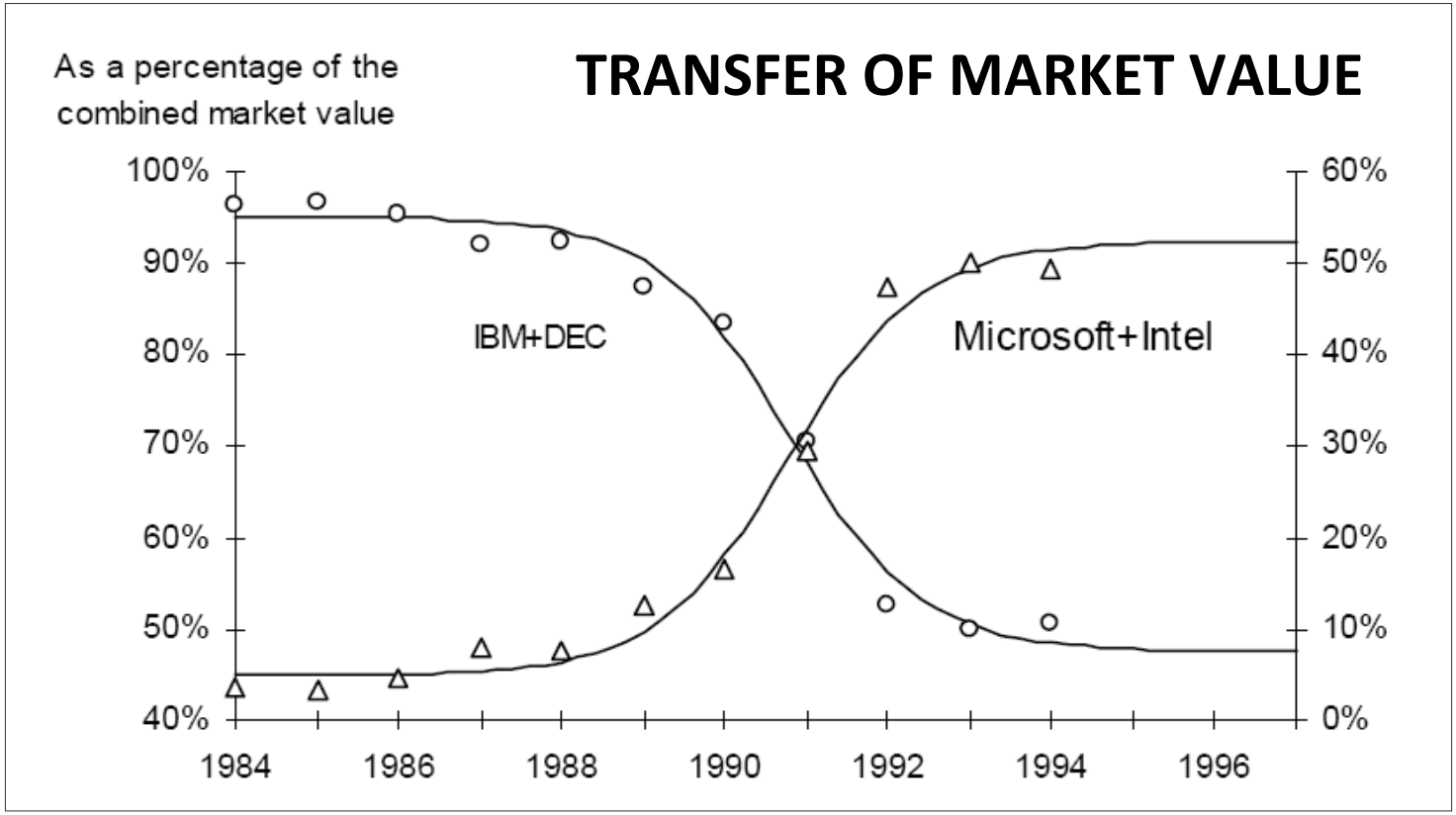
Creative person life cycles;

Discovery of chemical elements;

Competition between diseases …

Computer diffusion dynamics;

Competition for Nobel; Prizes



* Source: Modis, T. Conquering Uncertainty - Understanding Corporate Cycles and Positioning Your Company to Survive the Changing Environment. (McGraw-Hill, New York, 1998), 204.

Q3: Where is it applied and why?

