



Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences



Mathematics as foundation for the digital transformation

Reinhard Riedl

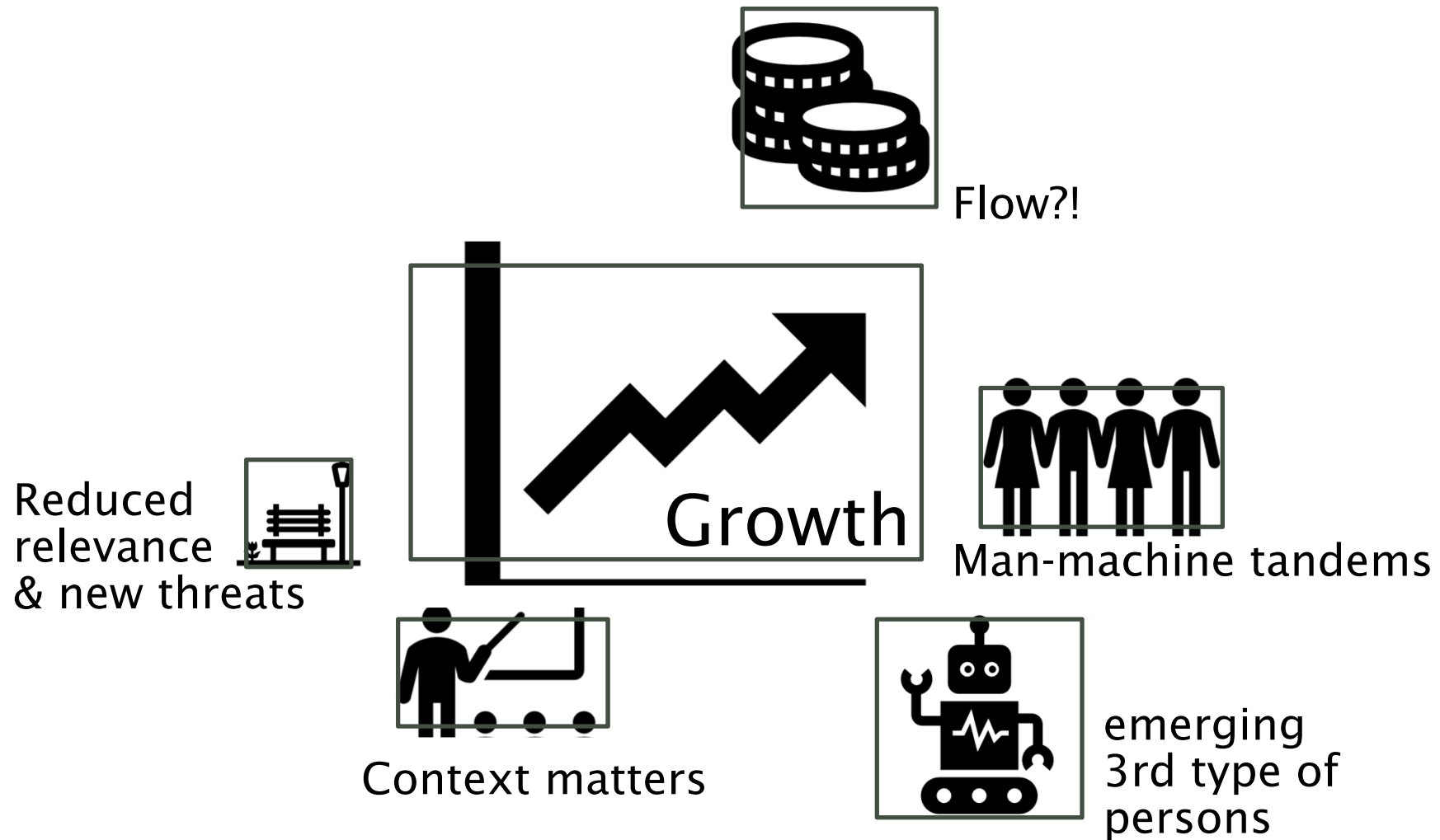
IDEA – Institut for Digital Enabling

 BFH-Center Digital Society

Mathematics provides the language for WHAT IS / could be,
computer sciences the language for HOW TO industrialize
(inspired by Edwards)

I. Let us start with the end – economics!

Economic theories have changed their view of production factors over time





Entrepreneurs make innovations based on creativity → creativity is key ...

... which is why so many people despise or even hate Schumpeter's work.

**Revolutions, that is
inventions and innovations
take place within existing ecosystems
and they depend on social capital ...
How can we measure that?**

HOW CAN WE MEASURE THAT?
and they depend on social capital ...
take place within existing ecosystems
inventions and innovations
Revolutions, that is

Conjecture: The economic potential of a country depends on its **knowledge & knowhow** materialized in the **production of goods** → ... → we have to look at the richness of exported goods to predict future growth!

