ICTP School on Applications of Open Spectrum and White Spaces Technologies
ICTP, Trieste-Miramare, 3 - 14 March 2014

Study on broadband penetration

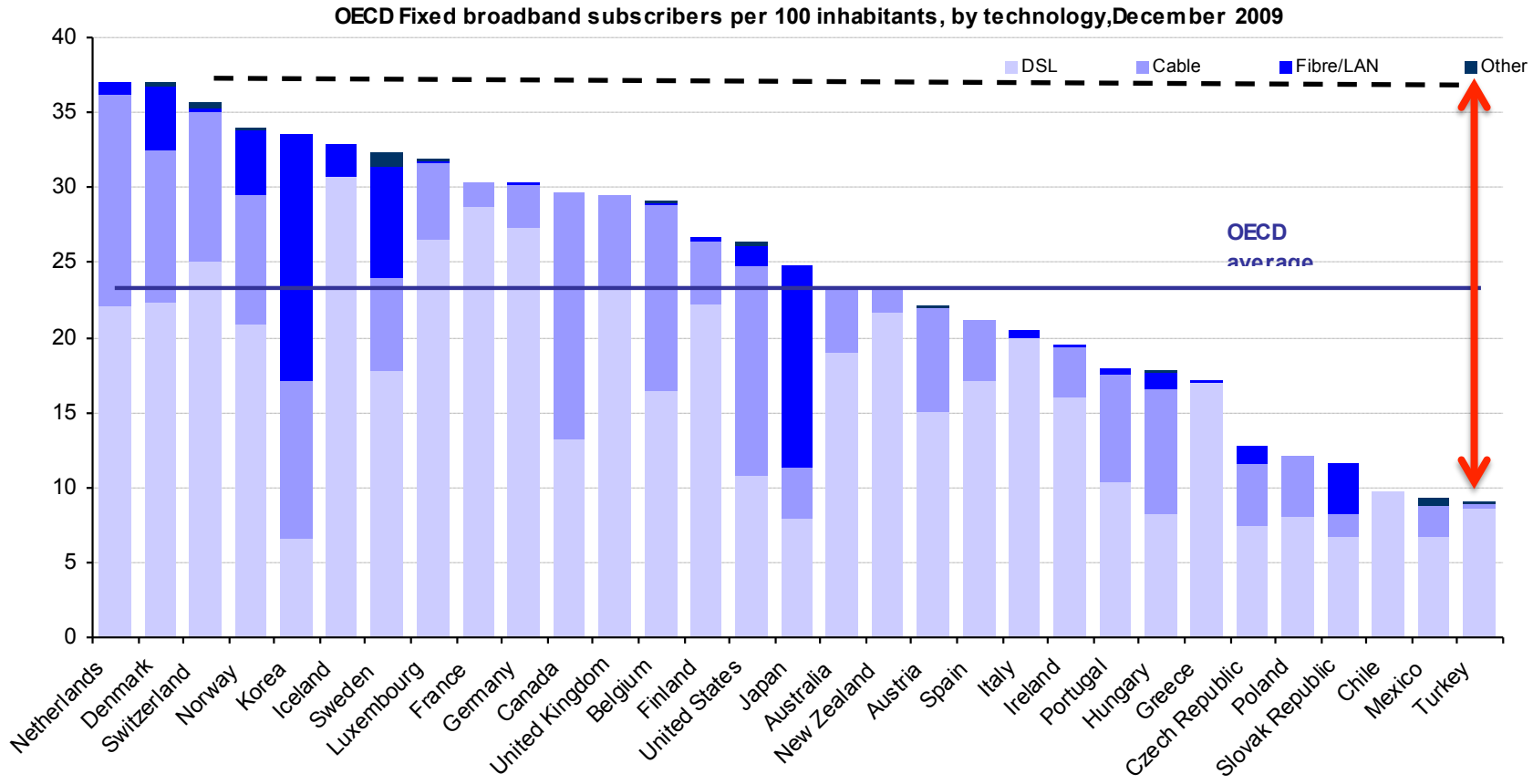
Prof. Ryszard Struzak

- Beware of misprints! These materials are preliminary notes intended for my lectures only and may contain misprints.
- Feedback is welcome: if you notice faults, or you have improvement suggestions, please let me know.
- This work is licensed under the Creative Commons Attribution License (http://creativecommons.org/ licenbses/by/1.0) and may be used freely for individual study, research, and education in not-for-profit applications. Any other use requires the written author's permission.
- These materials and any part of them may not be published, copied to or issued from another Web server without the author's written permission.
- If you cite these materials, please credit the author and ICTP.
- Copyright © 2012 Ryszard Struzak.

Topics

- Analysis of empirical data
  - Bb. household subscribers, 35 countries, 10 years
  - Technology-neutral models of bb. access growth
- Study of models - growth limits
- Application examples
- Analysis of correlation
- Comments on barriers & ways out

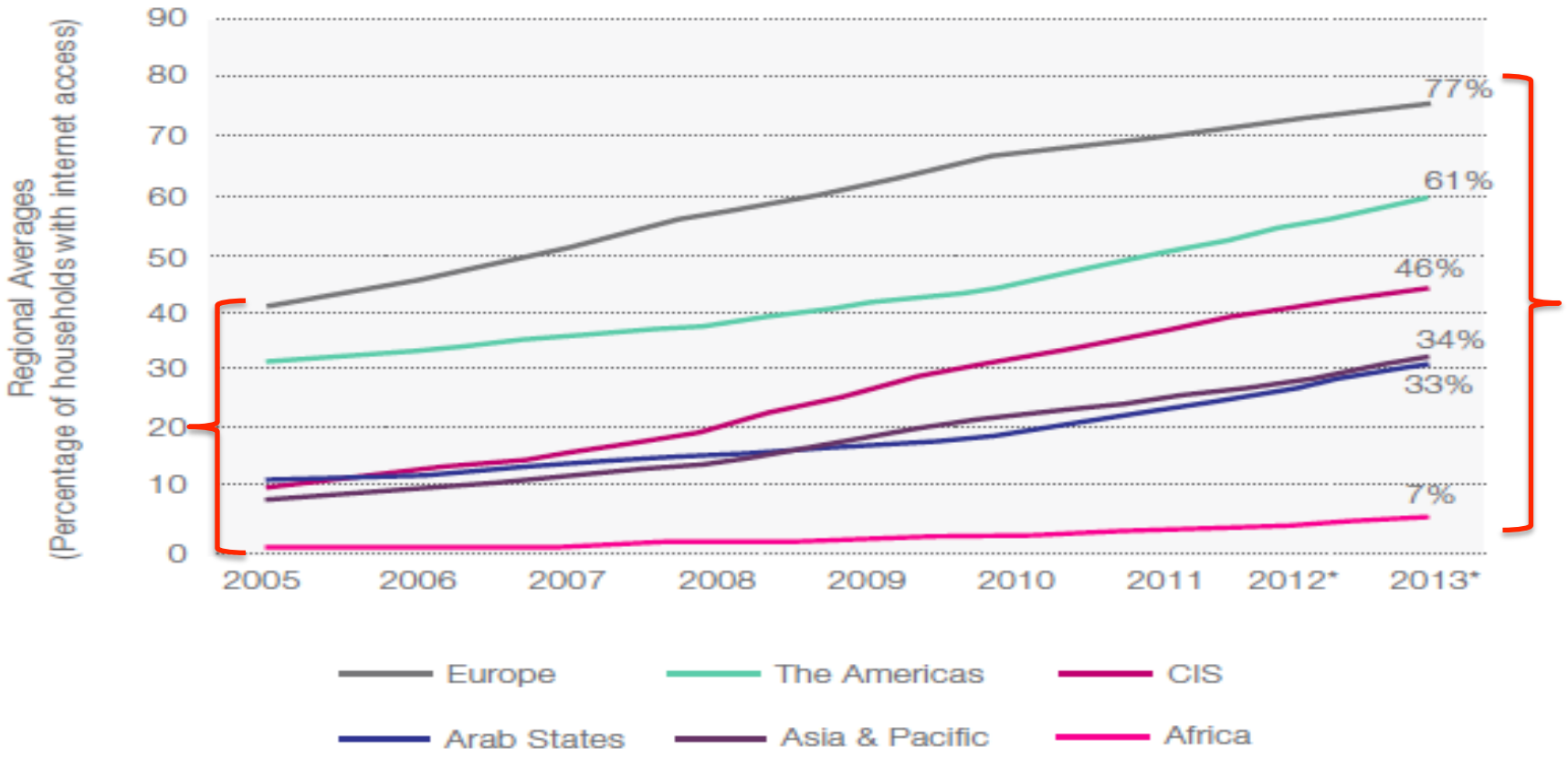
Bb. penetration rate in OECD



Source: OECD (Jan 2010)

Households with Internet Access (2005-2013)

Regional Averages

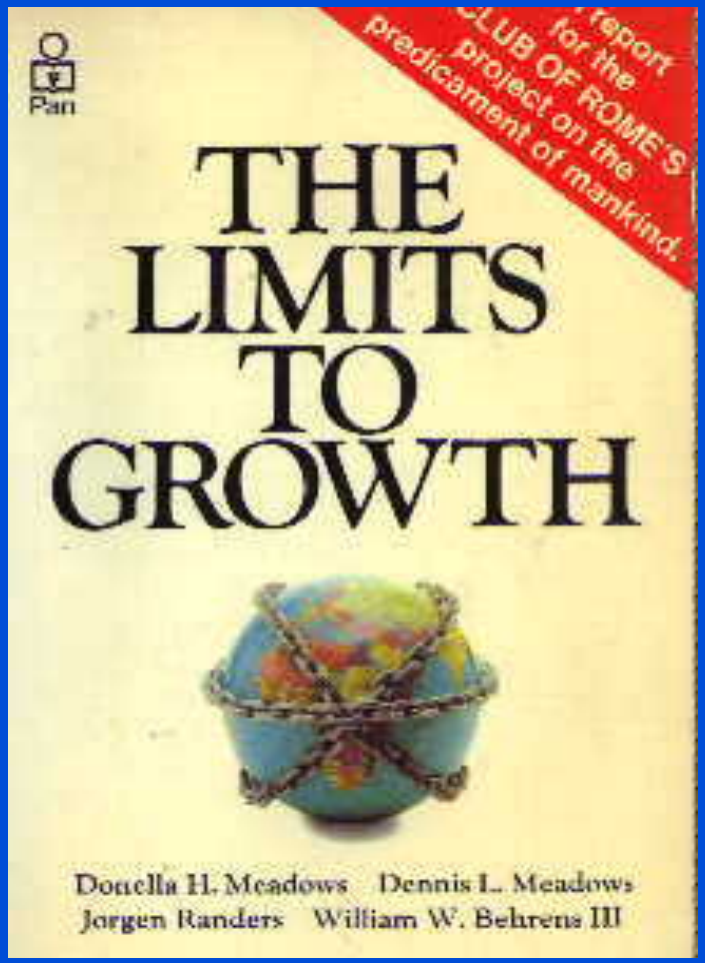


Source: The State of Broadband 2013: Universalizing Broadband. A report by the Broadband Commission, ITU & UNESCO Sept. 2013 (T.3)

Limits to growth

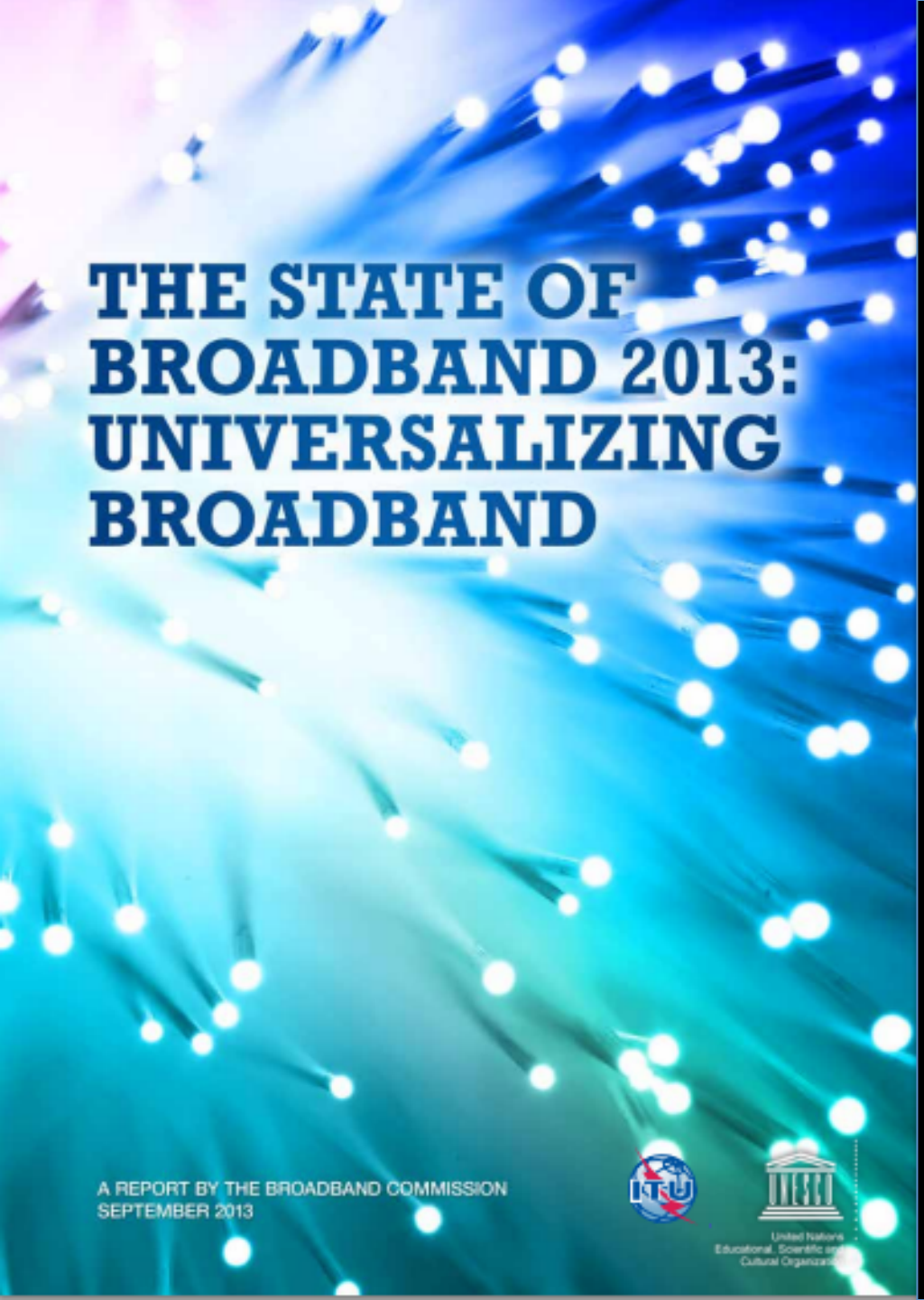
- Countries develop, but the digital divide increases faster

- Is there any natural limit?



OECD view

- Broadband is „a new territory” that creates new problems never met earlier…
- „…Governments should focus […] on improving metrics and analysis to better understand […] trends, their impacts on the economy and society as well as policy…”
  - *[OECD Council Recommendation on Broadband Developmant, 2004]*



UNESCO & ITU 2013

… broadband connectivity, services and applications are essential to modern society, offering widely recognized social and economic benefits.