[long-term evolution of socio-technical systems in competition]

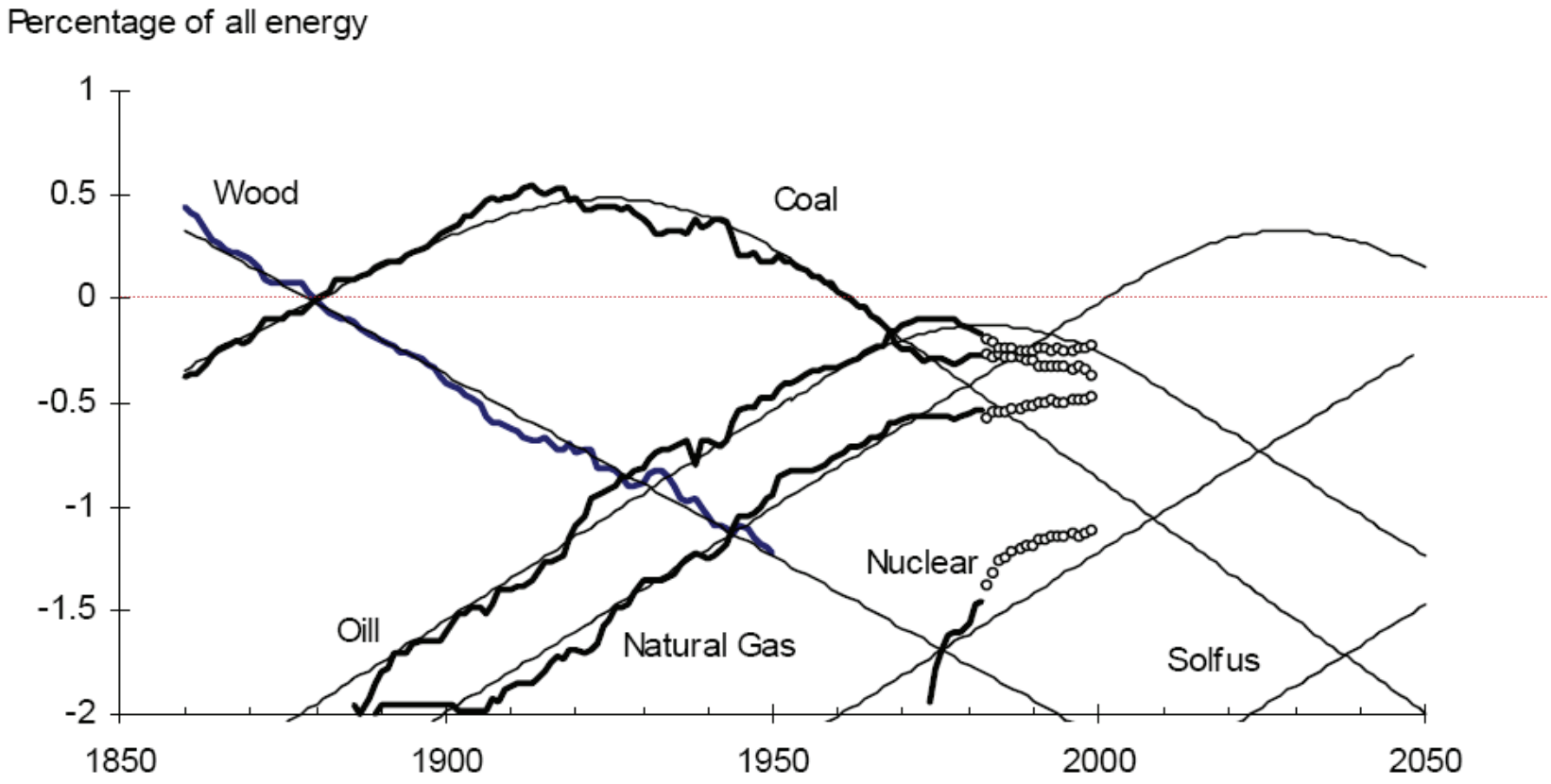
International Institute for Applied Systems Analysis
(IIASA , Laxenburg, Austria) during the last 35 years:

- the future of primary energy sources and vectors,
- the evolution of agricultural technologies,
- the substitution of transportation systems,
- the development of discoveries,
- the elaboration of inventions and the diffusion of innovation,
- the transformation of the aircraft industry,
- macro- and micro- economic trends,
- the growth of crime and terrorism,
- environmental changes and problems,
- the evolution of telecommunication systems…

Q3: Where is it applied and why?

[long-term study of socio-technical systems in competition]

COMPETITION BETWEEN PRIMARY ENERGY SOURCES



* Source: Adapted by Modis T. from a graph by Cesare Marchetti in "Infrastructures for Movement," Technological Forecasting and Social Change, vol. 32, no. 4 (1987): 373–93.