Basic ideas of the theory of economic complexity

- ▶ The matrix M describes the relative comparative advantages (RCAs) of countries with respect to products
 - ▶ M_{cp} is equal to 1 if the RCA $R_{cp} \geq 1$ for country c and the product p (we say « c exports p »), and 0 otherwise
 - ▶ $M_{cp} = 1$: product p is said to be in the «export basket» of c
 - ▶ k_c denotes the **diversity of the country c** , $k_c = \sum_p M_{cp}$
 - ▶ k_p denotes the **ubiquity of the product p** , $k_p = \sum_c M_{cp}$
- ▶ PCI estimates the knowhow needed to produce products and
ECI estimates the knowhow available in the countries

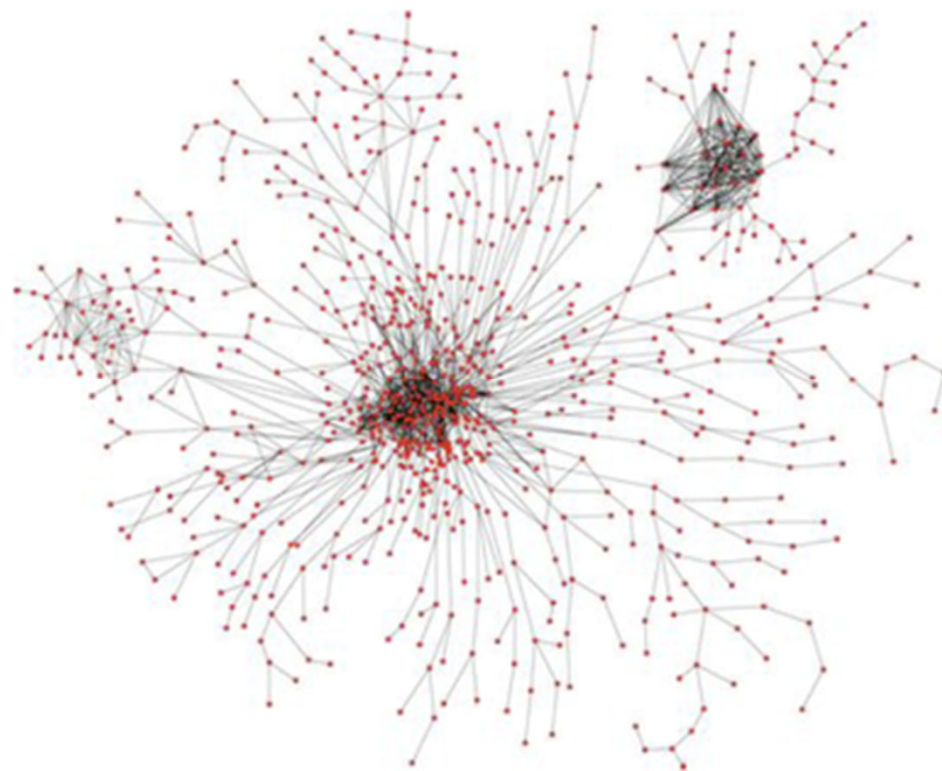
$$R_{cp} = \frac{X_{cp}}{E(X_{cp})}$$

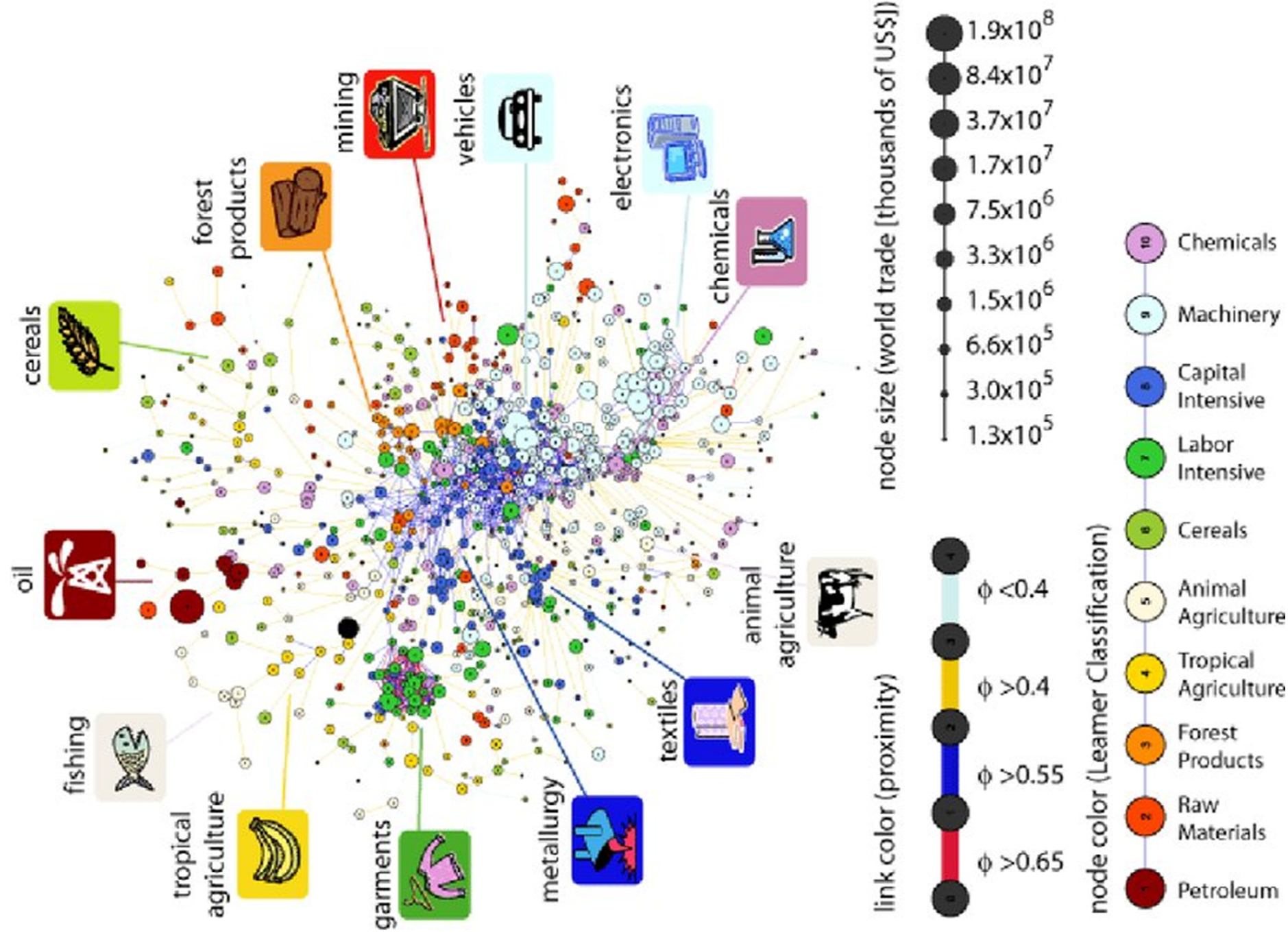
$$ECI_c = \frac{1}{k_c} \sum_p M_{cp} PCI_p$$