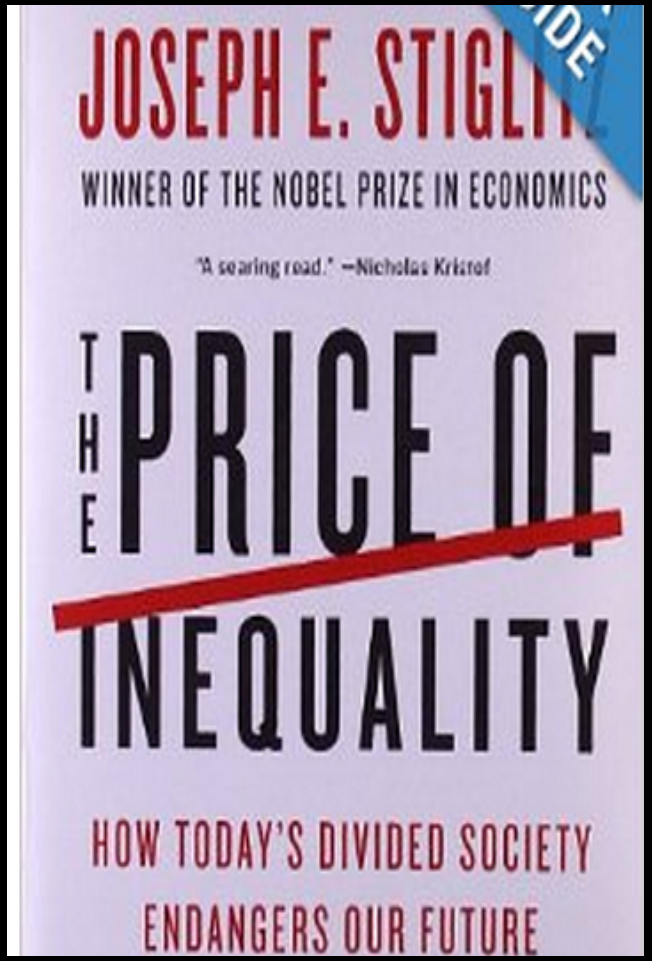
… the Commission views broadband as a cluster of concepts: always on, high-capacity connectivity enabling combined provision of multiple services …

www.broadbandcommission.org/Reports

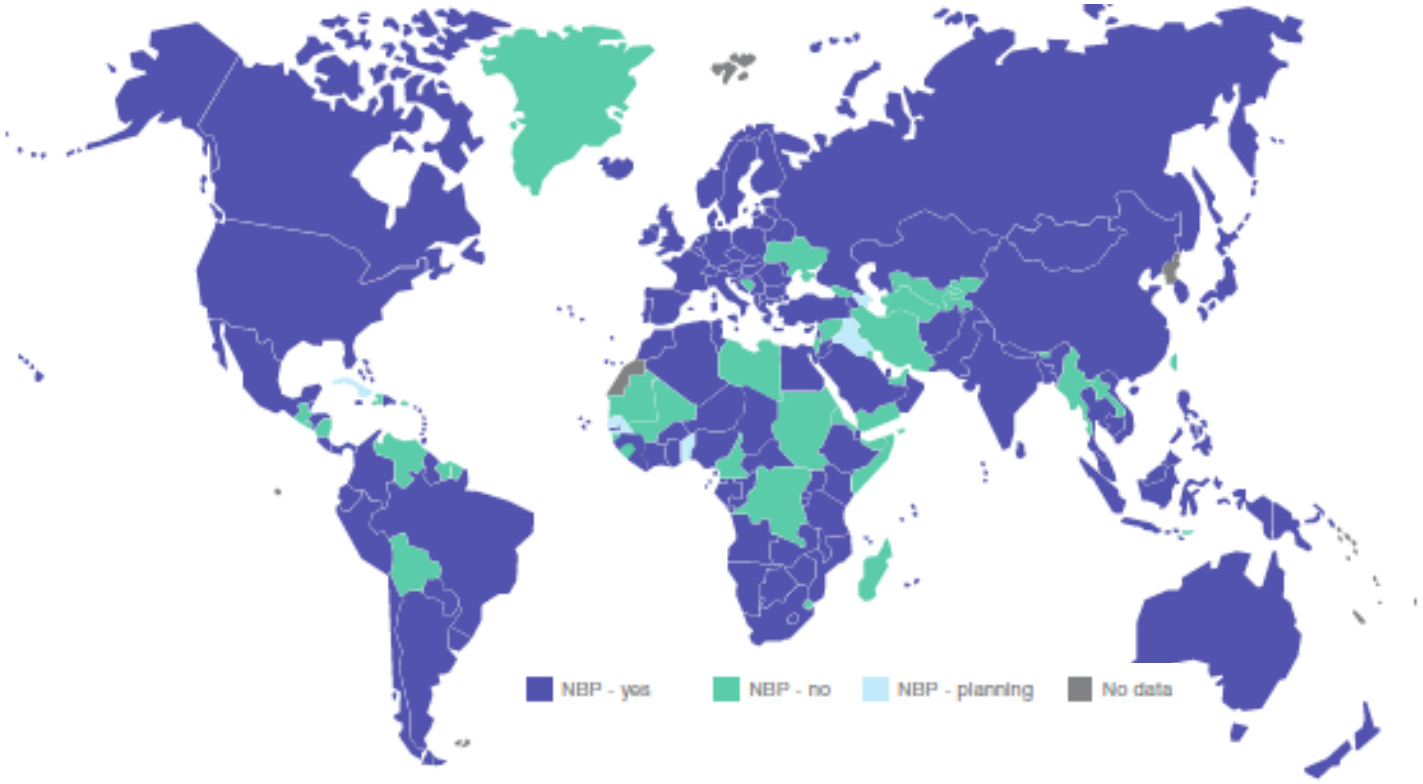
http://en.wikipedia.org/wiki/National_broadband_plans_from_around_the_world

- "Everyone, everywhere should have the opportunity to participate

- … no one should be excluded from the benefits of the Information Society offers."
  - The WSIS Declaration of Principles, 2003, item #4



National Broadband Plans (2013)



Source: The State of Broadband 2013: Universalizing Broadband - A report by the Broadband Commission, September 2013

Broadband Commission: by 2015, Internet user penetration should reach 60%worldwide, 50% in developing countries and 15% in LDCs.

http://en.wikipedia.org/wiki/National_broadband_plans_from_around_the_world

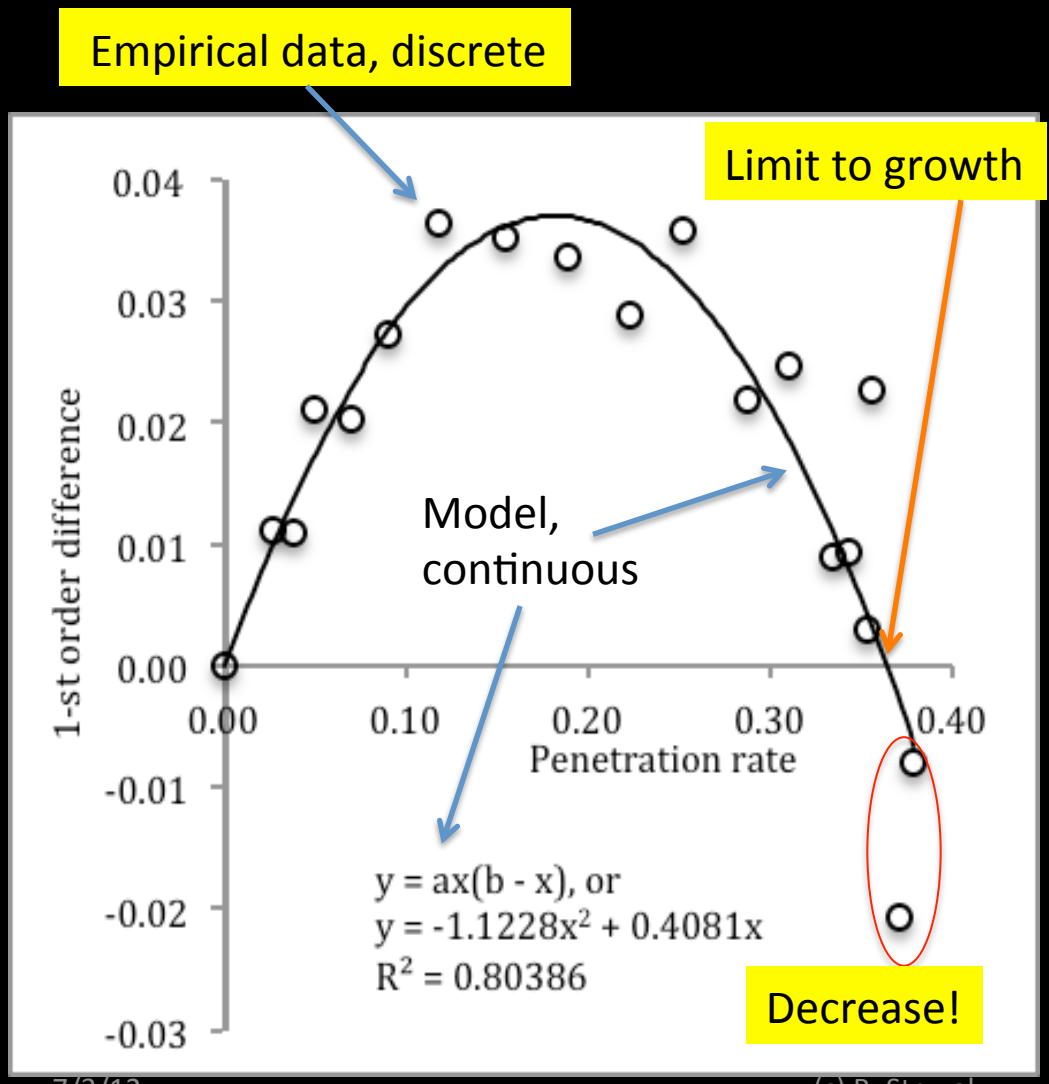
Topics for discussion

- Analysis of empirical data
  - Bb. household subscribers, 35 countries, 10 years
  - Technology-neutral models of bb. access growth
- Study of models
  - Growth limits (irreducible gaps)
- Application examples
- Analysis of correlation
- Comments on barriers & ways out

Country data ingested

Australia
Austria
Belgium
Bulgaria
Canada
Cyprus
Czech Rep.
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Iceland
Ireland
Italy
Japan
Latvia
Lithuania
Luxemburg
Malta
Mexico
Netherlands
Norway
Poland
Portugal
Rep. of Korea
Romania
Slovakia
Slovenia
Spain
Sweden
U. Kingdom
United States

Penetration rate (example Netherlands 2000-2010)



R^2 (coeff. of determination) is a standard measure of the match between the model and observations

$R^2 = 1$: the model perfectly matches the data and explains fully their variability.

$R^2 = 0$: model and observation are completely unrelated.

$0 < R^2 < 1$: some observations do not fit the model.

Models (normalized)

Differential equation:

$$\frac{dx}{dt} = x(1-x)$$

Continuous logistic model:

$$x(t) = \frac{1}{1+\exp(-t)}$$

Difference equation:

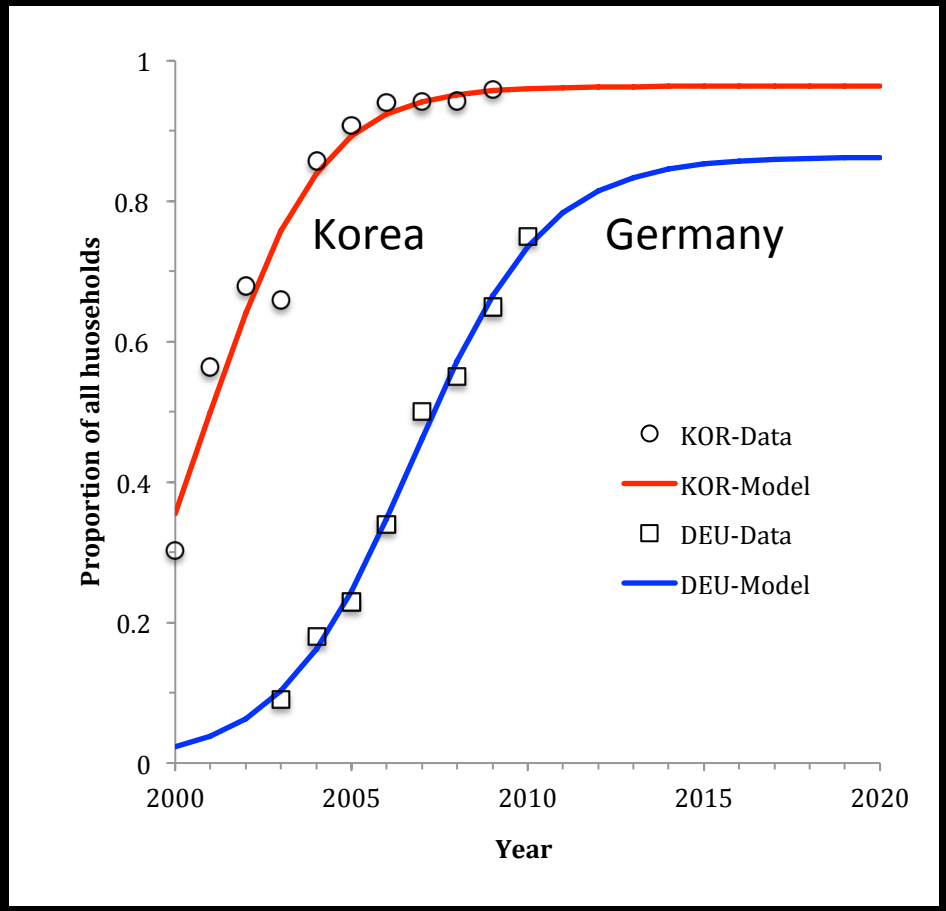
$$\frac{\Delta x}{\Delta t} = x(1-x)$$

Discrete logistic model:

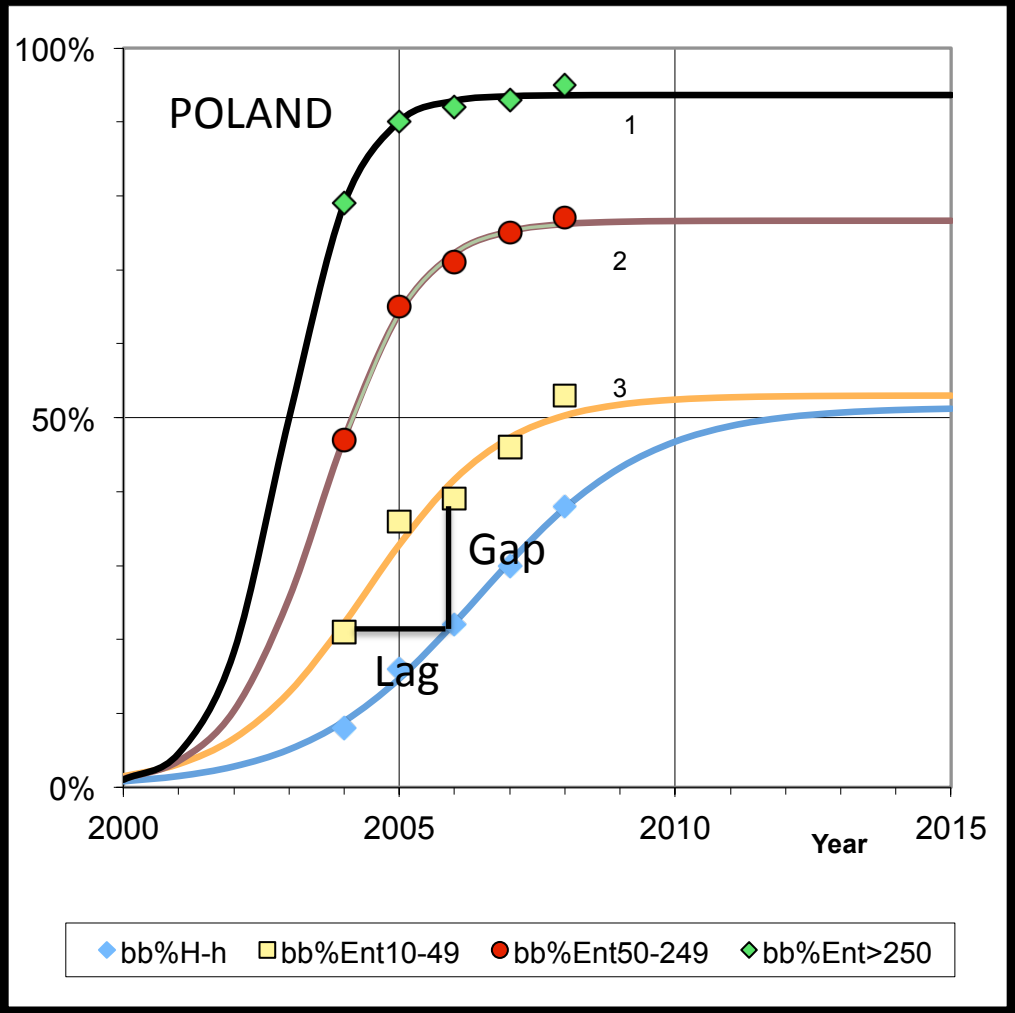
$$x(t+\Delta t) = rx(t)[1-x(t)]$$

Continuous models

$$x(t) = \frac{a}{1 + \exp[b(c - t)]}$$

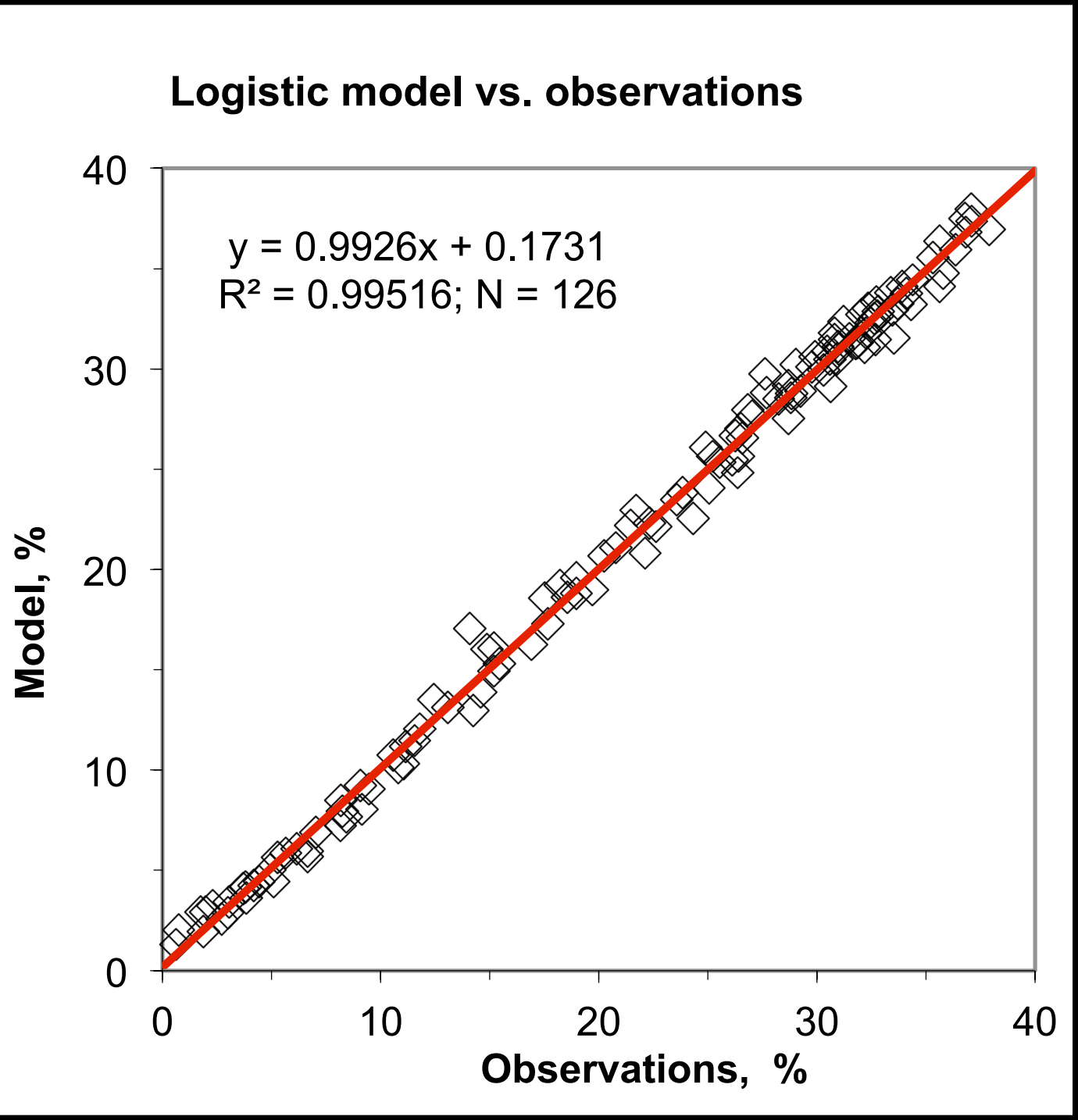


- Numerical values of a, b, c represent all the relevant factors: financial, technical, regulatory, cultural, etc. determined for each country

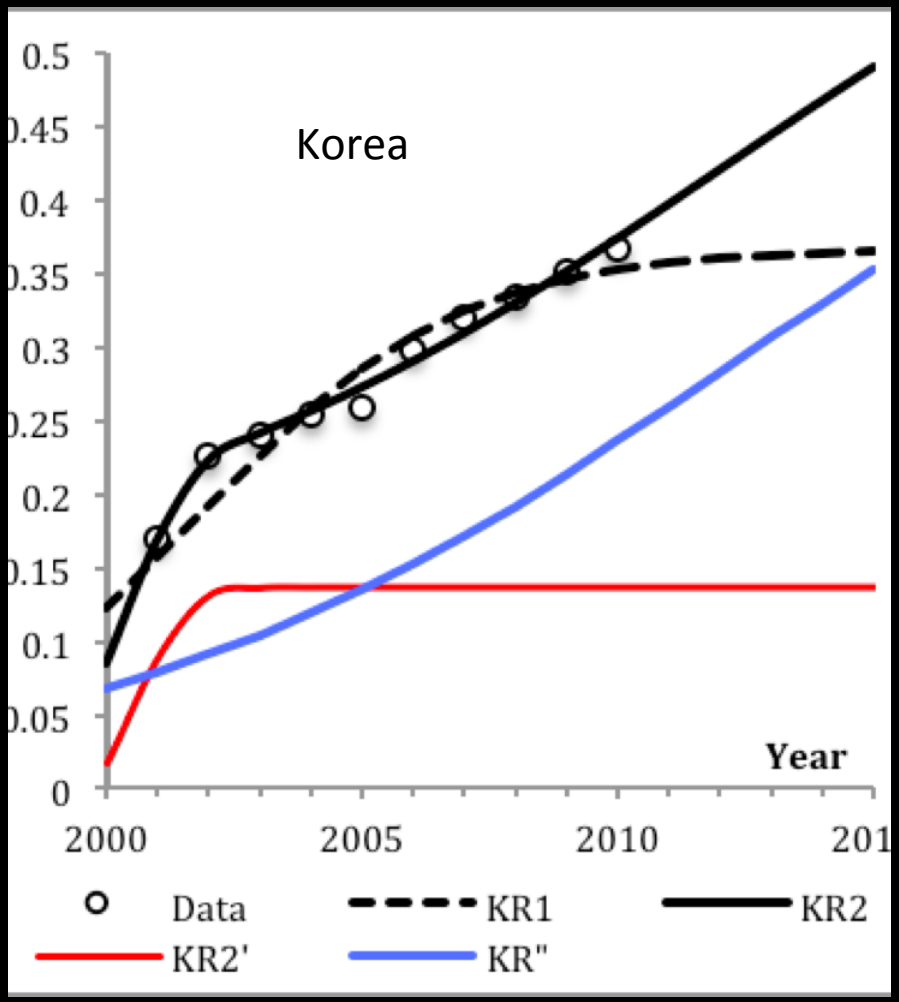


3 parameters combine all the factors that influence the process: financial, social, technical, human, regulatory, etc.

Analogue; a sinusoid depends on 3 parameters too

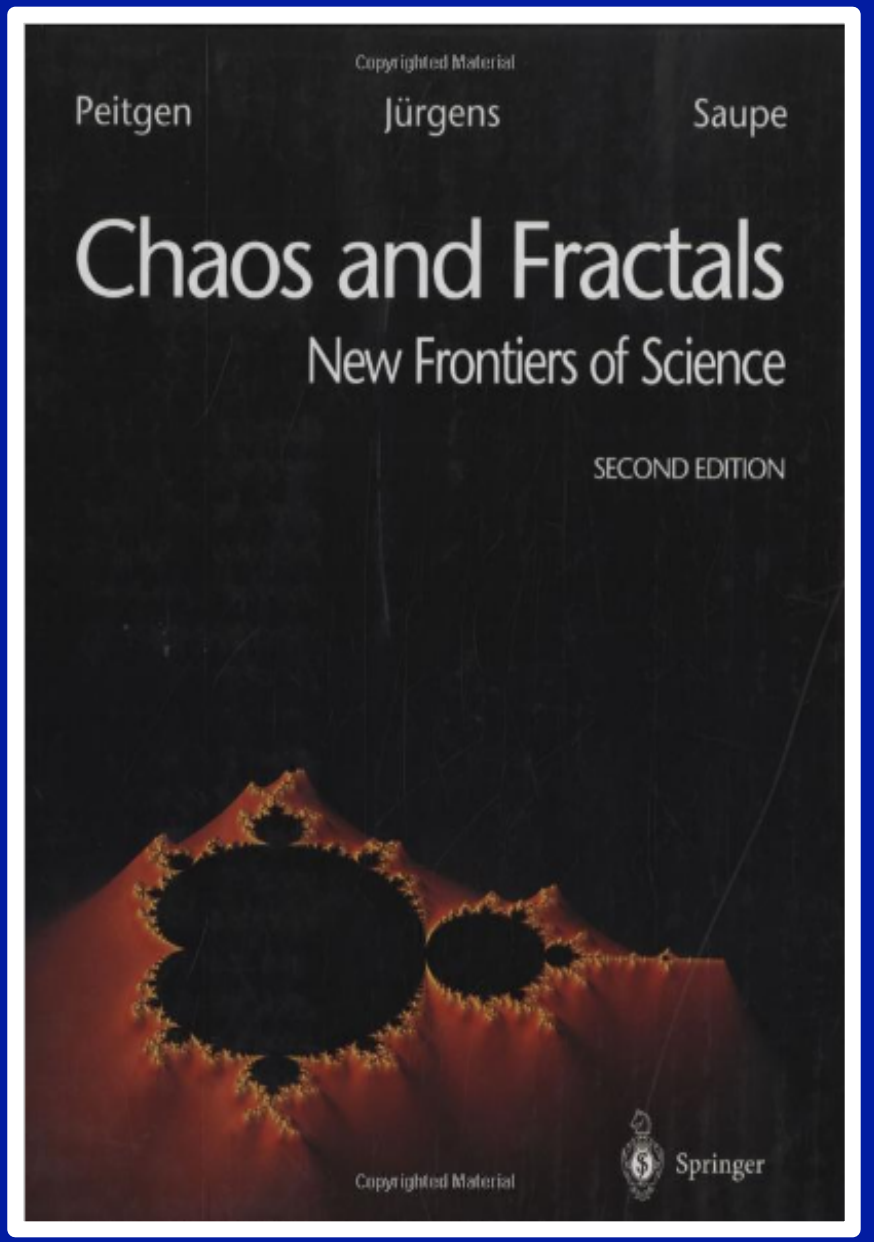

Logistic model vs. observations
y = 0.9926x + 0.1731
R² = 0.99516; N = 126
Model, %
Observations, %
0
10
20
30
40

Multiple logistic models



- The logistic function cannot approximate decreasing trends
- Two (or more) logistic functions can model both increasing and decreasing trends

$$p = \sum_{i=1}^{N} \frac{a_i}{1 + \exp[b_i(c_i - t)]}$$

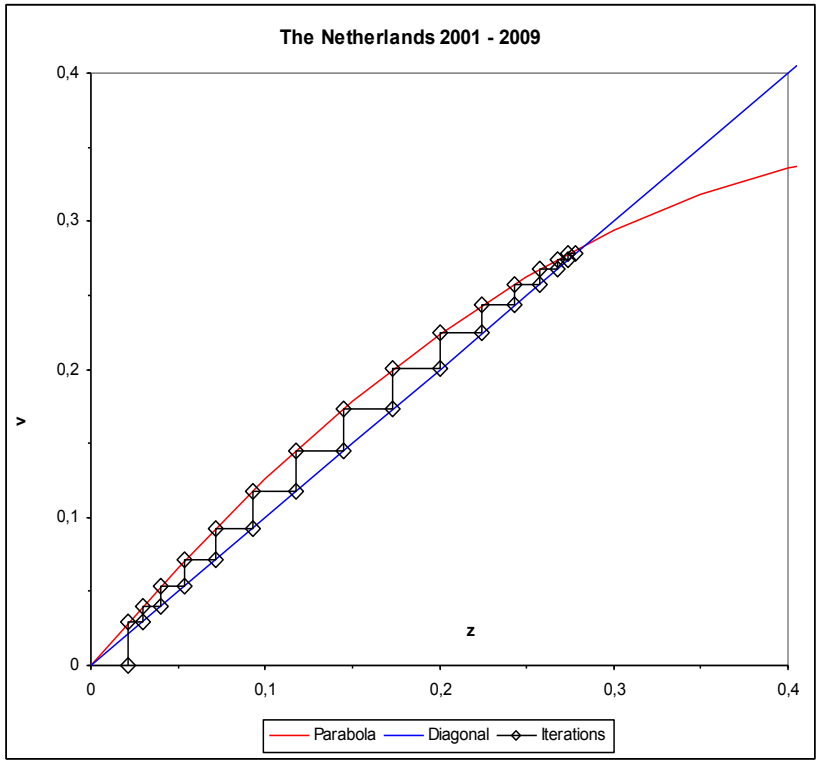


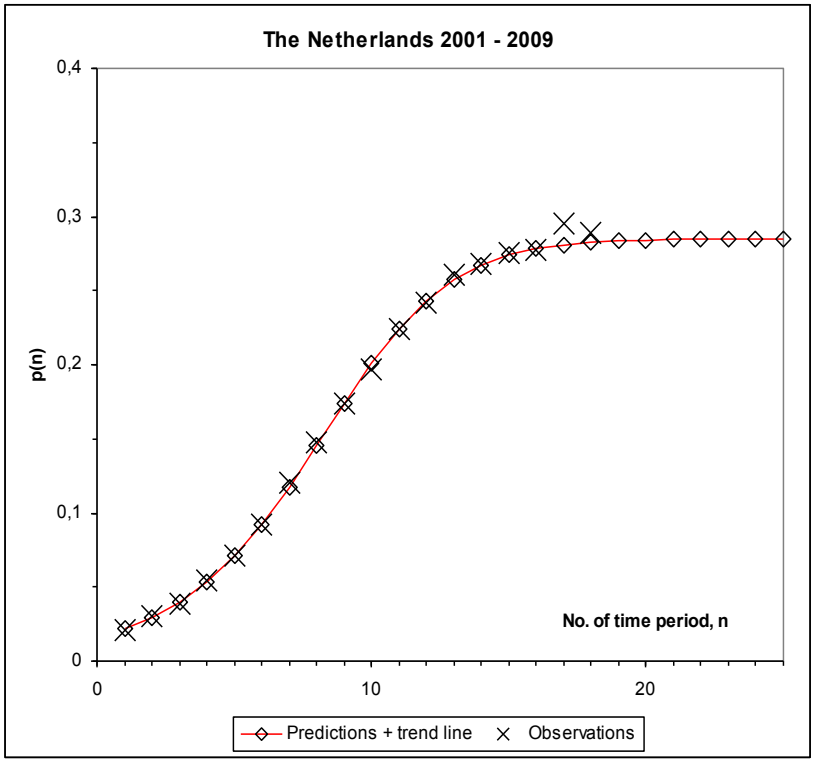
Discrete model

$$x(t+\Delta t) = rx(t)[1-x(t)]$$

- Finite difference (discrete) model, or logistic map may lead to monotonic, non-monotonic, periodic, or chaotic behavior, depending on “r”