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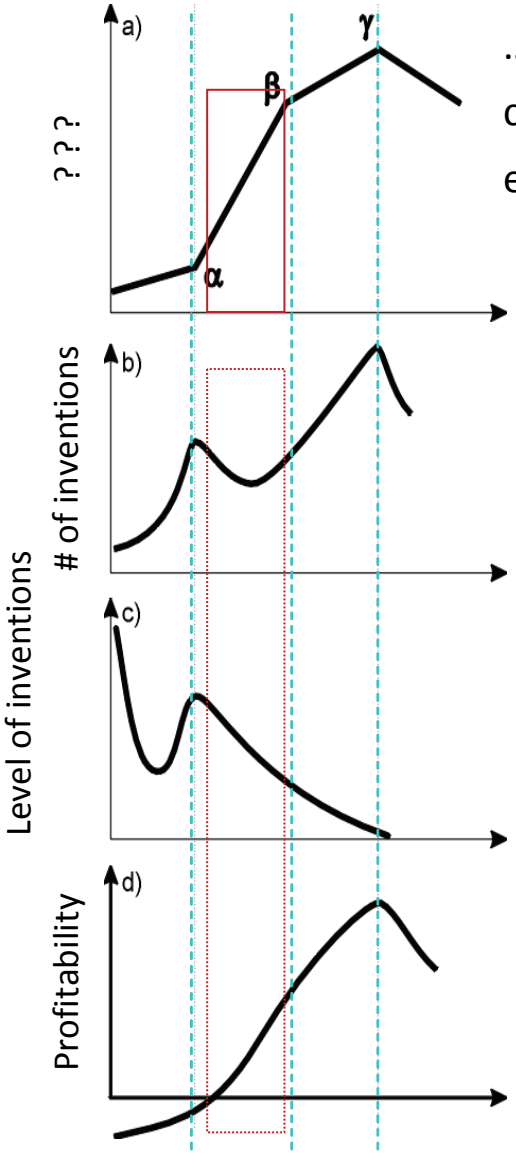
Q4: Qualitative or quantitative?

[problem statement]

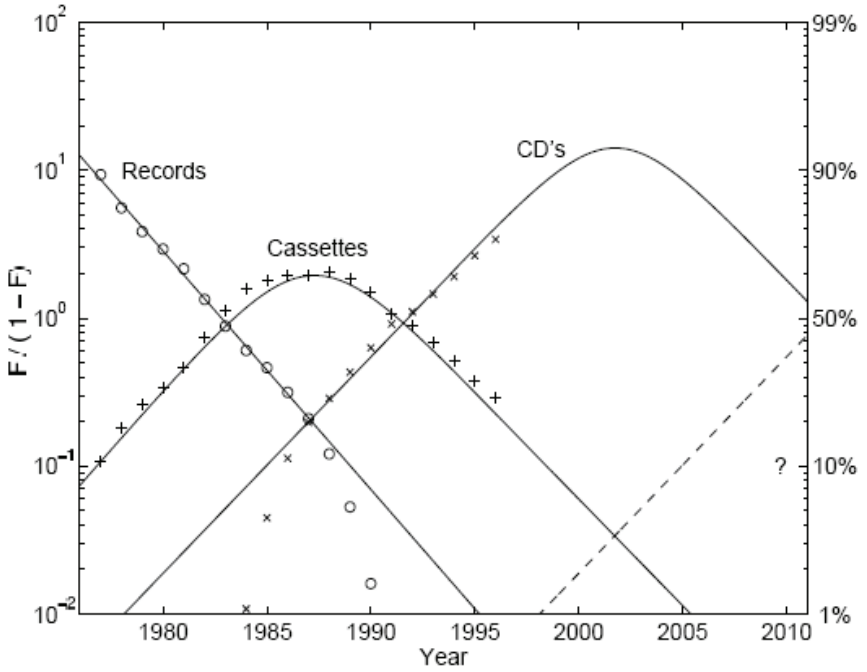


…and the fourth can be extrapolated (?)

OR

Technology **A** on three of the four descriptor curves…

US MUSIC RECORDING MEDIA (1997)



* Source: Meyer, P.S., Yung, J.W. and Ausubel, J.H. A Primer on Logistic Growth and Substitution: The Mathematics of the Loglet Lab Software. Technological Forecasting and Social Change, 1999, 61(3), 247-271.

For long-term forecast:

How can we satisfy the law (dialectic) of transformation quantity to quality?

Q4: Qualitative or quantitative?