$$PCI_p = \frac{1}{k_p} \sum_c M_{cp} ECI_c$$

- ▶ These measures can be further improved by taking the hardness to produce certain goods into consideration (e.g. with the reflection method).
- ▶ **Product space** is defined by the affinity matrix Φ_{ij}

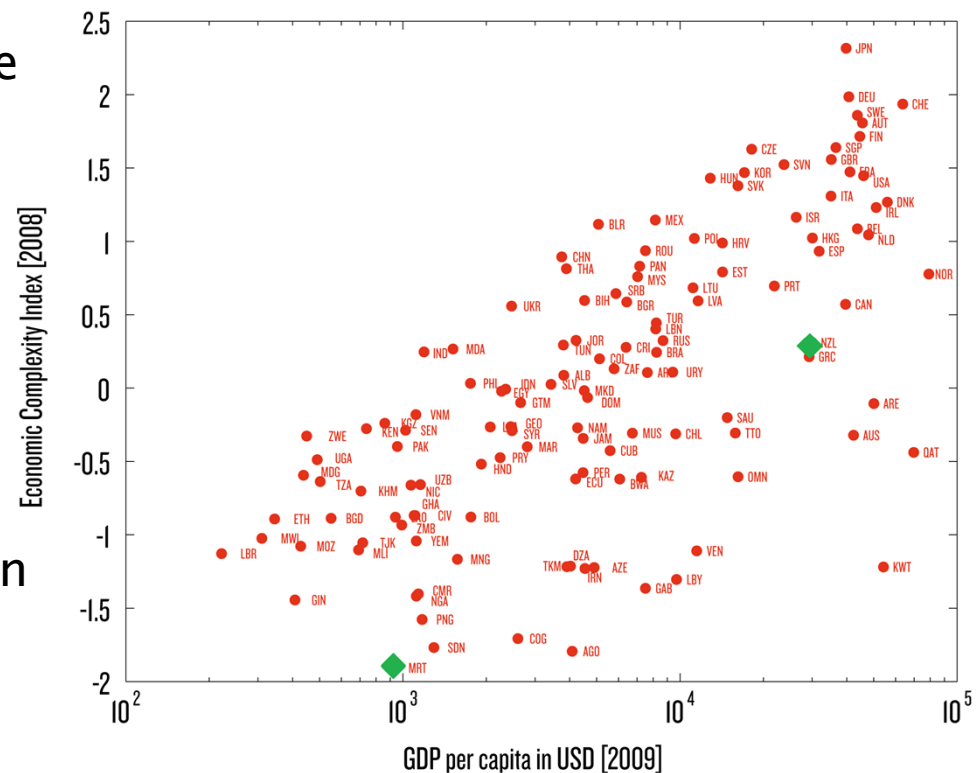
$$\phi_{i,j} = \min\{\Pr(RCAx_i \geq 1 \mid RCAx_j \geq 1), \Pr(RCAx_j \geq 1 \mid RCAx_i \geq 1)\}$$





Development of countries is in parts captured by the traversing of product space

- ▶ **Transition** takes place towards products with a high average proximity to products in the «export basket»
- ▶ If the average **centrality** of the products in the export basket is high, its development opportunities are high
- ▶ (Adapted) ECI strongly correlates with GDP
- ▶ Being above the approximation line means good perspectives for growth above the average



Economic complexity leads to future-oriented country rankings

THE ATLAS OF ECONOMIC COMPLEXITY
MAPPING PATHS TO PROSPERITY
Hausmann, Hidalgo et al.