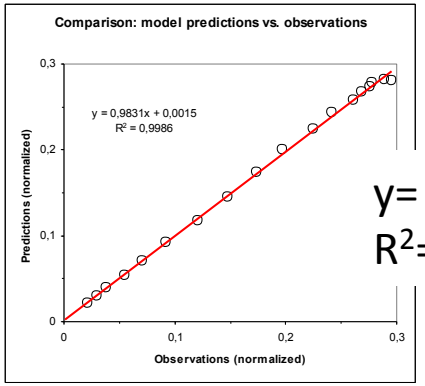
Discrete model: monotonic growth





$$z_n = \frac{a}{1+ab} p_n, \; or \;\; p_n = \frac{1+ab}{a} z_n$$

$$z_{n+1} = r z_n (1 - z_n), \; with \;\; r = (1+ab)$$



y= 0,9831x+0,0015

R^2=0,9986

Discrete model: cyclic variations

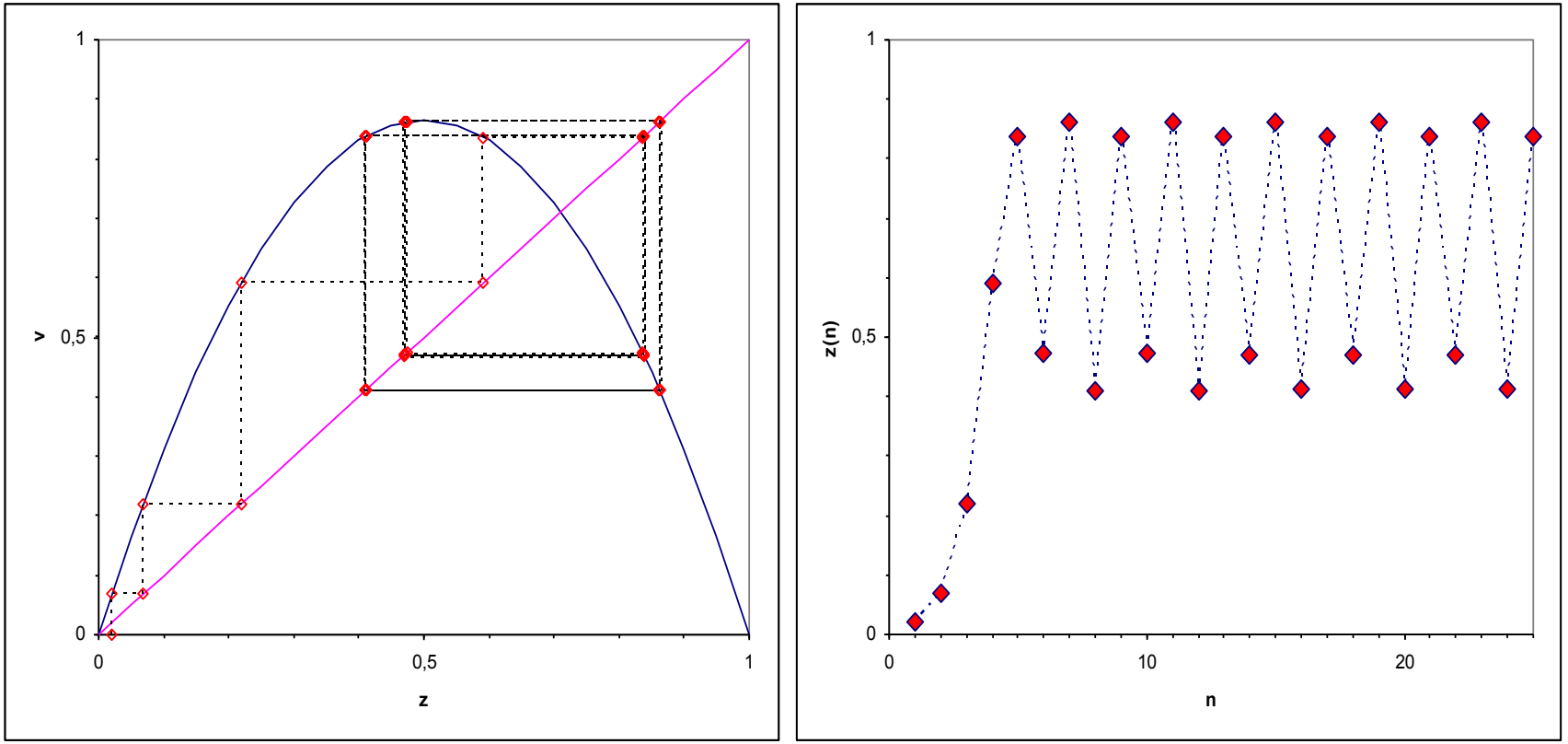


Figure 8. Left: Graphical iteration of relation (11) for z_0 = 0,02 and r = 3,46.
Right: Results of 25 iterations (left diagram) as time series.

Discrete model: chaotic fluctuations

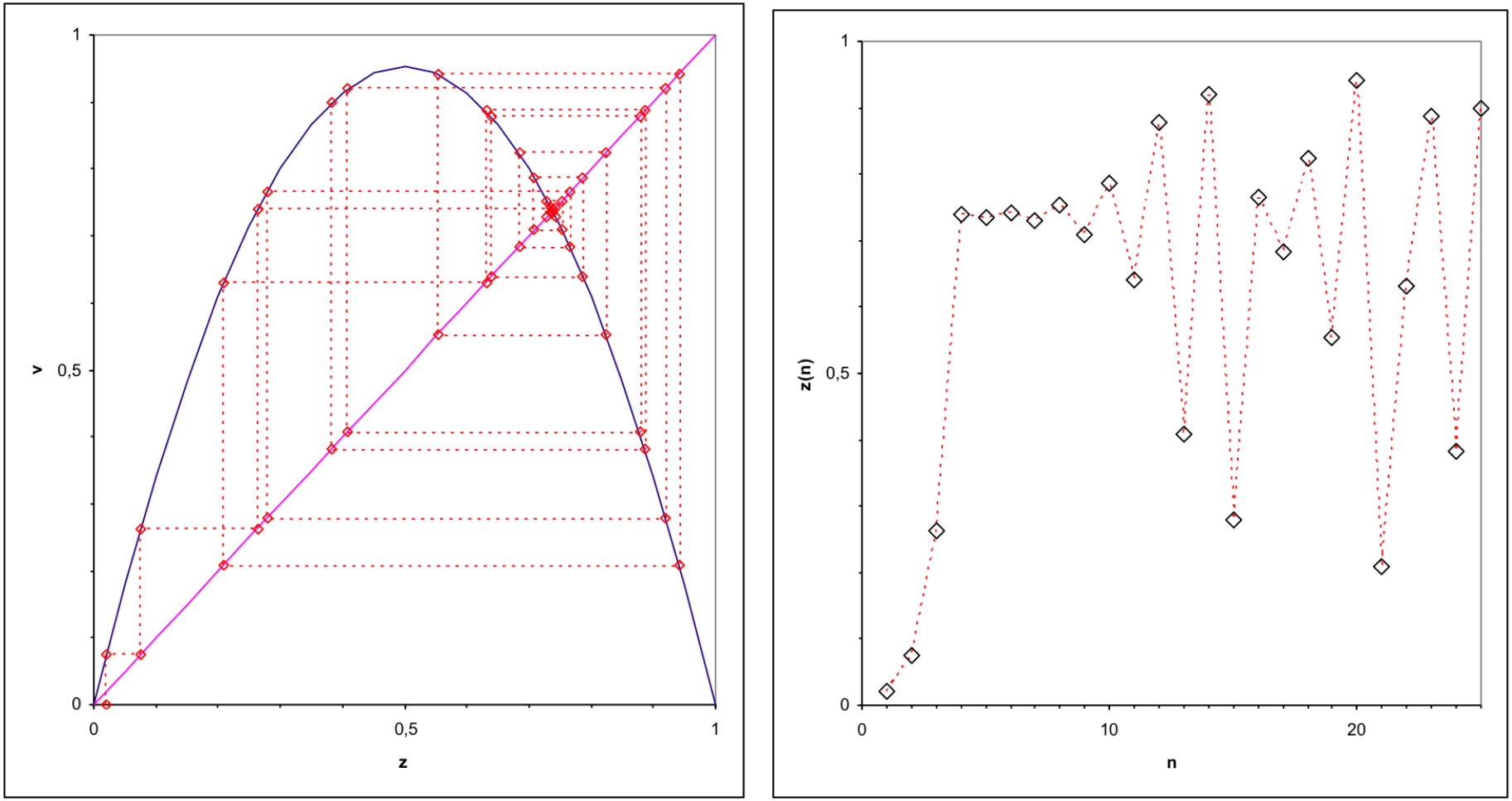
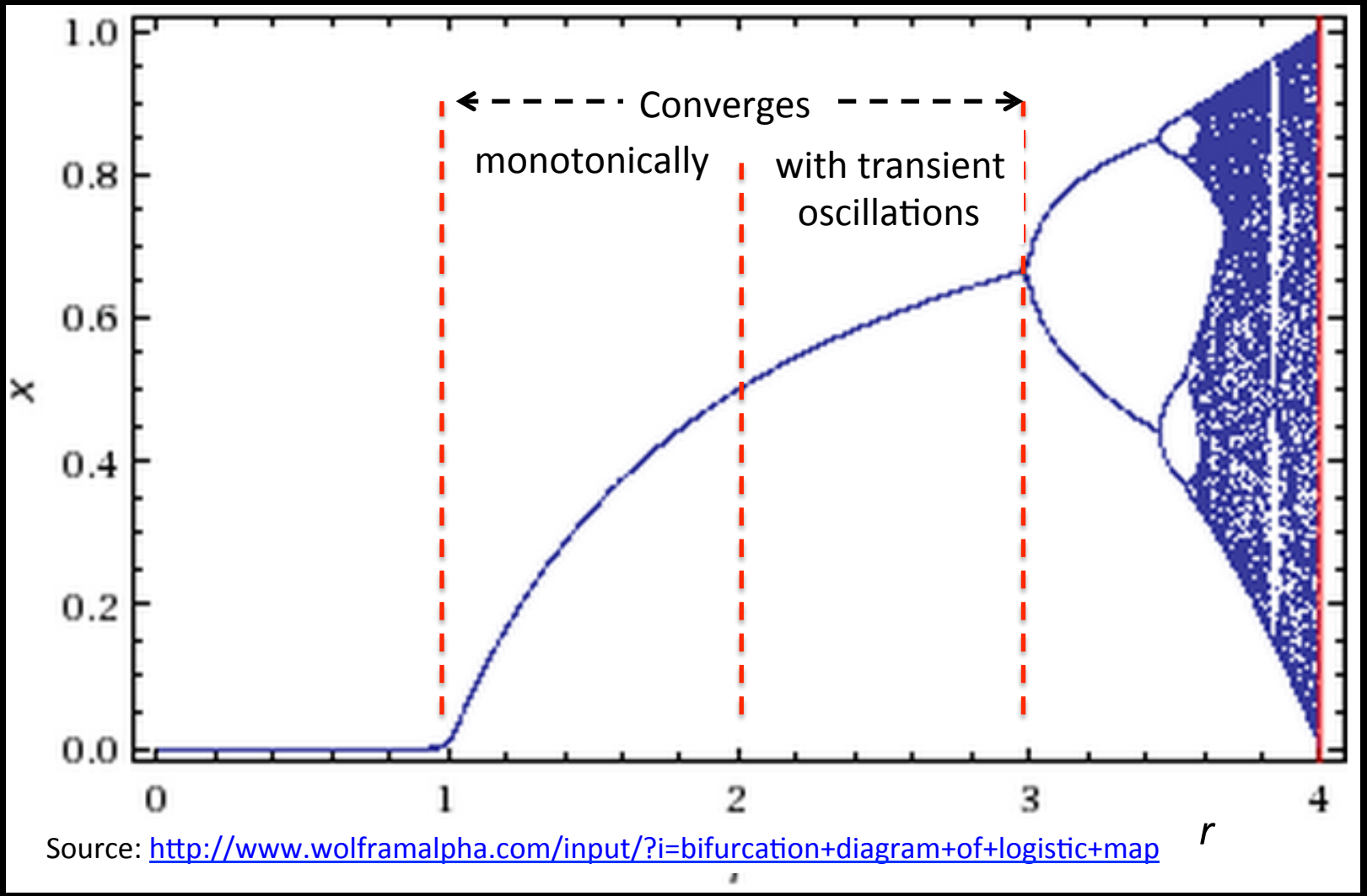


Figure 10. Left: Graphical iteration of recurrence relation (11) for z_0 = 0,02 and r = 3,81. Right: Results of 25 iterations (from the left diagram) as time series.

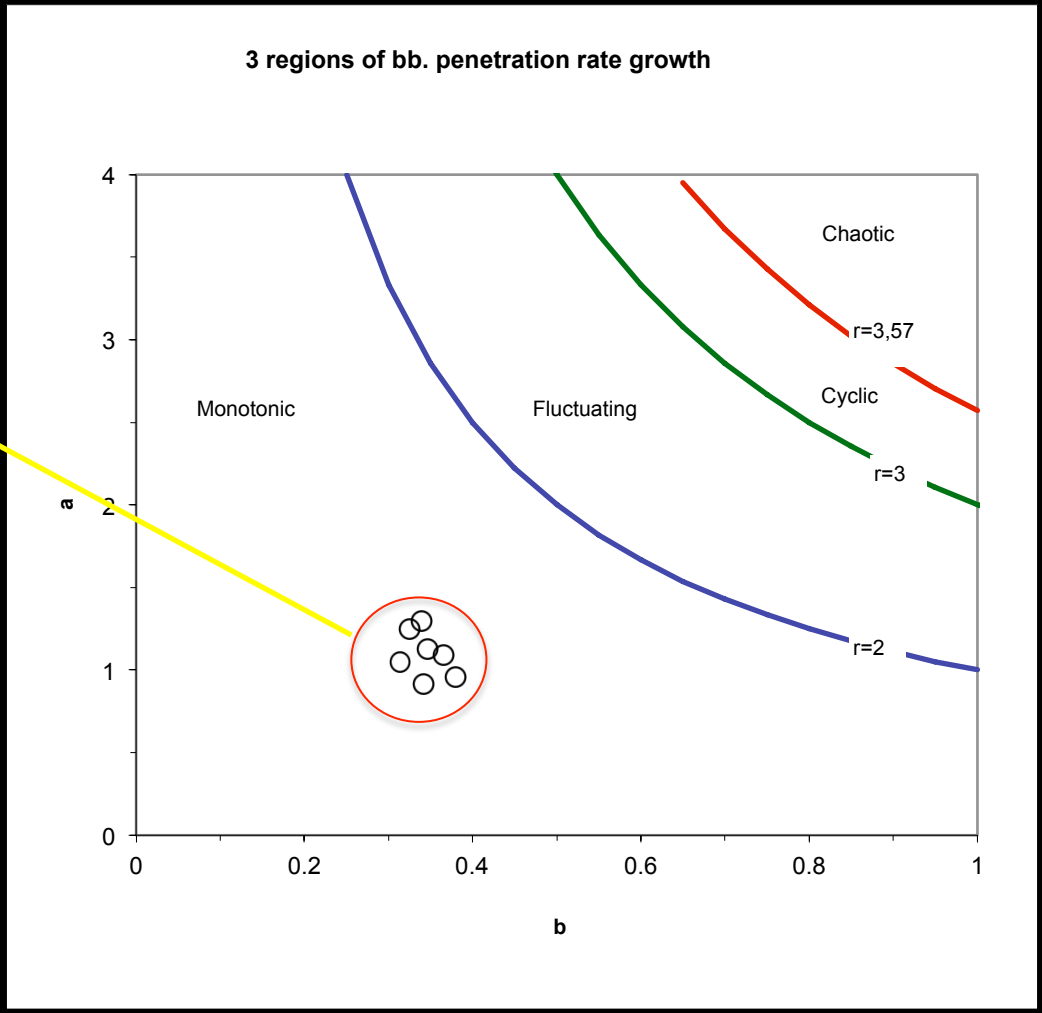
Bifurcation diagram of the logistic map



Source: http://www.wolframalpha.com/input/?i=bifurcation+diagram+of+logistic+map

Regions of bb. penetration rate growth

7 leading EU countries



Potential consequences of ignoring the limits

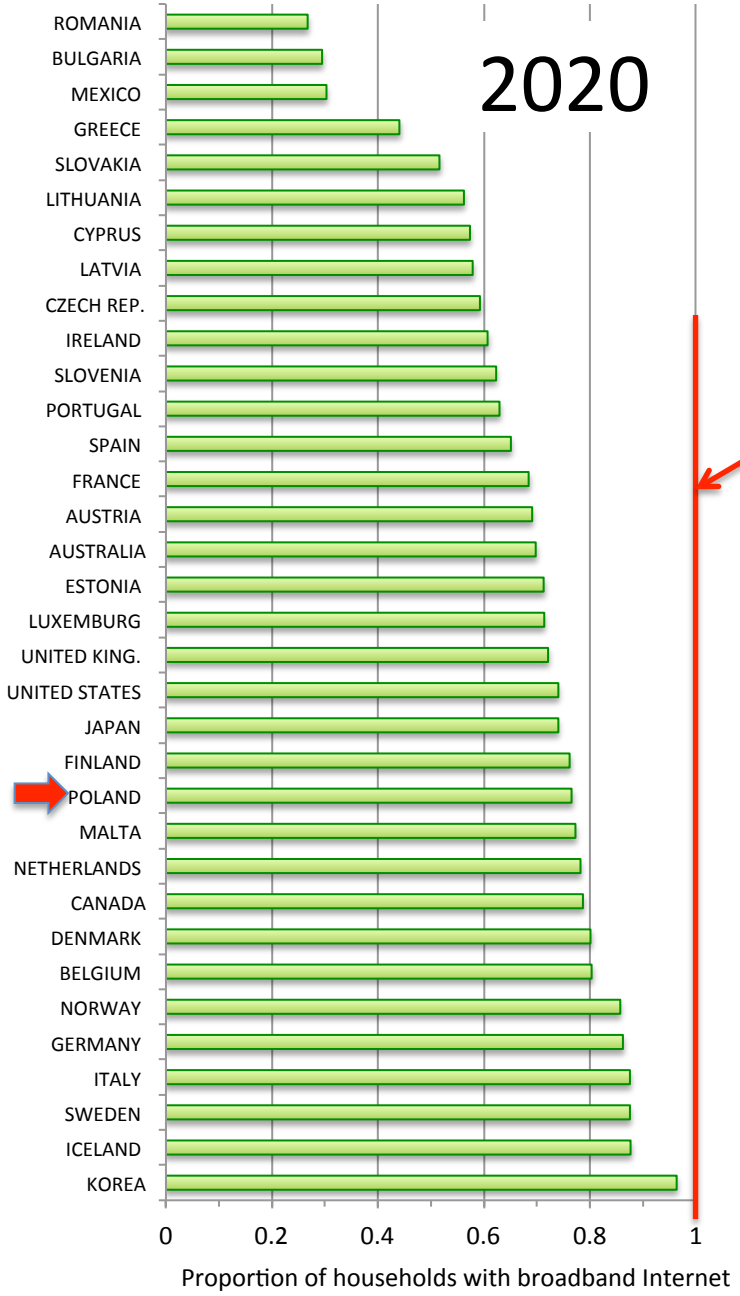
- Wrong targets
- Unrealizable projects
- Increased costs
  - due to delays and necessary corrections
- Frustrations
- Eroding confidence
  - in the competence of experts & politicians that propose (or endorse) such unrealizable projects