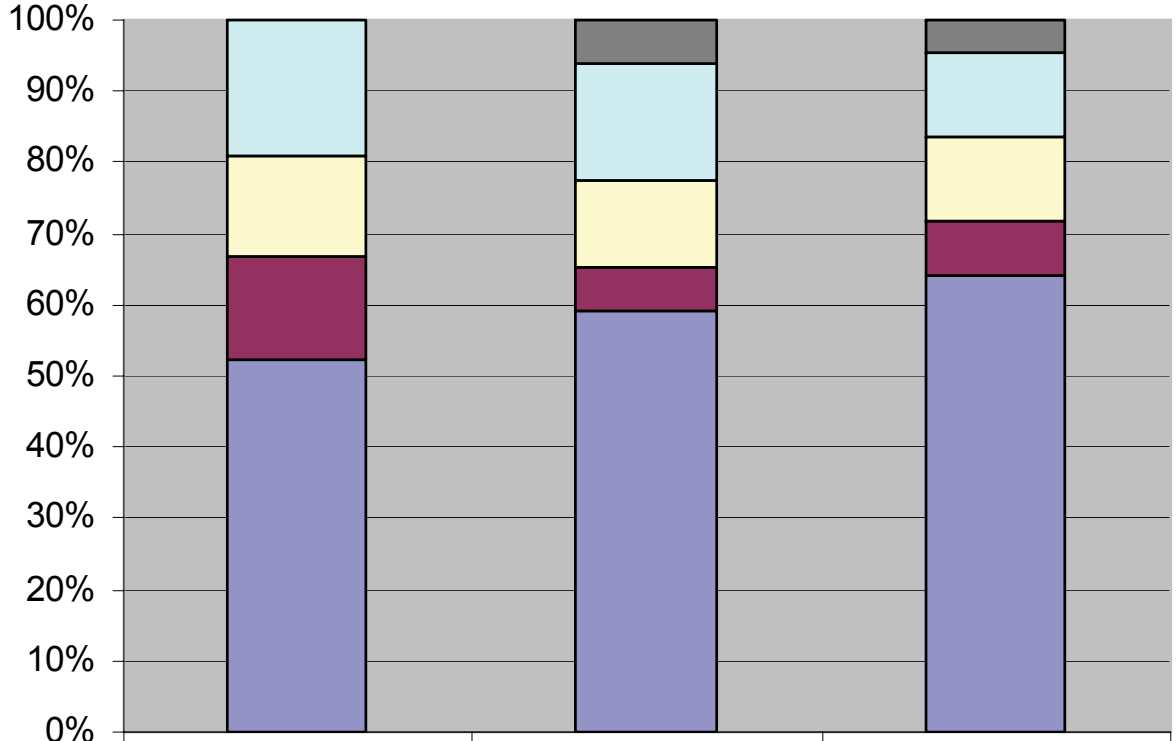
[How was stated problem addressed?]

Context	Qualitative	Quantitative
Inventive problem solving	Quick and easy to perform. No necessity to collect and refine data. Ambiguity of definition (e.g. large, small). Partial & biased.	Clear definition of features and values to improve. How to measure a new quality?
Management of innovation	Low resistance for implementation. How to position the innovations in time, in space, and in competitive environment?	Plausibility for decision making and strategic planning. Higher-impartial. It takes a lot of time for data gathering and refining.
Technological forecast	Compatible with long-term forecast. Inaccuracy of forecasting in time (when?) and in space (where?). Higher-biased. How to deal with competitive technologies?	Results are measurable and precise. Repeatable, adaptable, and cost effective. Based on past data and trends. Indirect biases through computation models, assumptions and data.

Q4: Qualitative or quantitative?

[S-curve in publications of TRIZ community]

[1996-2006]
More than 1300 articles;
only 11 papers report some trials to apply quantitative S-curve analysis



	1996-1999	2000-2002	2003-2006
Non-grouped hypothesis	0	3	3
In context of forecasting	4	8	8
In context of problem solving	3	6	8
Case studies using S-curve	3	3	5
Just mentioned	11	29	43

Q5: So what?

[conclusions]

- Extrapolation of trends using logistic S-curves model is essentially **quantitative** forecasting methods with qualitative interpretation of result.

- When the analysed process cannot be measured a qualitative application of S-curves produces misleading results and conclusions.

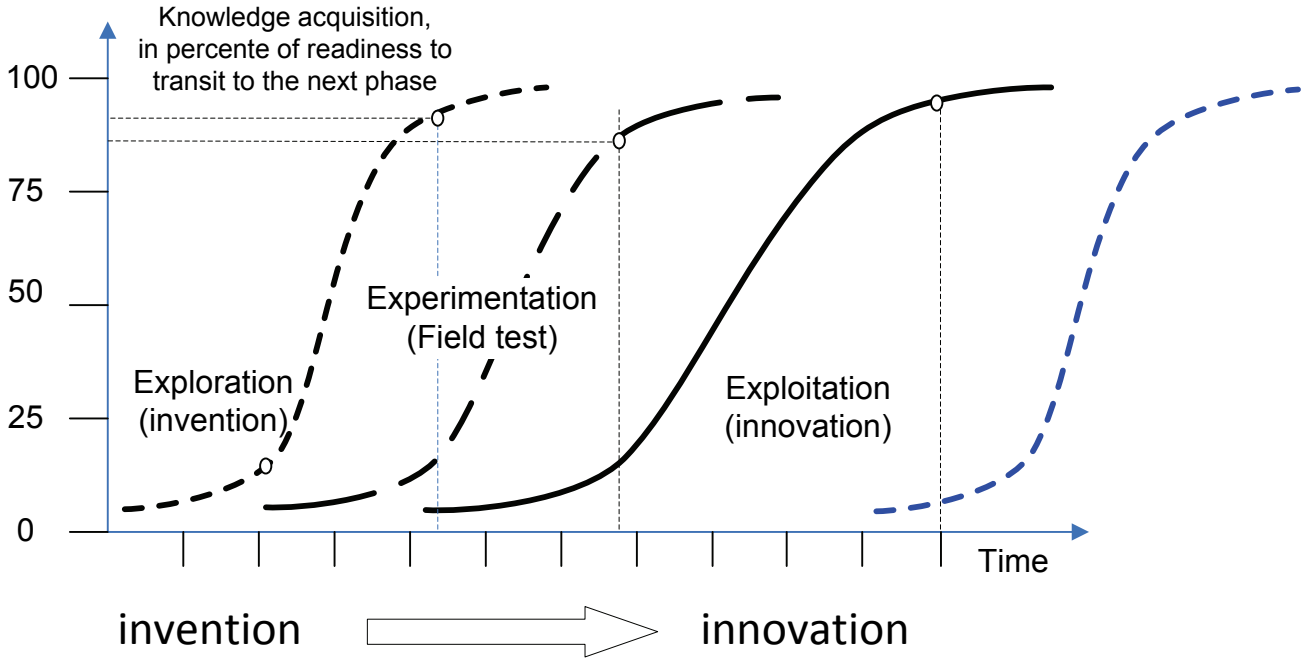
- The forecast can be dramatically different, depending on the selected parameter and the way to scale it.