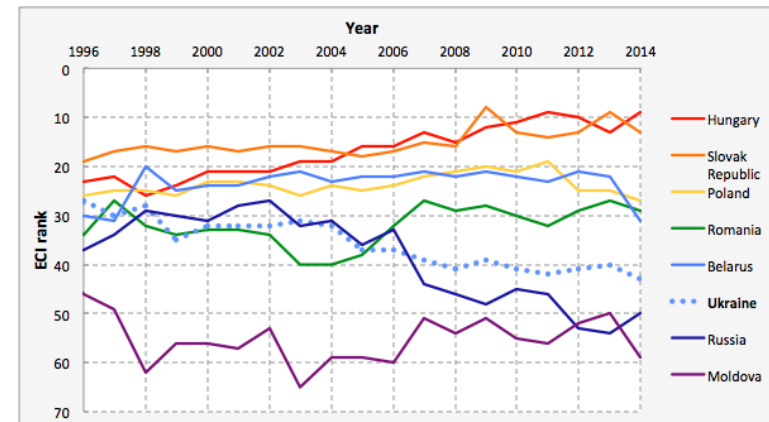
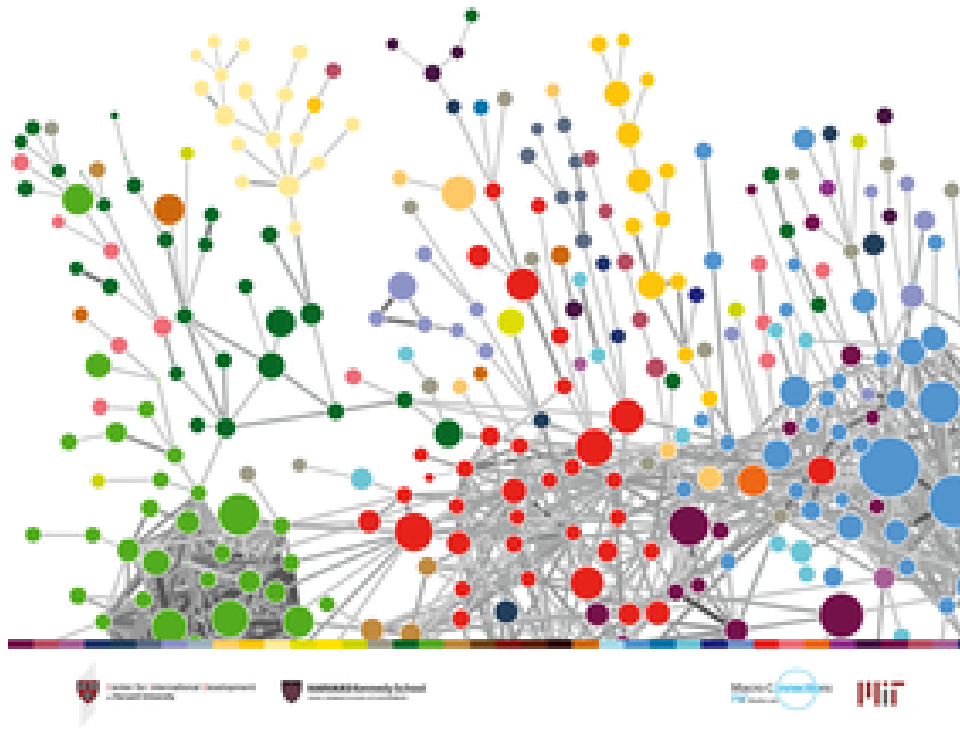
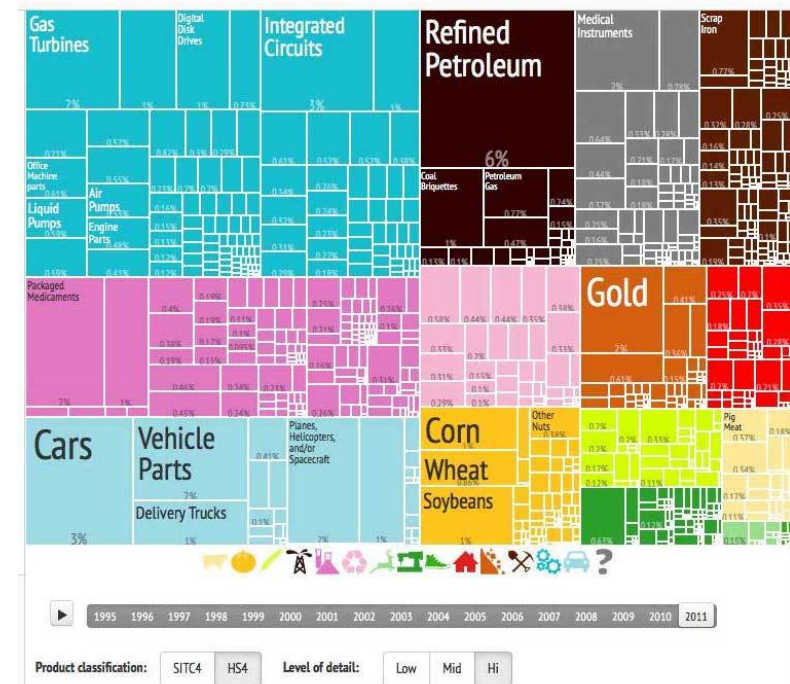


Figure 1. ECI country rankings

What did the United States export in 2011?