Topics for discussion

- Analysis of empirical data
  - Bb. household subscribers, 35 countries, 10 years
  - Technology-neutral models of bb. access growth
- Study of models
  - Growth limits (irreducible gaps)
- Application examples
- Analysis of correlation
- Comments on barriers & ways out

- The findings can be useful in:
  - planning,
  - design,
  - implementation/deployment,
  - performance tracking

  of broadband infrastructure



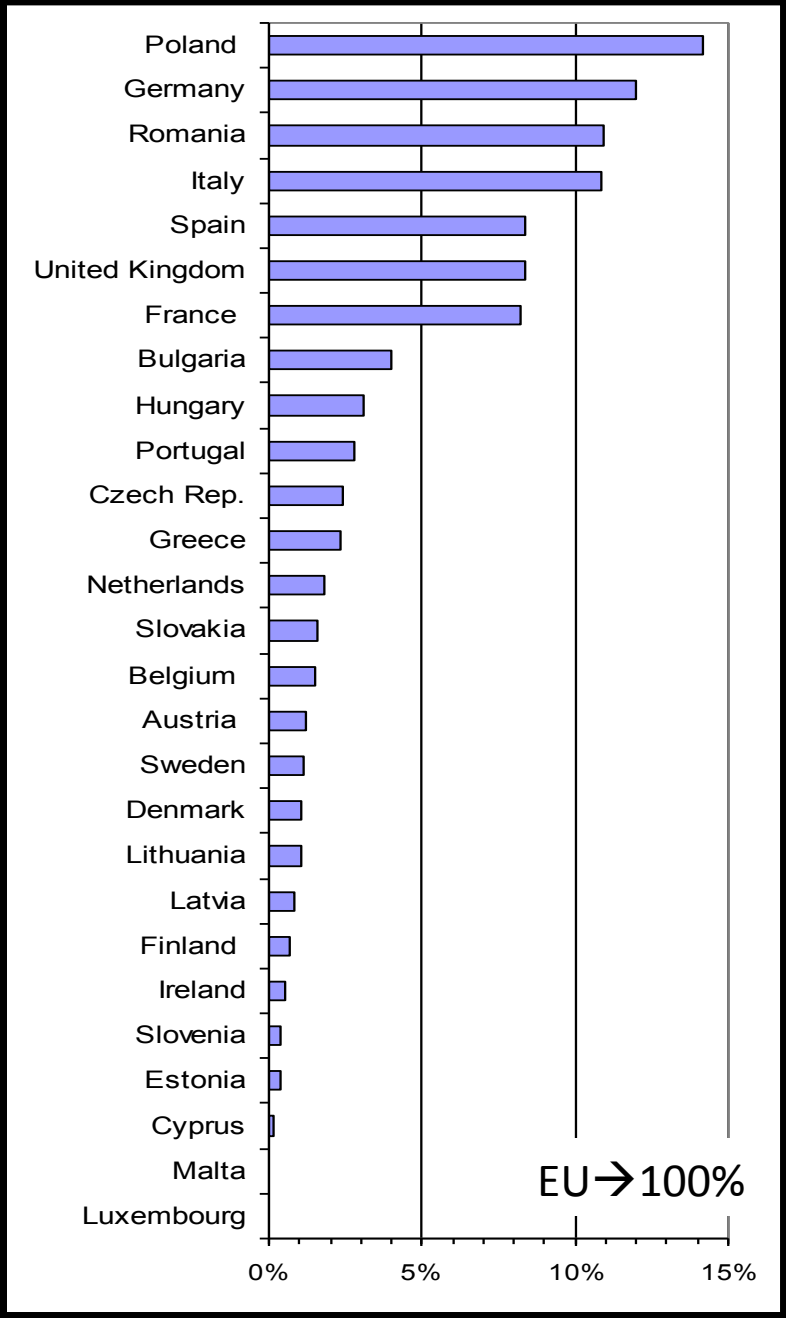
Checking the EU target

- The EU 2020 target: 100% of households (30 Mbytes/s)

  (and > 50% with 100 Mbytes/s.)

- No EU country can reach the target with present a, b, c

- The targets must be changed, or new development mechanism applied, or an extra (public) aid employed

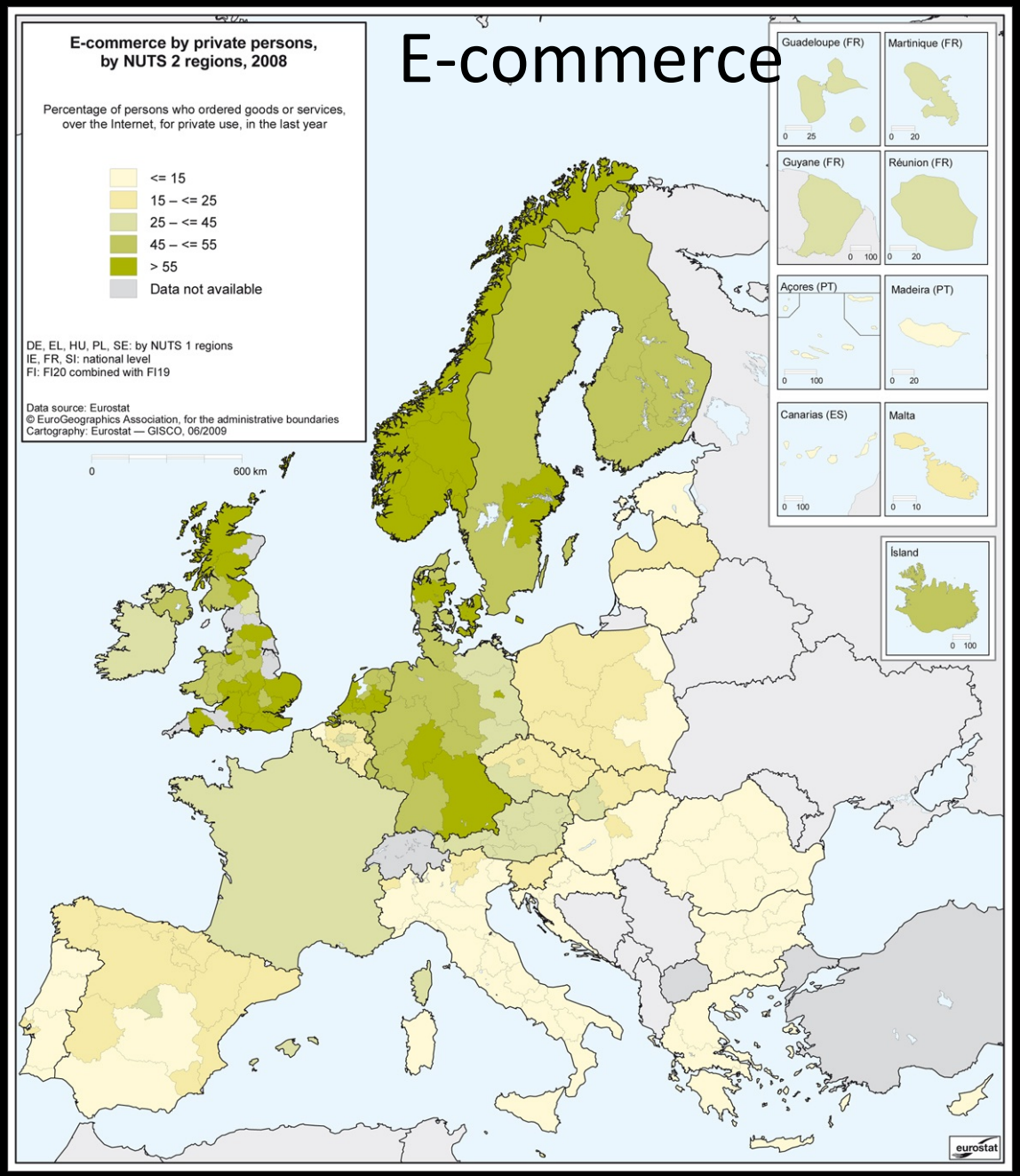


Distributing the EU aid

- Reaching an uniform penetration rate means diversified aid
- The models can help in the distribution of aid in a reasonable and just way

Source: R Struzak: „*Broadband Internet in EU Countries: Limits to Growth*"; IEEE Comms. Mag. Apr.2010

E-commerce



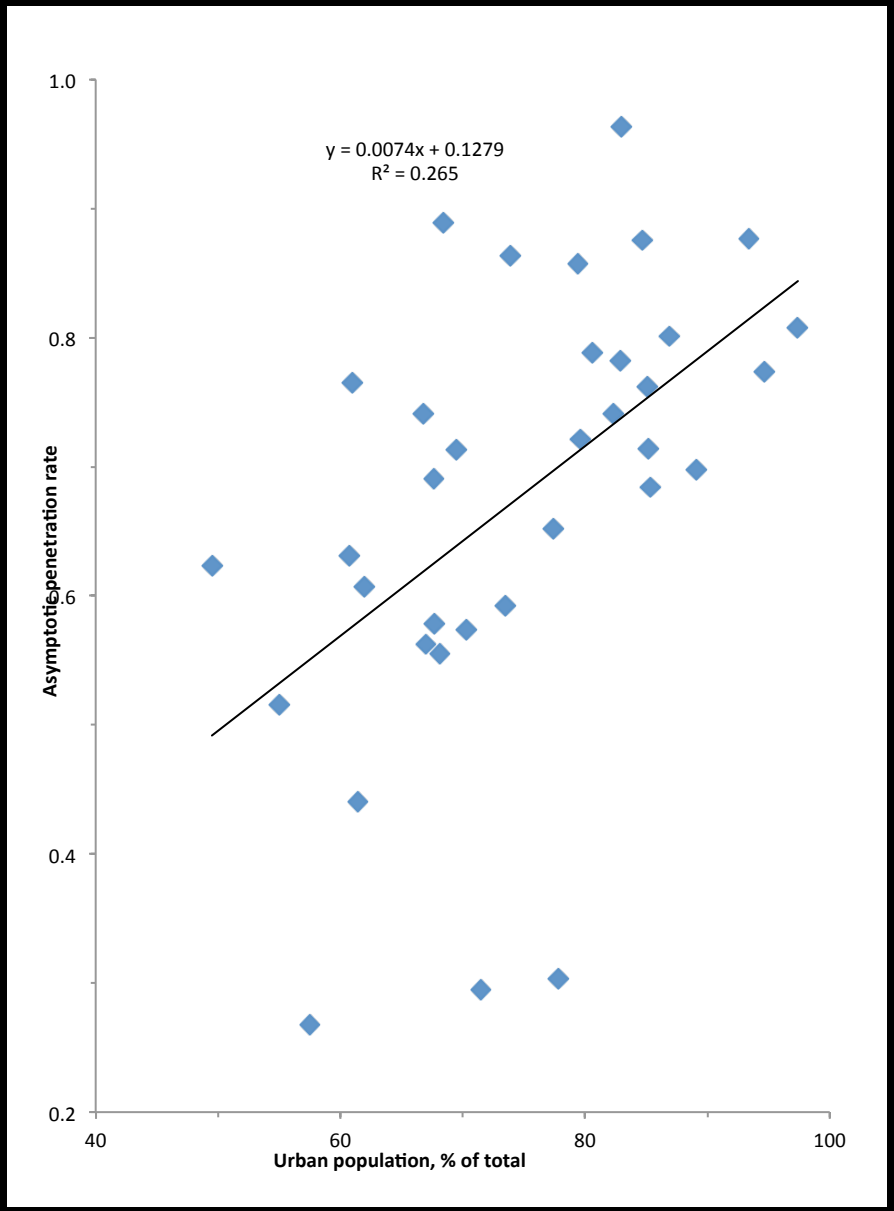
Popularity of broadband services varies among lowest administrative units

The aid is not distributed following reasonable and transparent rules

Models could help

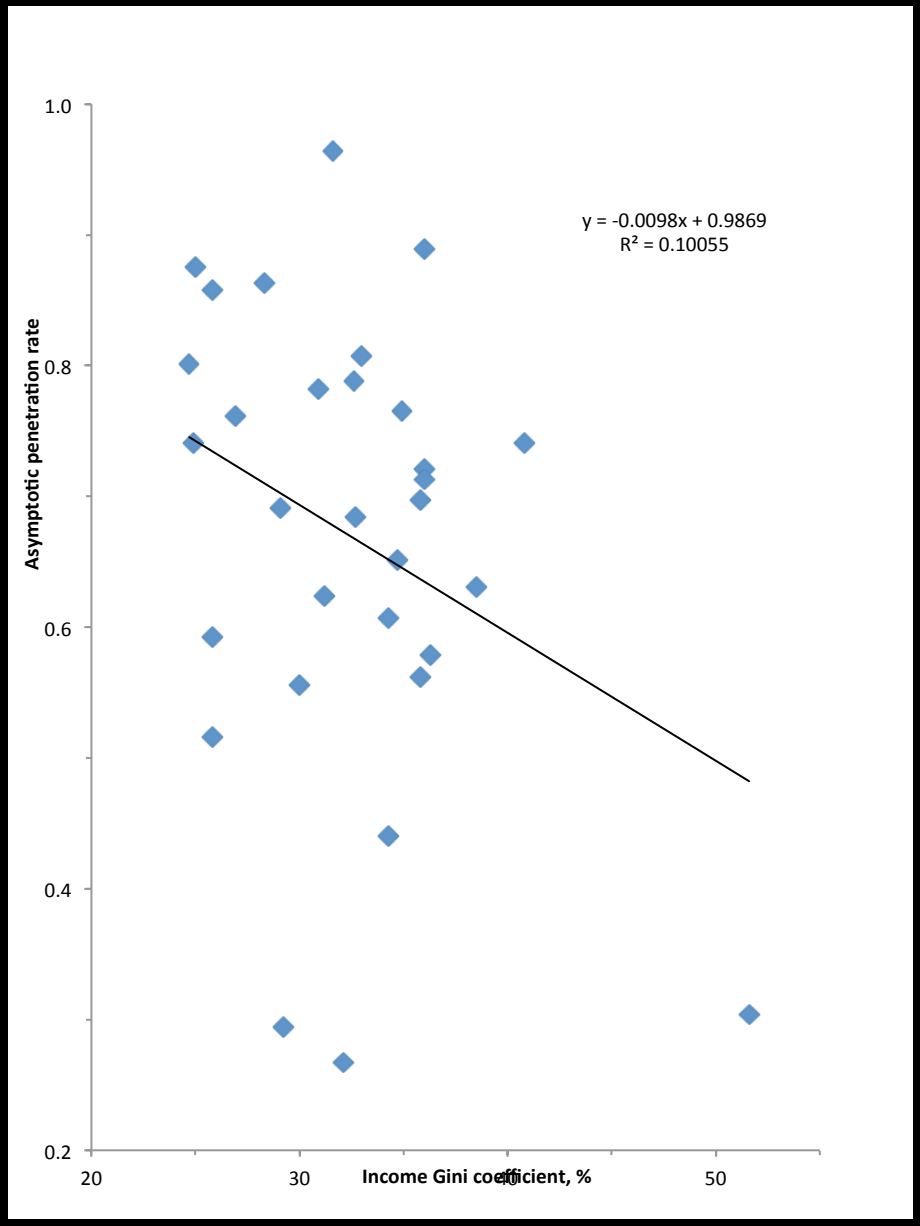
Topics for discussion

- Analysis of empirical data
  - Bb. household subscribers, 35 countries, 10 years
  - Technology-neutral models of bb. access growth
- Study of models
  - Growth limits (irreducible gaps) for each country
- Application examples
- Analysis of correlation
- Comments on barriers & ways out