Q6: What would we do with it?

[prospective]

How to forecast the future of *emerging technologies* using a simple logistic S-curve?

- before system passes the 'infant mortality' threshold;
- before having enough data for growing variable trend.



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Q6: What would we do with it?

[prospective]

It is proposed:

- to measure knowledge growth by applying a network of contradictions as a guideline to differentiate signal and noise information;
- to employ the concept of limiting resources from super-system for validation the network of contradiction for system;
- to adapt the knowledge growth factor as an underlying cause of technology substitution mechanism.

Q6: What would we do with it?

[summary]

Observation results:

Simple logistic S-curve have been used extensively in the widest range of application (outside of TRIZ community). It produce an appropriate outputs for technological forecast of large spectrum of systems.

Assumption:

Efficiency of knowledge growth determines technology substitutions.

Hypothesis:

Emerging technologies future can be reliably forecasted by applying simple logistic S-curves of knowledge growth in framework of transition from invention to innovation (exploration-experimentation-exploitation).

Verification and validation:

Interim results through two projects with European Institute for Energy Research (EIFER, Karlsruhe), reports and conference papers.

Developed approaches, techniques and method should be checked through practical forecast in coming future.

The ultimate test of the forecaster is an accurate and reliable forecast not the elegant or easily applied method.
Theodor Modis, 2007

Thank you

for your attention :)

Dmitry KUCHARAVY,

dmitry.kucharavy@insa-strasbourg.fr

LGECO - Design Engineering Laboratory, INSA Strasbourg

24 bd de la Victoire, 67084 STRASBOURG, France

Dmitry KUCHARAVY

OTSM-TRIZ
technologies center
www.trizminsk.org

More than 18 years experience in TRIZ as engineer, researcher, consultant, and instructor.

1987-1988: the first acquaintance with TRIZ as mechanical design engineer;

1989-1993: research engineer at IMLab, Minsk, Belarus;

1994-1998: freelance TRIZ-consultant, entrepreneur;

1997-1998: invited instructor in SADT, IDEF0, and TRIZ at Belarusian state and private universities;

1998-2001: professional TRIZ consultant & instructor at LG-Production and Research Center (LG-PRC, Pyeongtaek, S.Korea);

2001 - : research engineer, instructor, adviser and consultant at LGECO, INSA Strasbourg, France.

2003 - : doctoral student (Reliable Technological Forecasting methods) at the University of Louis Pasteur.

2004 - : OTSM-TRIZ instructor for educational Program “Advanced Master of Innovative Design” (AMID).