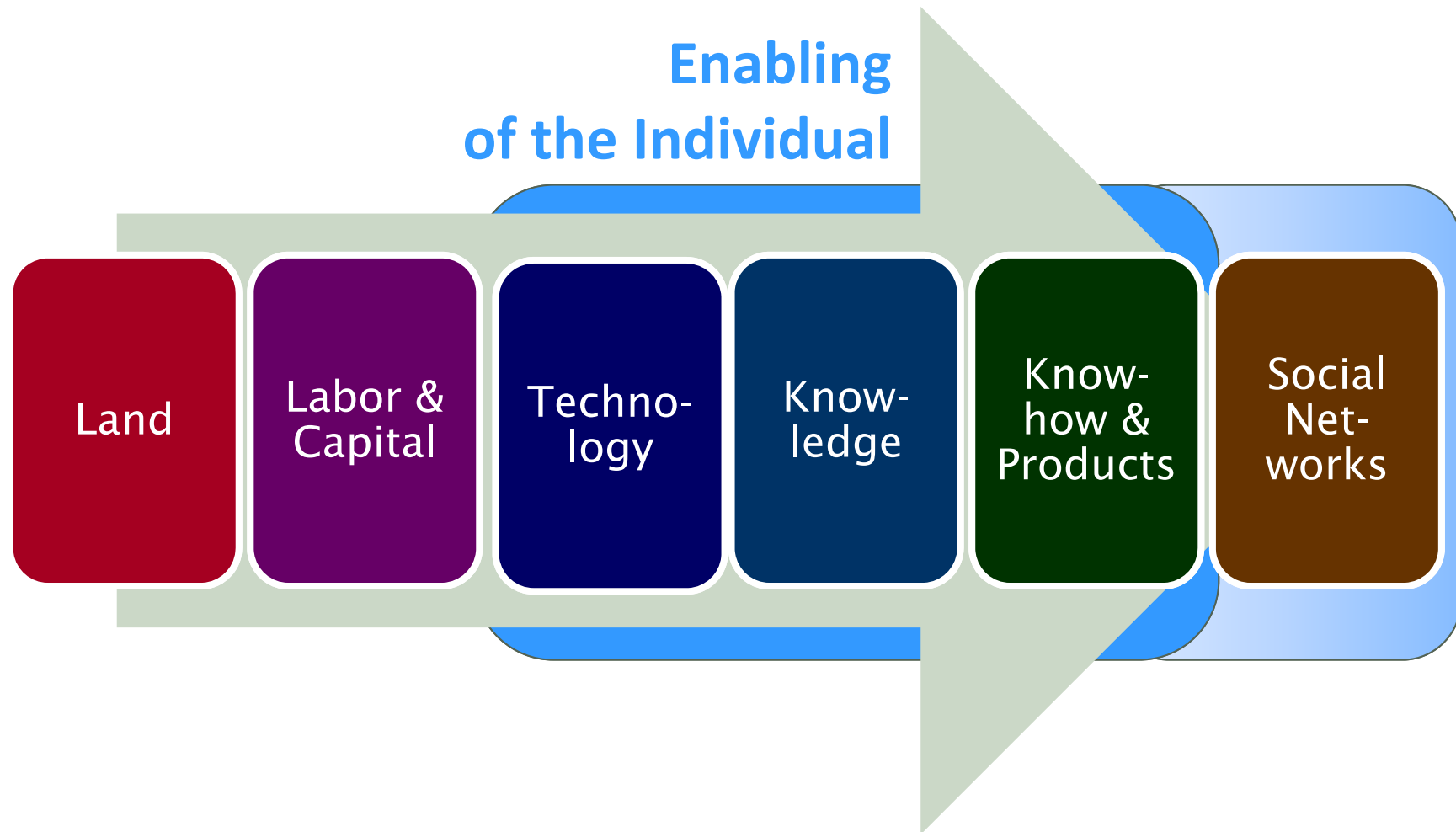
Why do we need mathematics here?

1. All the economics here is mathematics:
 - ▶ the adapted ECI is an eigenvector of a matrix and it allows for an interpretation in terms of durations of stopped random walks.
 - ▶ Network properties reflect the future opportunities of a national economy.
2. Mathematics helps to improve policy making.
 - ▶ The design of strategies for continuing education – and to some extent even for education – can benefit from an in depth analysis of the product space network.
3. The monster waiting in the background of the foundation of theories is entropy which very few have ever understood.