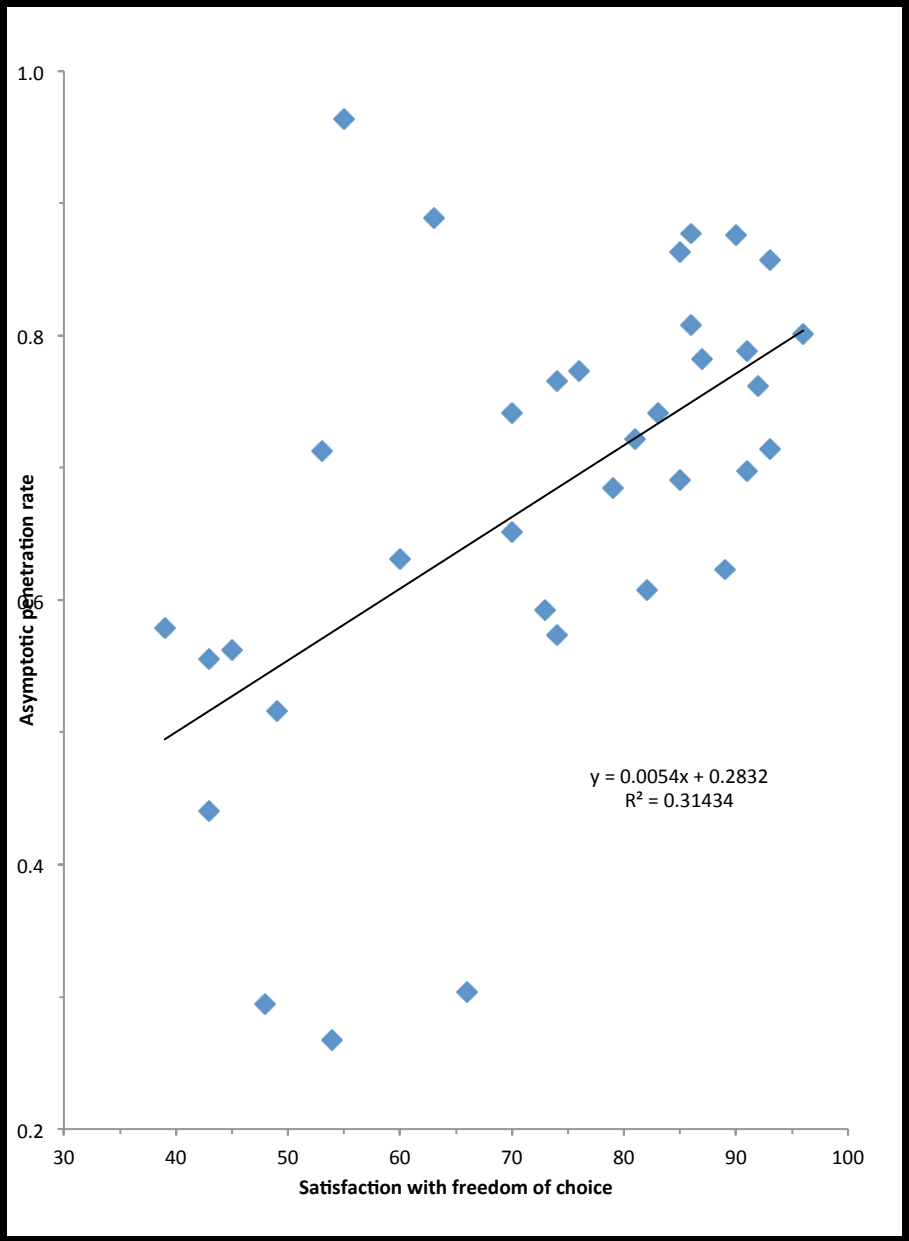
The urbanization vs. asymptotic penetration of broadband Internet in households

$R^2 = 0.265$



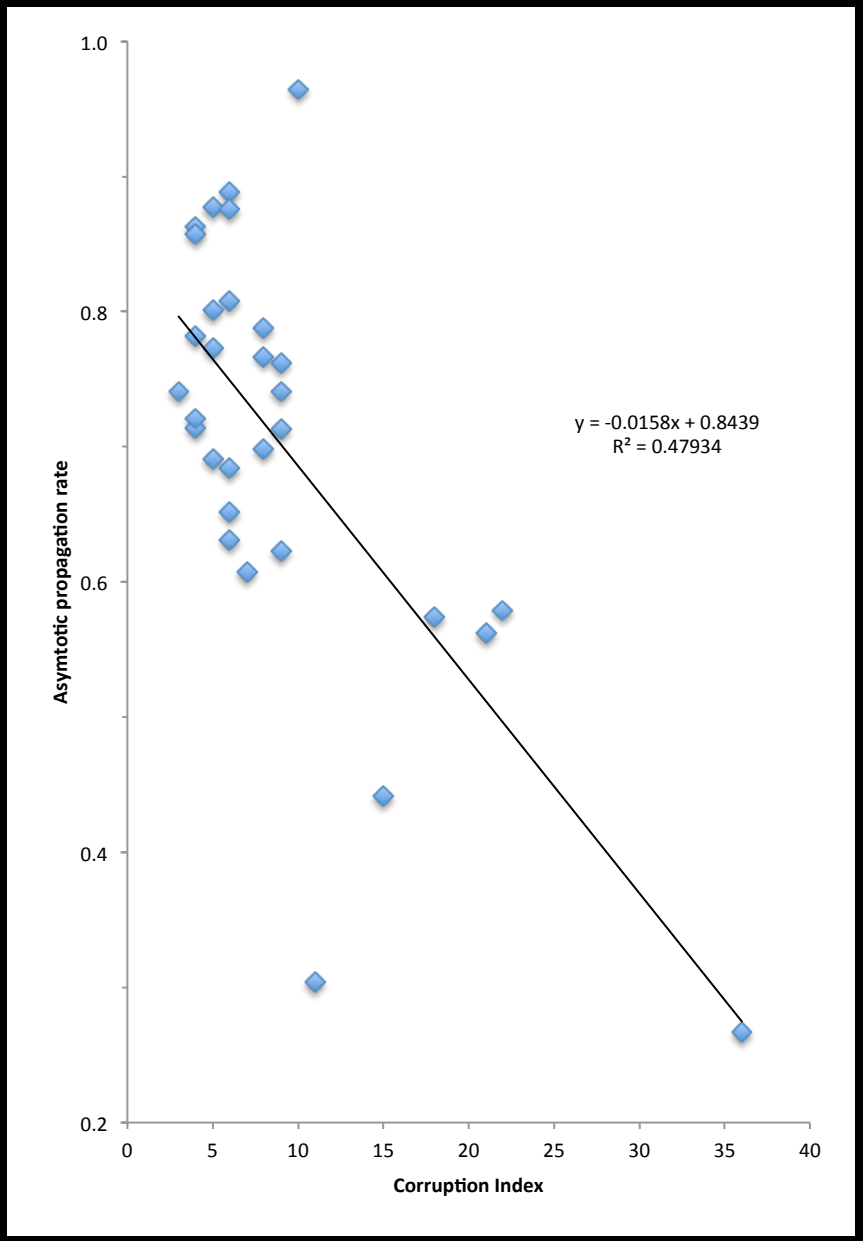
The Income Gini Coefficient vs. asymptotic penetration of broadband Internet in households

$R^2 = 0.10055$



The Satisfaction With Freedom of Choice vs. asymptotic penetration of broadband Internet in households

$R^2 = 0.31434$



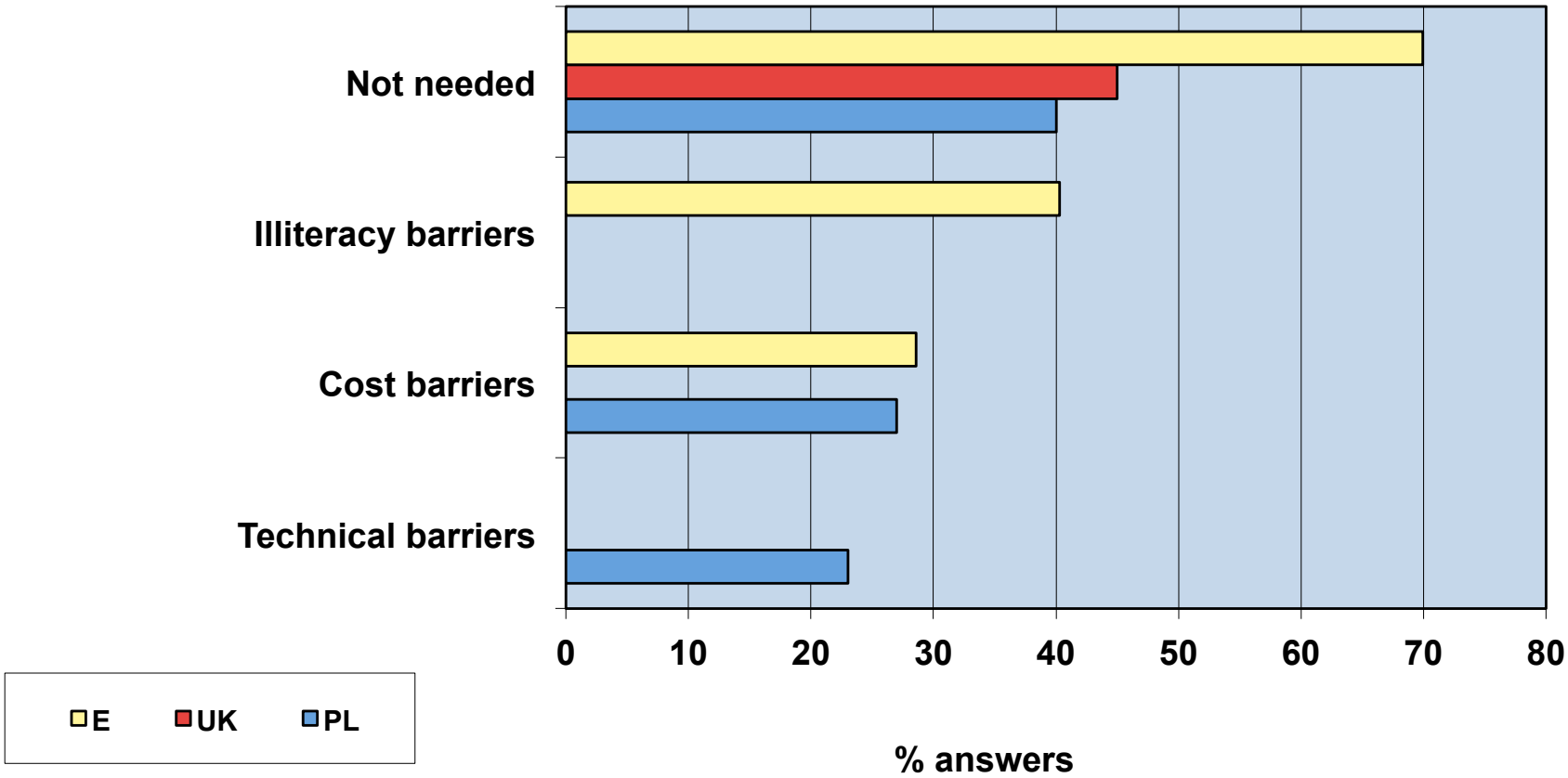
The Corruption Index vs. asymptotic penetration of broadband Internet in households

$R^2 = 0.47934$

Topics for discussion

- Analysis of empirical data
  - Bb. household subscribers, 35 countries, 10 years
  - Technology-neutral models of bb. access growth
- Study of models
  - Growth limits (irreducible gaps) for each country
- Application examples
- Analysis of correlation
- Comments on barriers & ways out

Why I don’t have Internet at home?



Sources: INE 2005, GUS 2007

Why not needed?

- Hierarchy of values - tradition
  - *"Age and economics are important factors, but the heart of the challenge is deeper. Many people just don't see a reason to use computers and do not associate technology with the needs and demands of their daily lives."*
    - » John Barrett, Director of Research at PARKS, May. 20, 2008 http://localtechwire.com/business/local_tech_wire/opinion/blogpost/2911845/
- Low perceived benefit/cost and/or benefit/risk ratio
  - Do available services/contents match the needs?
  - Fear of unknown/ Need to learn
  - Fear of E-crime E-insecurity

Barriers to Access (Bb. Comm. 2013)

1. Low purchasing Power …
2. Limited financial resources available …
3. The low levels of ICT skills …
4. The lack of basic commodities (water, electricity, etc.)
5. The limited availability of […] electronic equipment
6. High tax rates on telecom services or equipment
7. Lack of infrastructure/ high costs of deployment
8. Administrative delays in authorizations to deploy new infrastructure
9. Limited economic growth in certain areas
10. Limitations in amount of spectrum available
11. Limited availability of relevant local content

Source: The State of Broadband 2013: Universalizing Broadband. A report by the Broadband Commission, ITU & UNESCO Sept. 2013 (T.3)

Recommendations (Bb. Comm. 2013)

1. Promote market liberalization
2. Review and update regulatory service obligations
3. Consider Open Access Approaches to Infrastructure
4. Introduce and Develop a National Broadband Plan
5. Update and Utilize Universal Service Funds (USFs)
6. Review Licensing Schemes
7. Review & Reduce Taxation
8. Review Policy Frameworks for Spectrum
9. Spur Demand and Introduce Measures to Stimulate the Creation of Local Content
10. Support Accurate and Timely Statistical Monitoring
11. Consider Undertaking Public Consultations on Policy