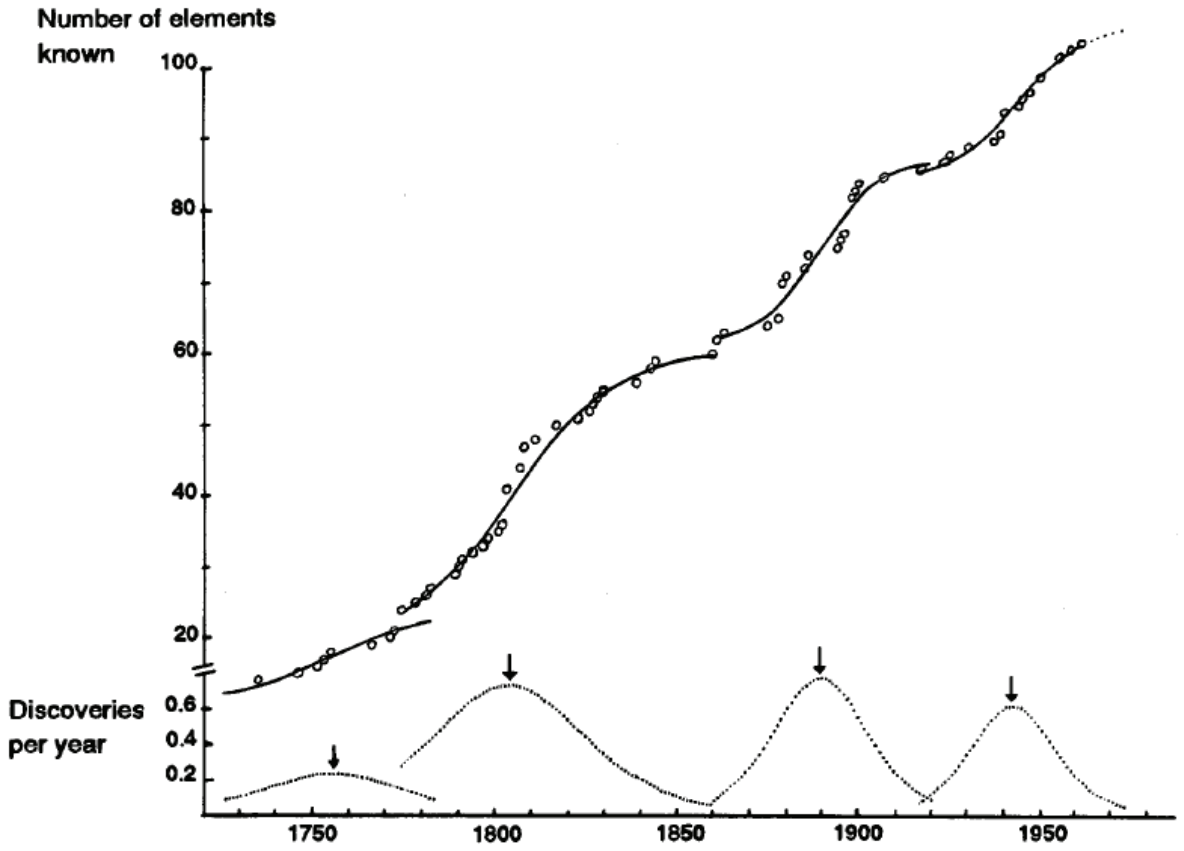
References

1. Altshuller, G.S. *About forecasting of technical systems development*. Seminars materials p. 8 (Baku, 1975). Manuscript in Russian
2. Modis, T., *Predictions - 10 Years Later*. 2002, Geneva, Switzerland: Growth Dynamics. 335.
3. Loglet Lab: http://phe.rockefeller.edu/LogletLab/
4. Meyer, P.S., *Bi-logistic growth* Technological Forecasting and Social Change, 1994. 47(1): p. 89-102.
5. Mensch, G. *Stalemate in Technology: Innovations Overcome the Depression* (Ballinger Pub Co, Cambridge, Massachusetts, 1978), 241. ISBN 088410611X.
6. Ayres, R.U., *Technological Forecasting and Long-Range Planning*. 1969: McGraw-Hill book Company. 237. ISBN 0070026637
7. Grubler, A. *Technology and Global Change*. (International Institute of Applied System Analysis, Cambridge, 2003), pp.211. ISBN 0 521 54332 0.
8. Modis, T. *Strengths and weaknesses of S-curves*. Technological Forecasting and Social Change, 2007, 74(6), 866-872.

Q2: Where is it applied and why?

[…discovery of new chemical elements]

THE STABLE ELEMENTS WERE DISCOVERED IN CLUSTERS



* Source: Modis, T. Predictions - 10 Years Later. (Growth Dynamics, Geneva, Switzerland, 2002), pp. 149. ISBN 2-9700216-1-7.