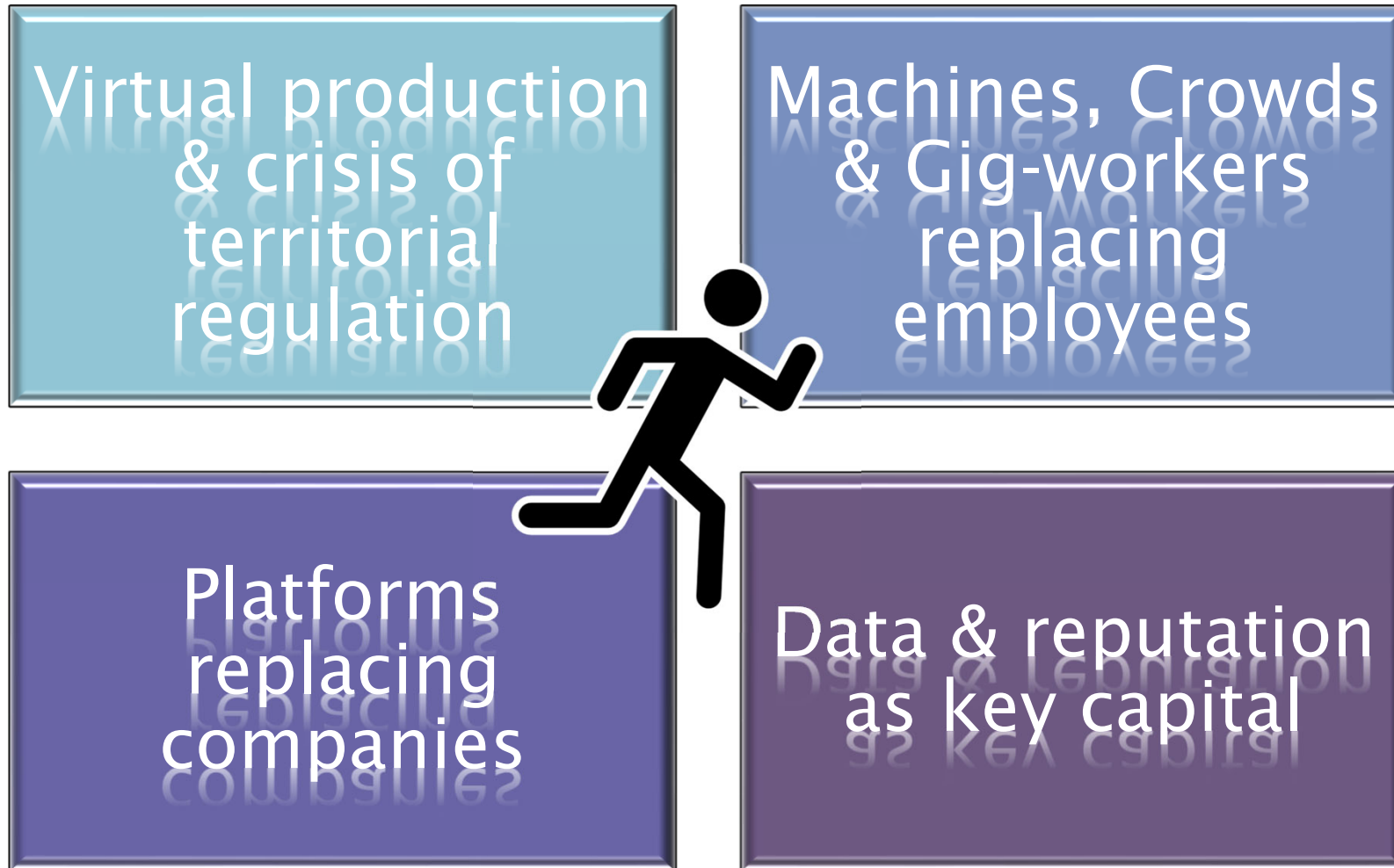
Mathematics plays a key role in the economic study of **social capital**, i.e. knowledge, knowhow, and sharing