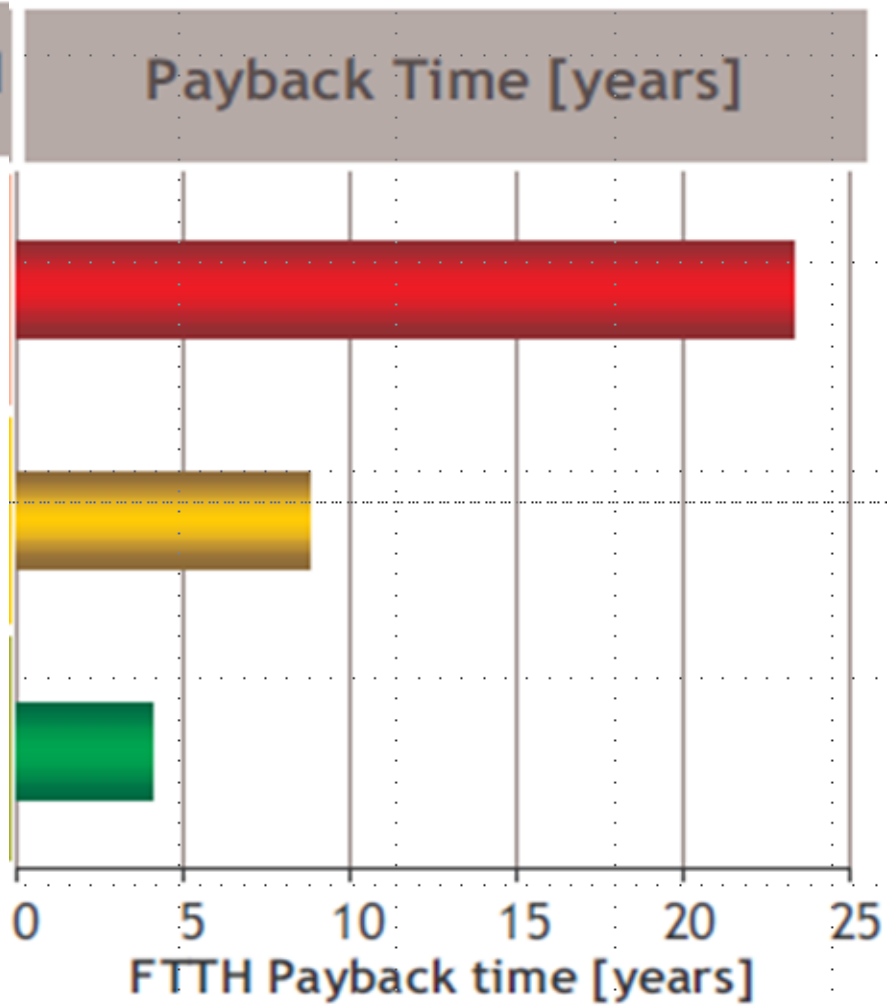
Source: The State of Broadband 2013: Universalizing Broadband. A report by the Broadband Commission, ITU & UNESCO Sept. 2013 (T.3)

Ways out

- Promote friendly financial + legal + regulatory environment for small business/rural communities
- Promote cheap/free access
- Promote awareness: educate, teach, train
- Promote sharing (e.g. towers, antennas)
- Generate demand:
  - Promote free e-governmental services, free content/ software that address practical needs
- Activate local communities

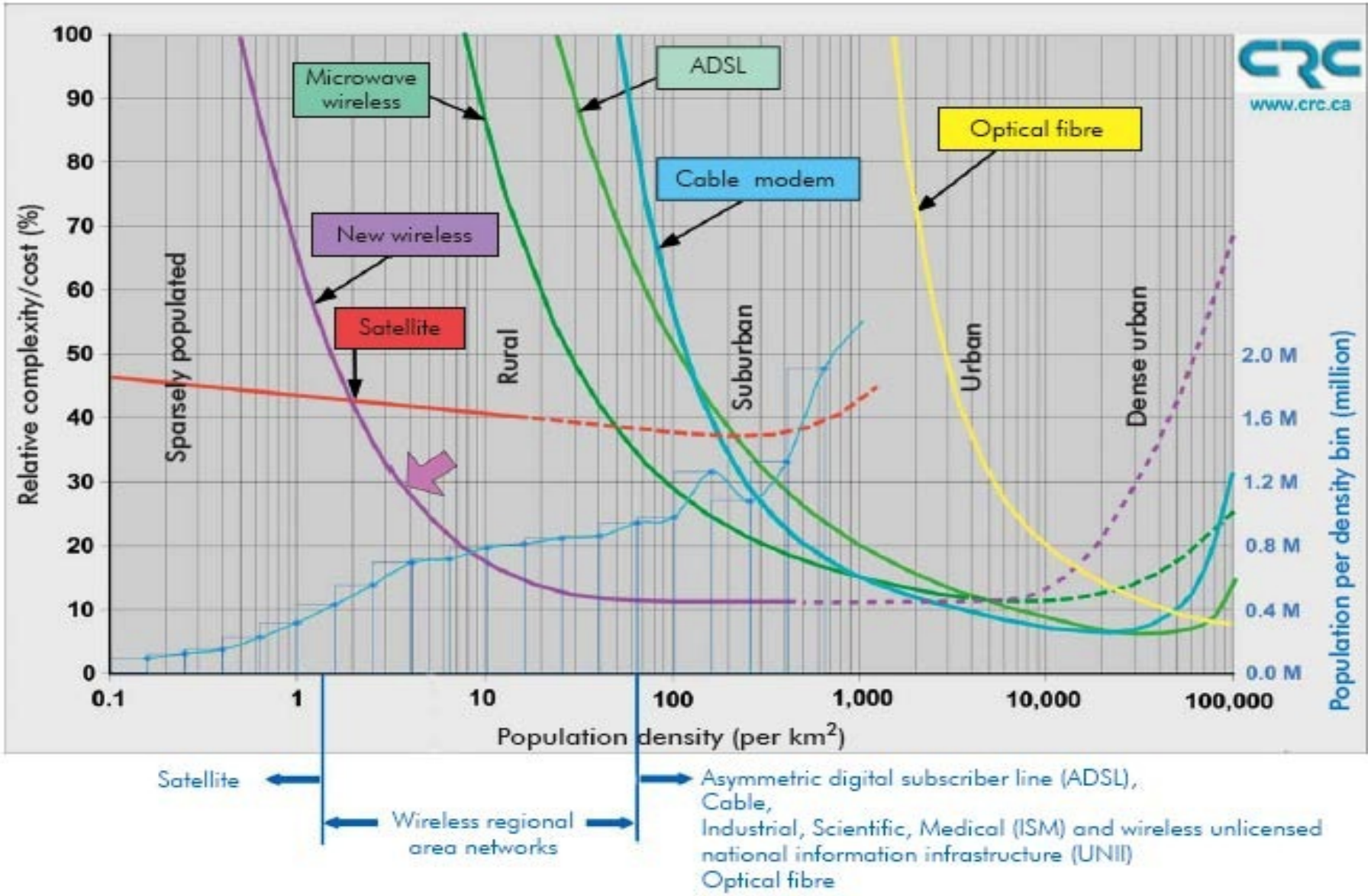
FTTH business

	Density	CAPEX / HH
Rural	150 HH/km²	6000€
Suburban	500 HH/km²	2000€
Dense Urban	4500 HH/km²	800€

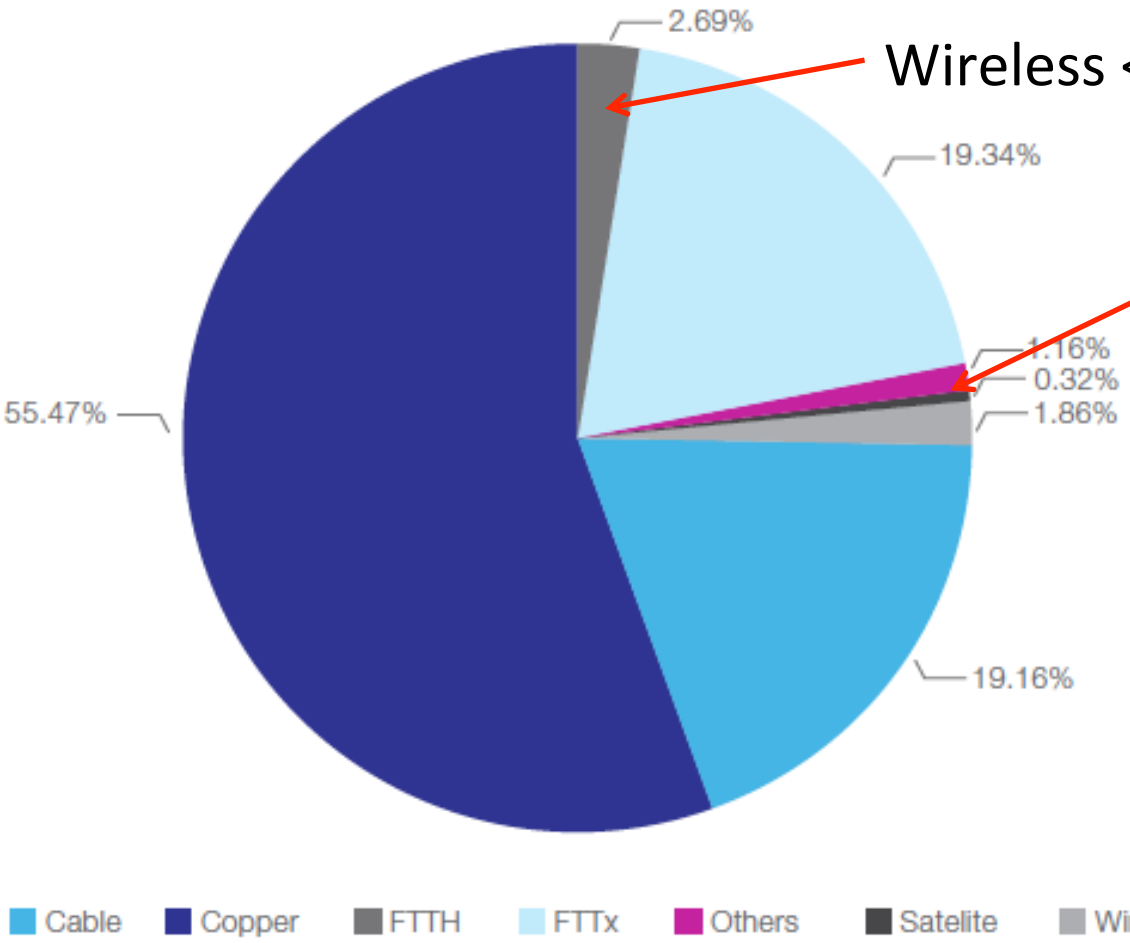


Adapted from: A snapshot on the broadband market Challenges and opportunities…Eric Festraets, ALCATEL-LUCENT Director Broadband Marketing and Consulting, BB Conference Warsaw, June 18th 2008

Figure 1 — Suitable broadband access technologies as a function of population density



Technologies sharing bb. market (2013)

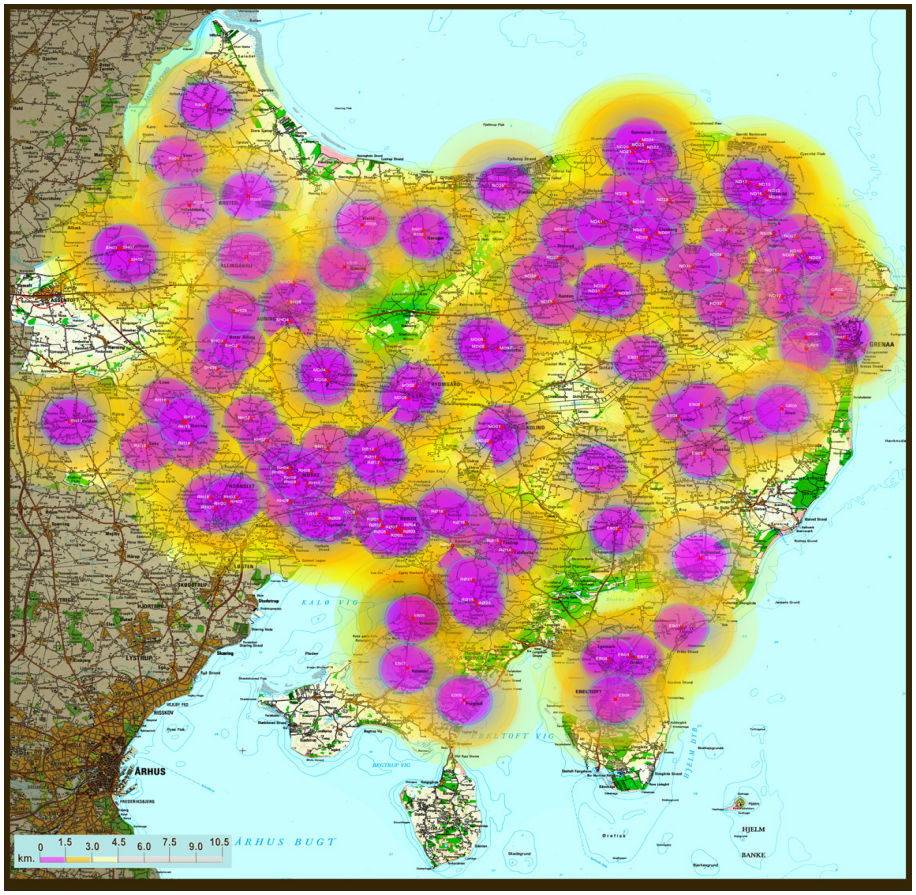


Wireless < 3%

Satellite < 0.4%

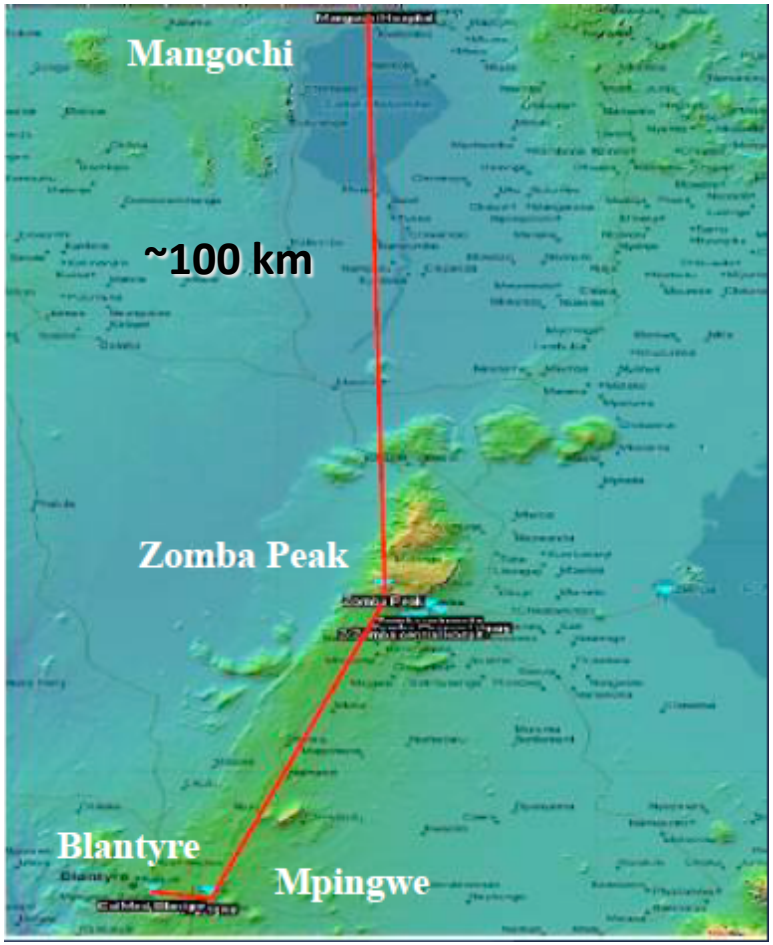
Possible explanation: most of broadband users are in rich/ urban regions

Source: The State of Broadband 2013: Universalizing Broadband. A report by the Broadband Commission September 2013



Denmark (Djursland): 1491 km2
Population: 82420 (58/ km2)
6000 houses w.access (1/3 cost)