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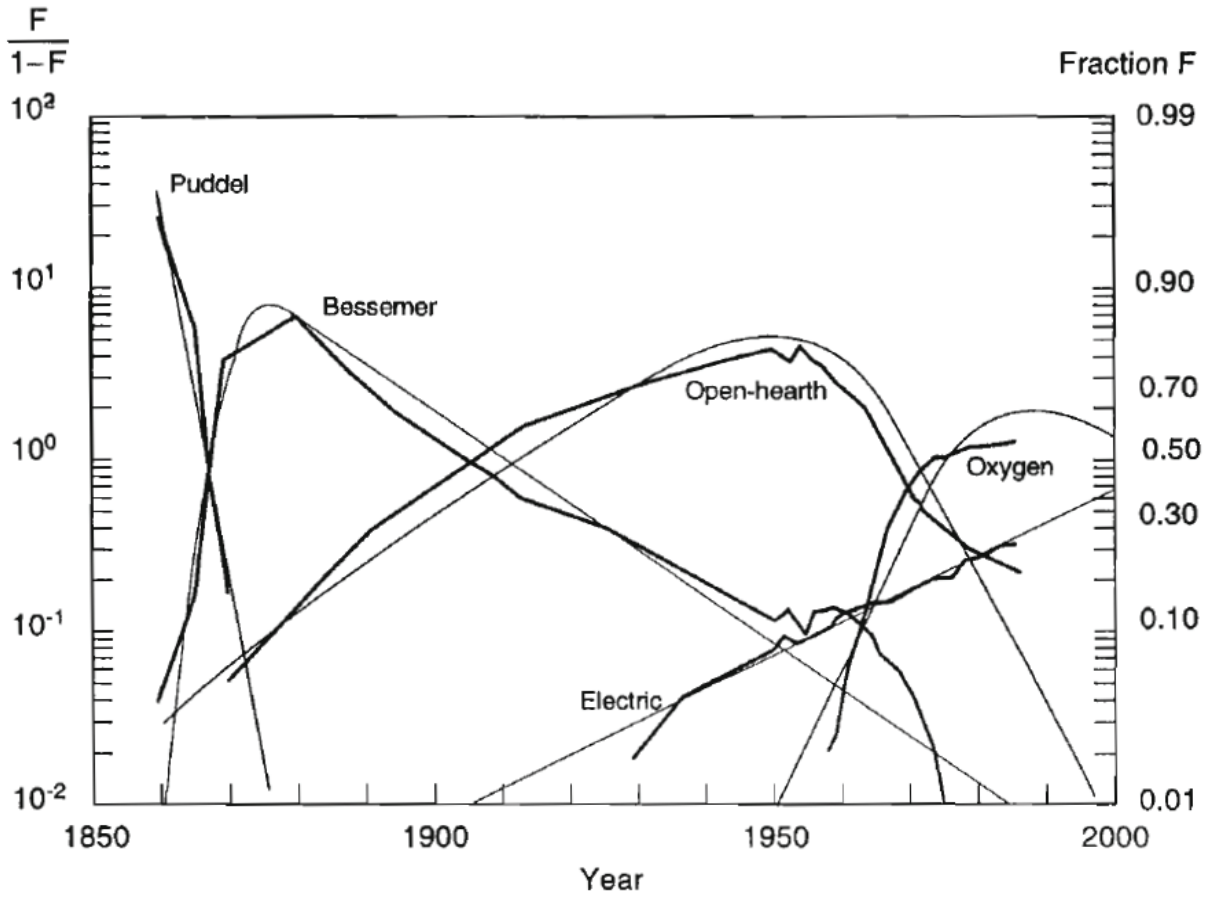
Q2: Where is it applied and why?

[…in global steel manufacturing]

SUBSTITUTION OF PROCESS TECHNOLOGIES



* Source: Grubler, A. Technology and Global Change. (International Institute of Applied System Analysis, Cambridge, 2003), pp.211. ISBN 0 521 54332 0.

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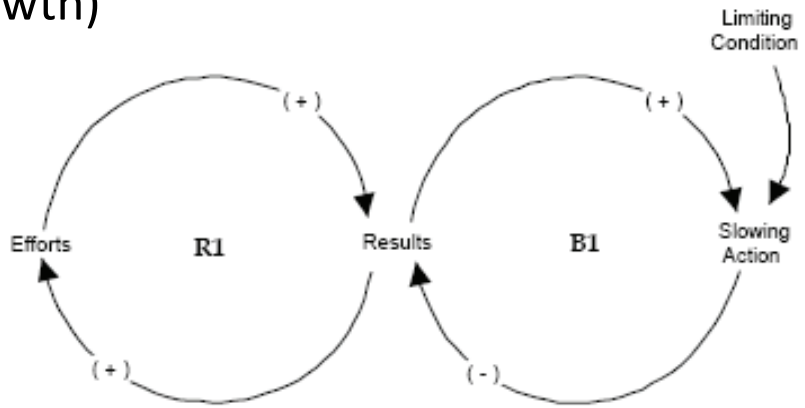
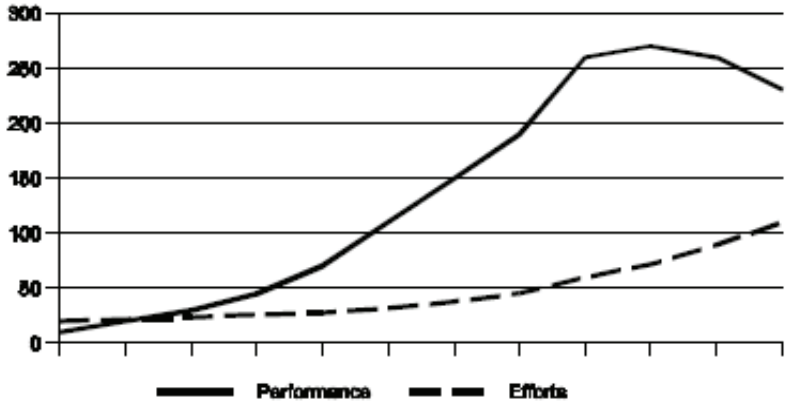
Q2: Where is it applied and why?

[system dynamics -> system archetypes]

Systems Archetypes describe common patterns of system's behavior (organizations).

1. **Limits to Growth** (aka Limits of Growth)
2. Shifting the Burden
3. Eroding Goals
4. Escalation
5. Success to the Successful
6. Tragedy of the Commons
7. Fixes that Fail
8. Growth and Underinvestment
9. Accidental Adversaries
10. Attractiveness Principle





* Source: Braun, W. *The System Archetypes*. (The Systems Modeling Workbook2002).