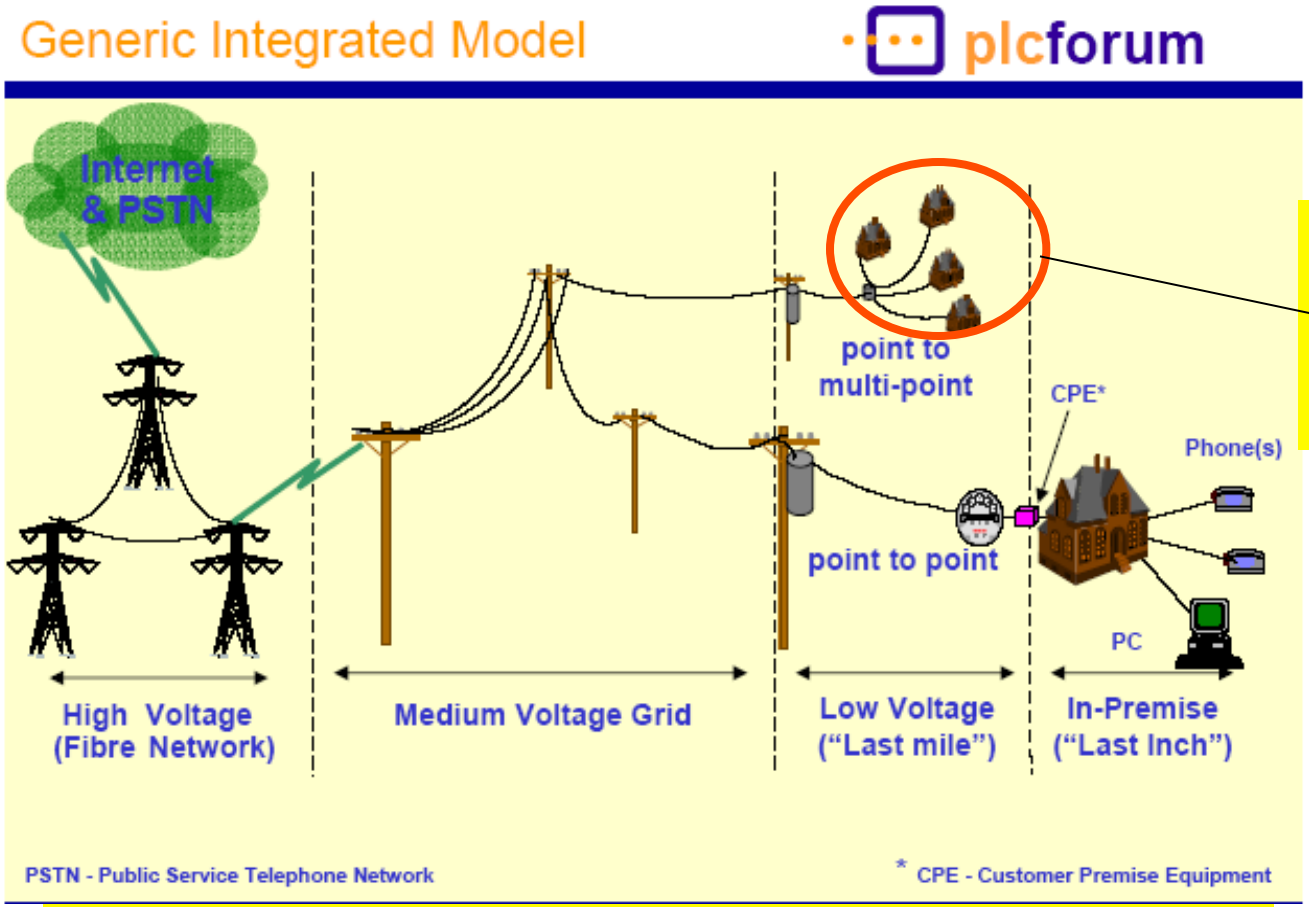
http://hos.nr-djurs.net/bjarke/DIIRWB-presentation_final-2.pdf



Malawi

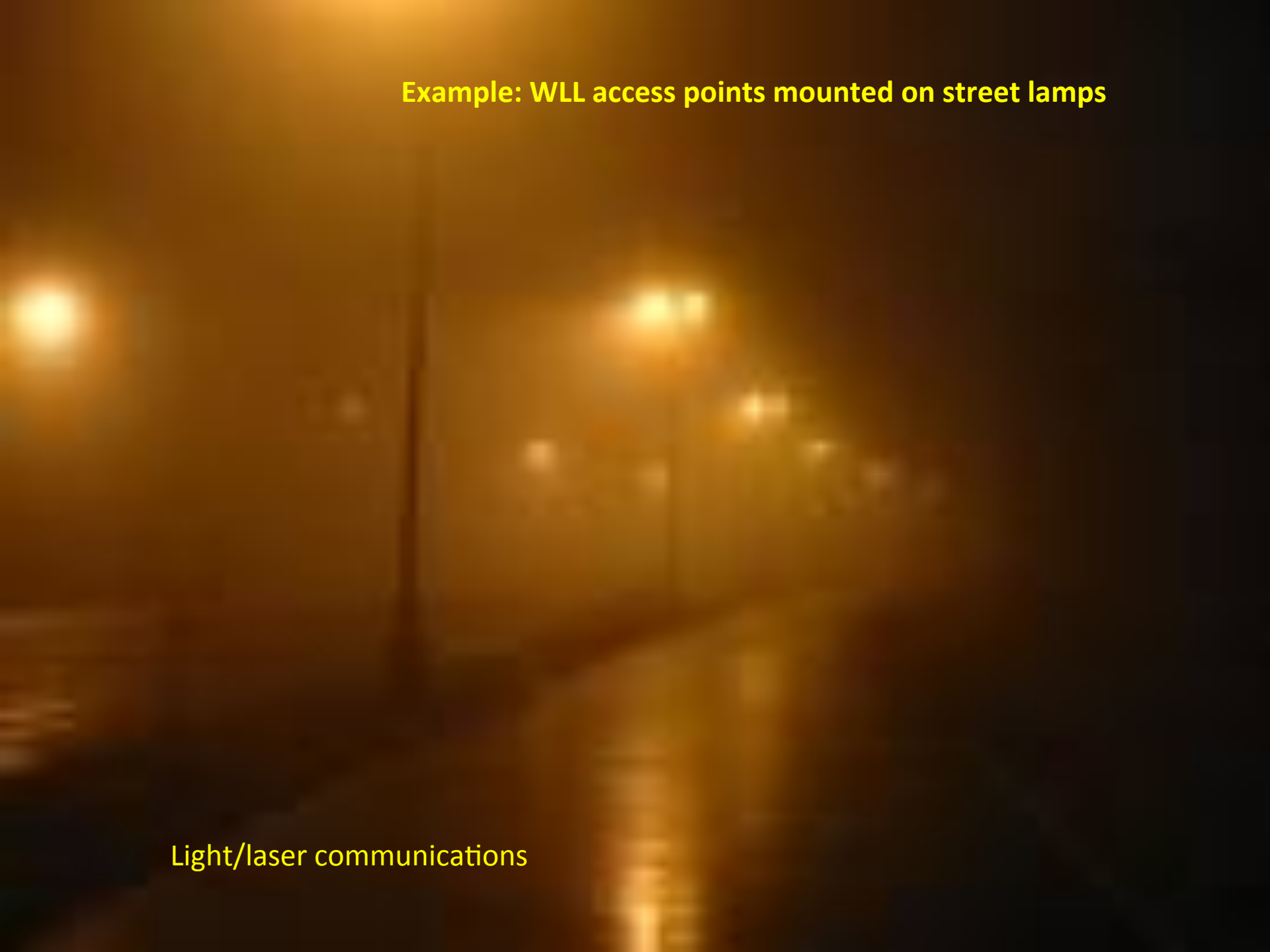
(Malawi Polytechnic + ICTP + NIT)

PowerLine Communications (PLC)



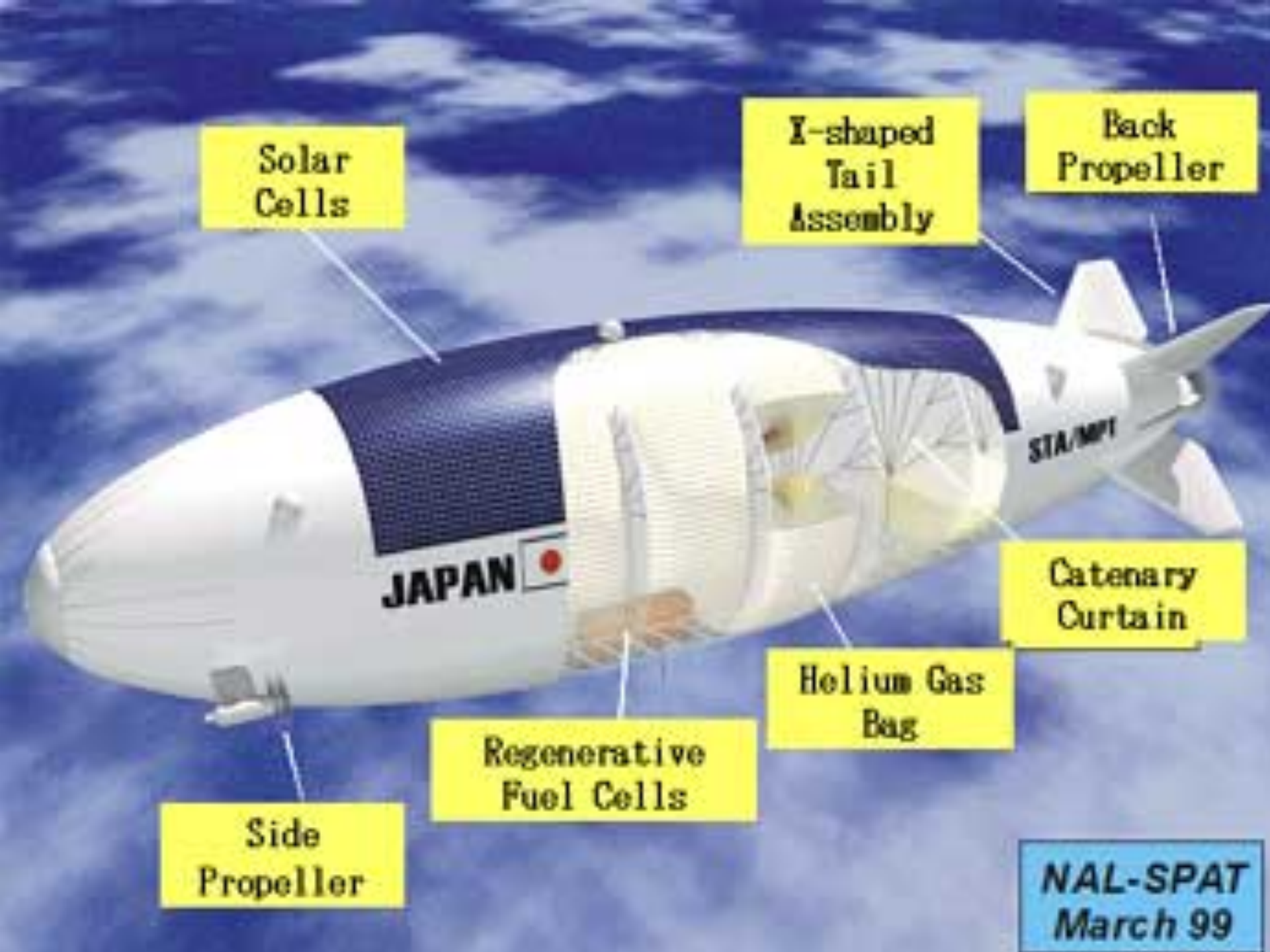
Wired or wireless

Integration with Automatic Meter Reading!

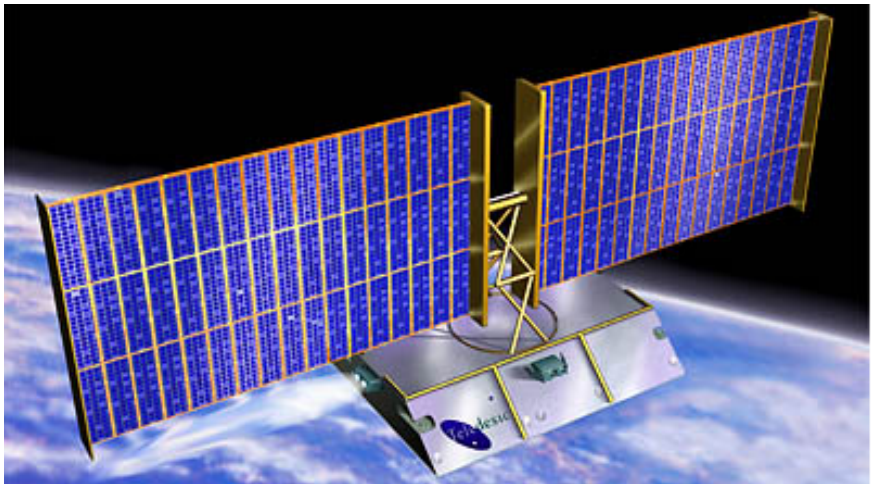

Example: WLL access points mounted on street lamps
Light/laser communications

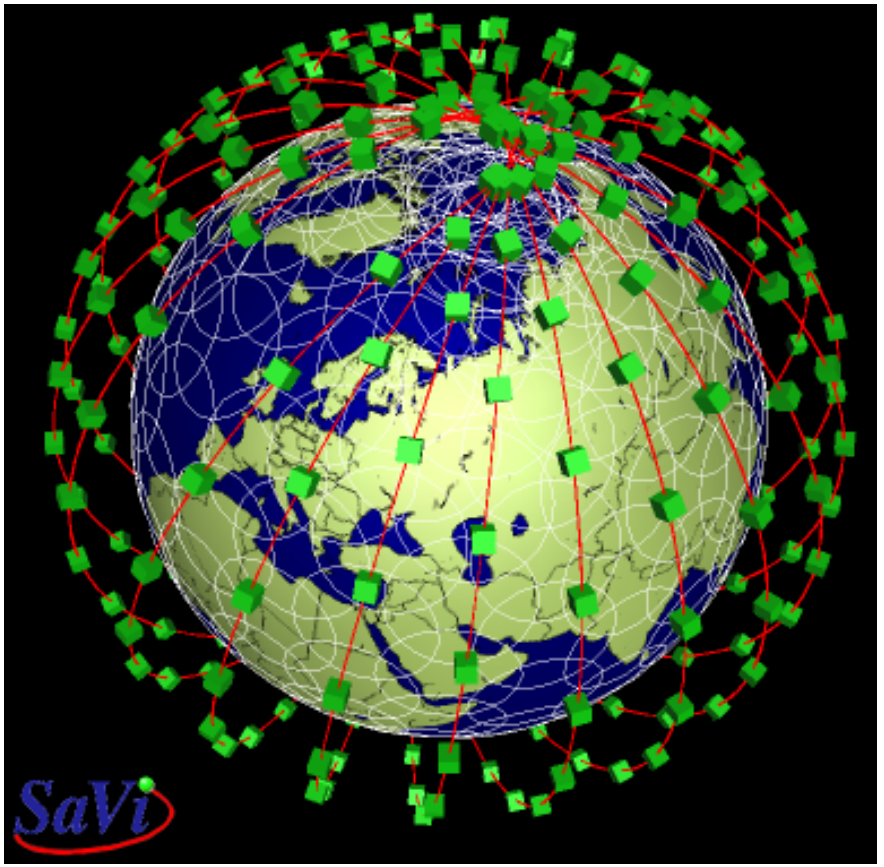
HAPS – high altitude platform station

R. Struzak: Mobile telecommunications via stratosphere;
http://www.intercomms.net/AUG03/content/struzak1.php http://www.ursi.org/files/RSBissues/RSB_334_2010_09.pdf


Solar Cells
X-shaped Tail Assembly
Back Propeller
JAPAN
Catenary Curtain
Helium Gas Bag
Regenerative Fuel Cells
Side Propeller
NAL-SPAT March 99

Internet-in-the-Sky





Teledesic - a bb. LEO network :
the global coverage, low latency, robustness, "fiber-like" QOS and affordable access from nearly 100% of the Earth's population and 95% of the landmass. Designed to support millions of simultaneous users.

http://en.wikipedia.org/wiki/Teledesic

http://web.archive.org/web/20011217200708/http://www.teledesic.com/

What we have learned

- There are inherent limits to Internet growth
  - high cost, market failure, lacking skill & motivations, wrong content, intellectual property rights
- Unequal Internet growth perpetuates existing disproportions
  - With the present development model continued the existing gap will increase: rural regions are the bottleneck
- Radio + free access to shared TV White spectrum could help to solve the problem

Models – basic tools

→ to understand better the process

→ to evaluate trends, to compare alternative solutions possible, to plan

→ to analyse & monitor implementation

→ to identify bottlenecks & learn from the past policy/regulations/planning

- Mathematically, Internet growth can be compared to
  - colonization of a host organism by a parasite
  - epidemic development of infectious disease, where pathogenes are transmitted from one person to another
  - growth of human population
    - Thomas Malthus (1776 – 1834)
    - Pierre François Verhulst (1804–1849) → Logistic Model

For further readings

- R. Struzak: Growth of broadband Internet in Poland – models, trends and limits; Telekomunikacja I Techniki Informacyjne 1-2/2009, pp. 38-49
- R. Struzak: Broadband Internet in EU Countries: Limits to Growth; IEEE Comms. Magazine, April 2010, 52 – 57
- R. Struzak: Diffusion of Broadband Services: An Empirical Study; IEEE Comms. Magazine, August 2012, 129 – 134

Thank you for your attention