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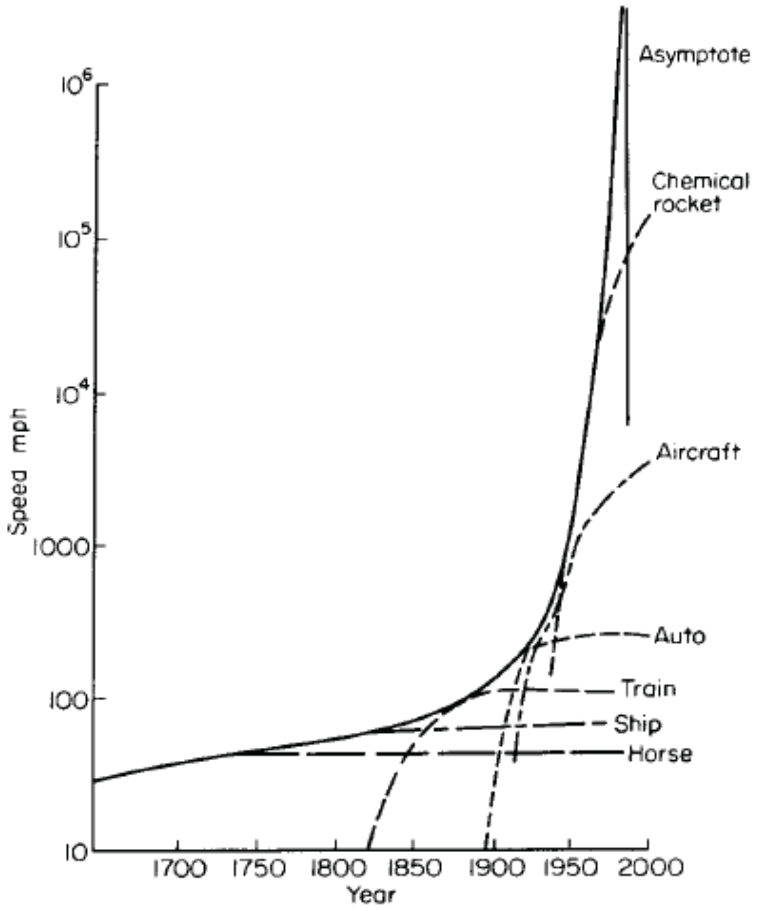
[The law of transformation of quantity into quality]

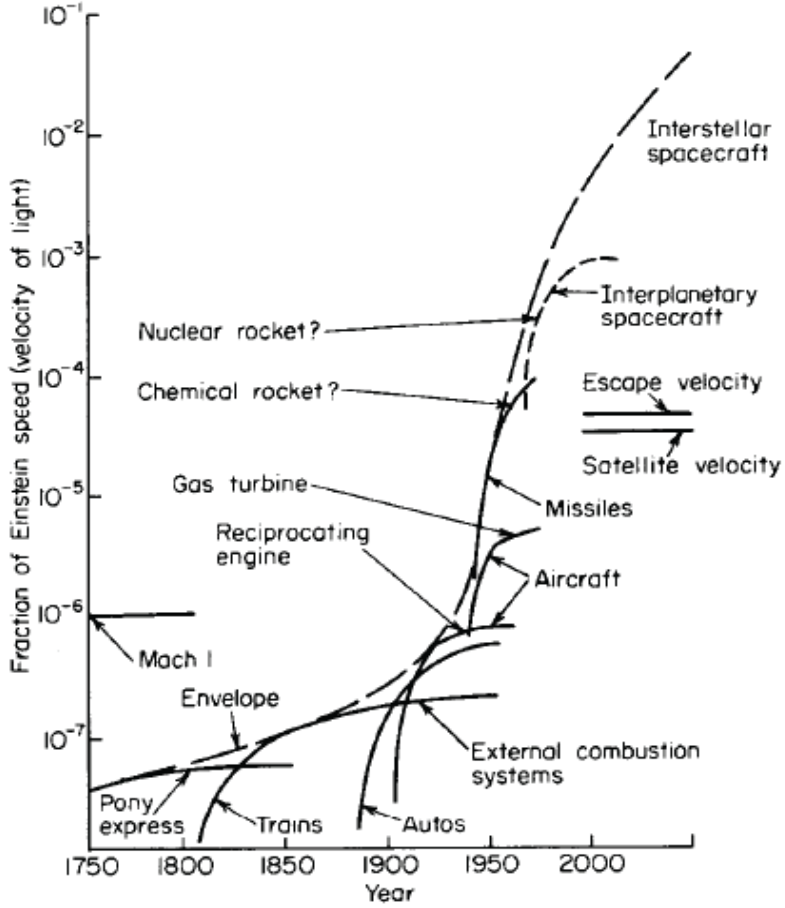
"For our purpose, we could express this by saying that in nature, in a manner exactly fixed for each individual case, qualitative changes can only occur by the quantitative addition or subtraction of matter or motion (so-called energy)."

[Engels' Dialectic of Nature. II. Dialectics. 1883]

Q5: So what?

[two ways to scale growing variable]





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