II. Let us continue with the means – the digital transformation!

The relevance of productions factors changes

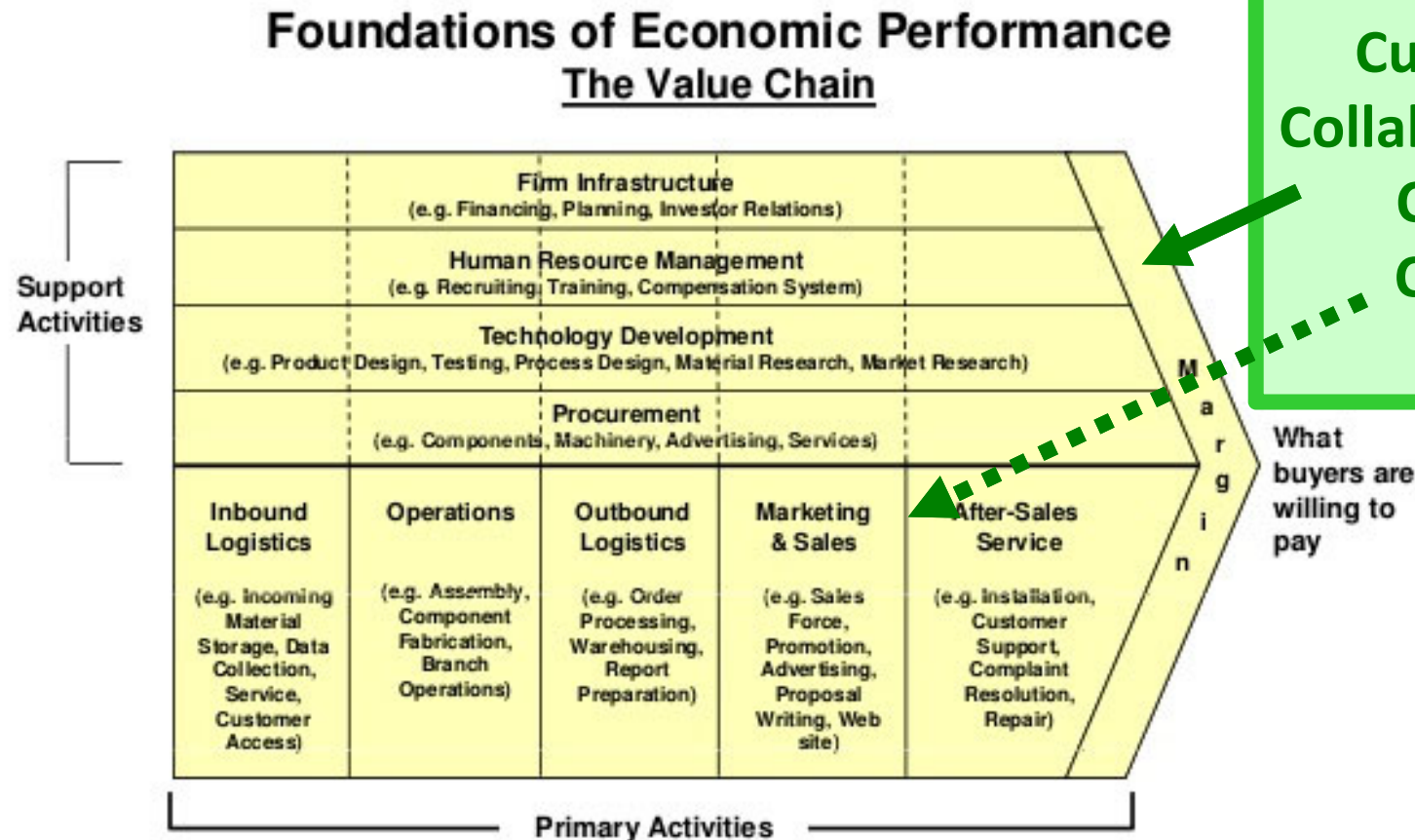


Production factors themselves change



**The digital transformation of the creation of value
leads to far reaching changes of the economy ...**

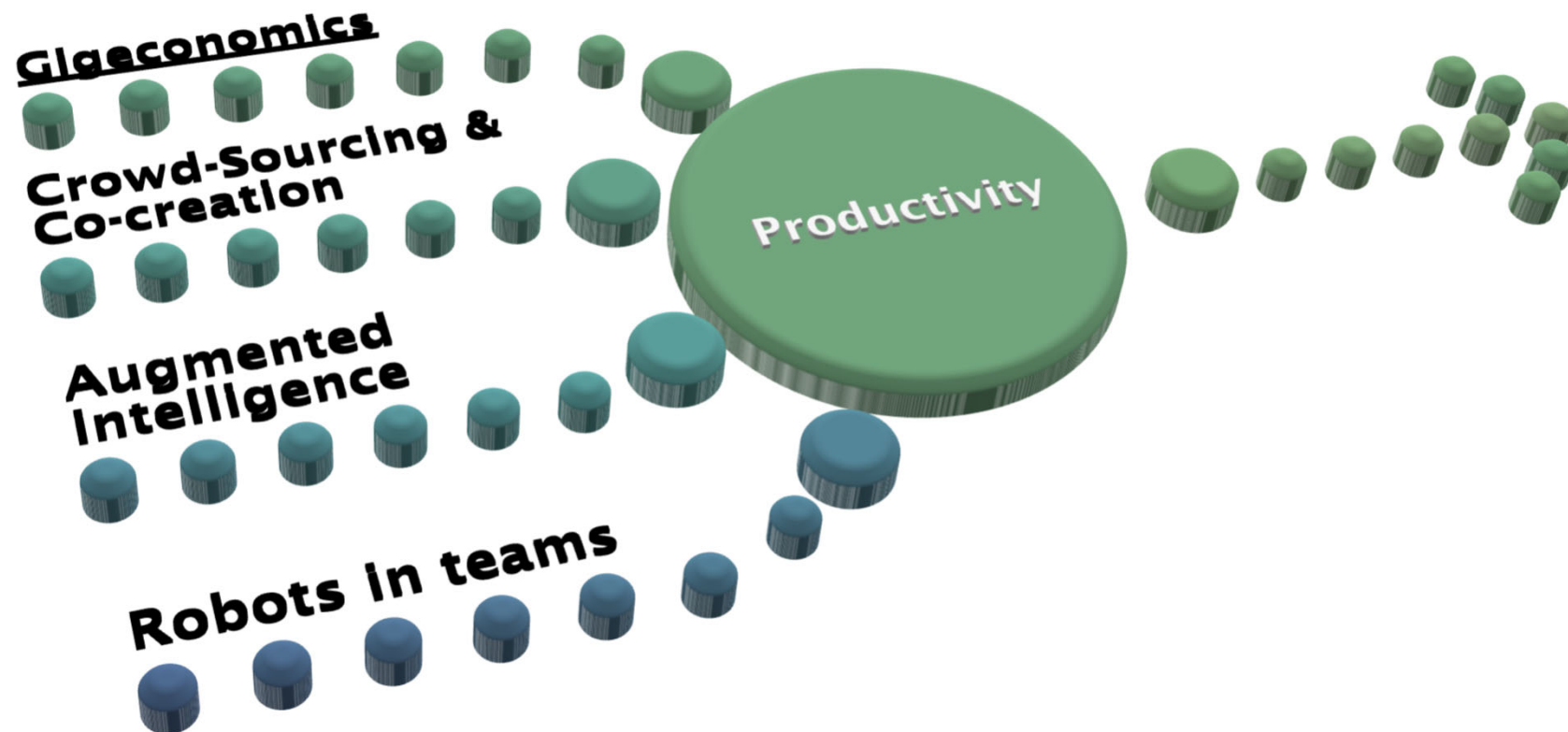
The traditional model of company based value creation designed by Michael Porter:



C⁵:
Customers,
Collaboration,
Creativity
Crowds &
Clouds

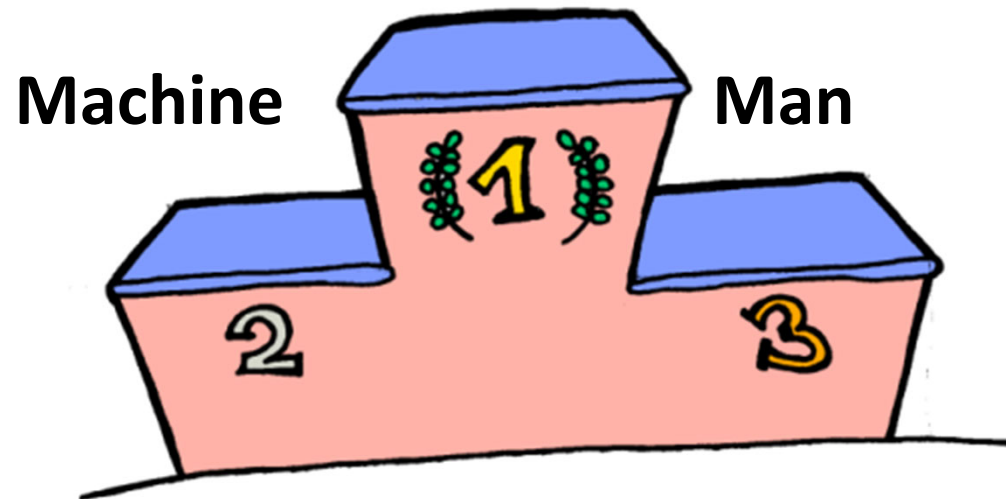
- Competing in a business involves performing a set of discrete **activities**, in which **competitive advantage resides**

New resources improve productivity
(and enable the implementation of innovations)



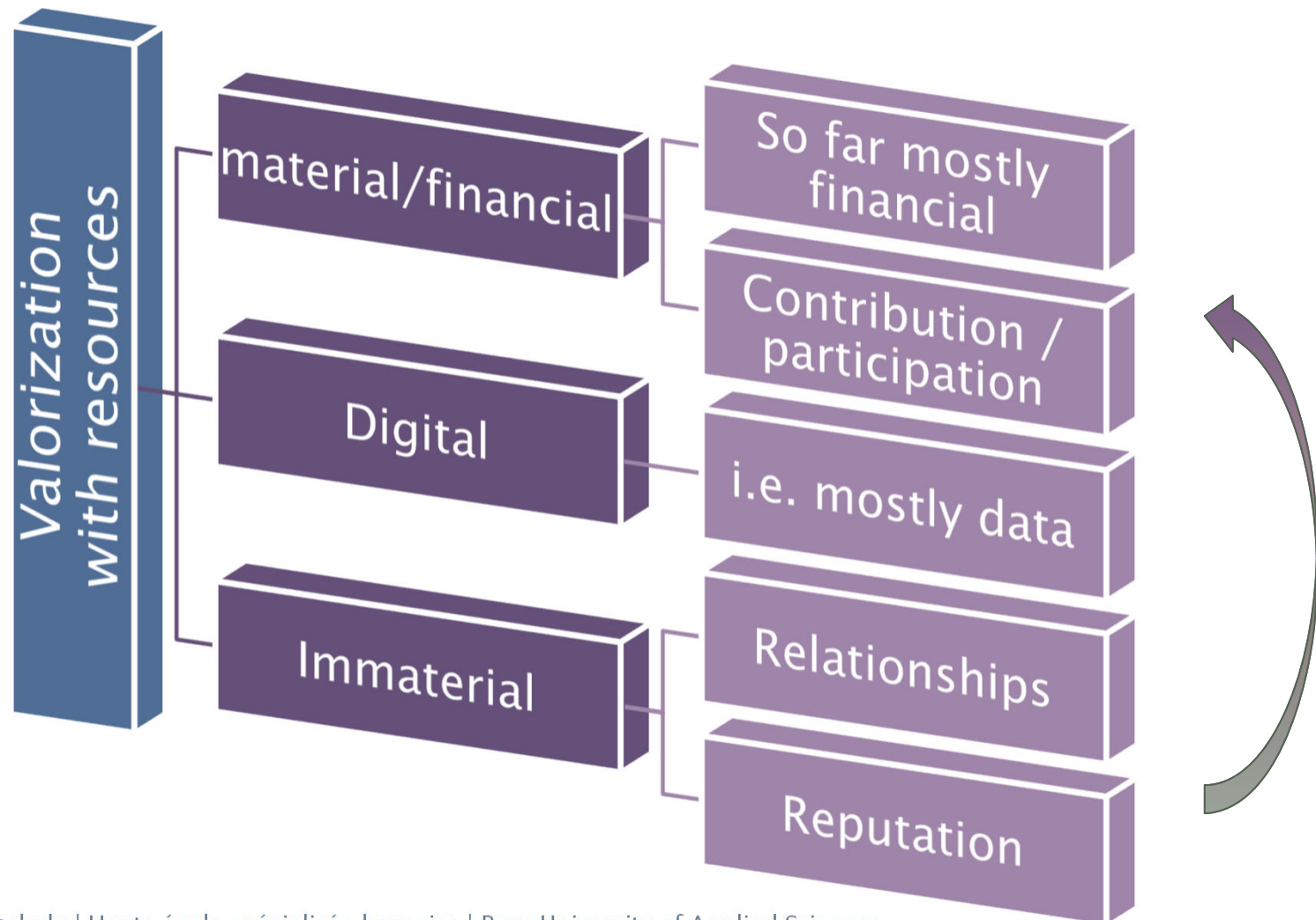
Competition man against machine in the discipline: «fixed context with experience»

Man & Machine

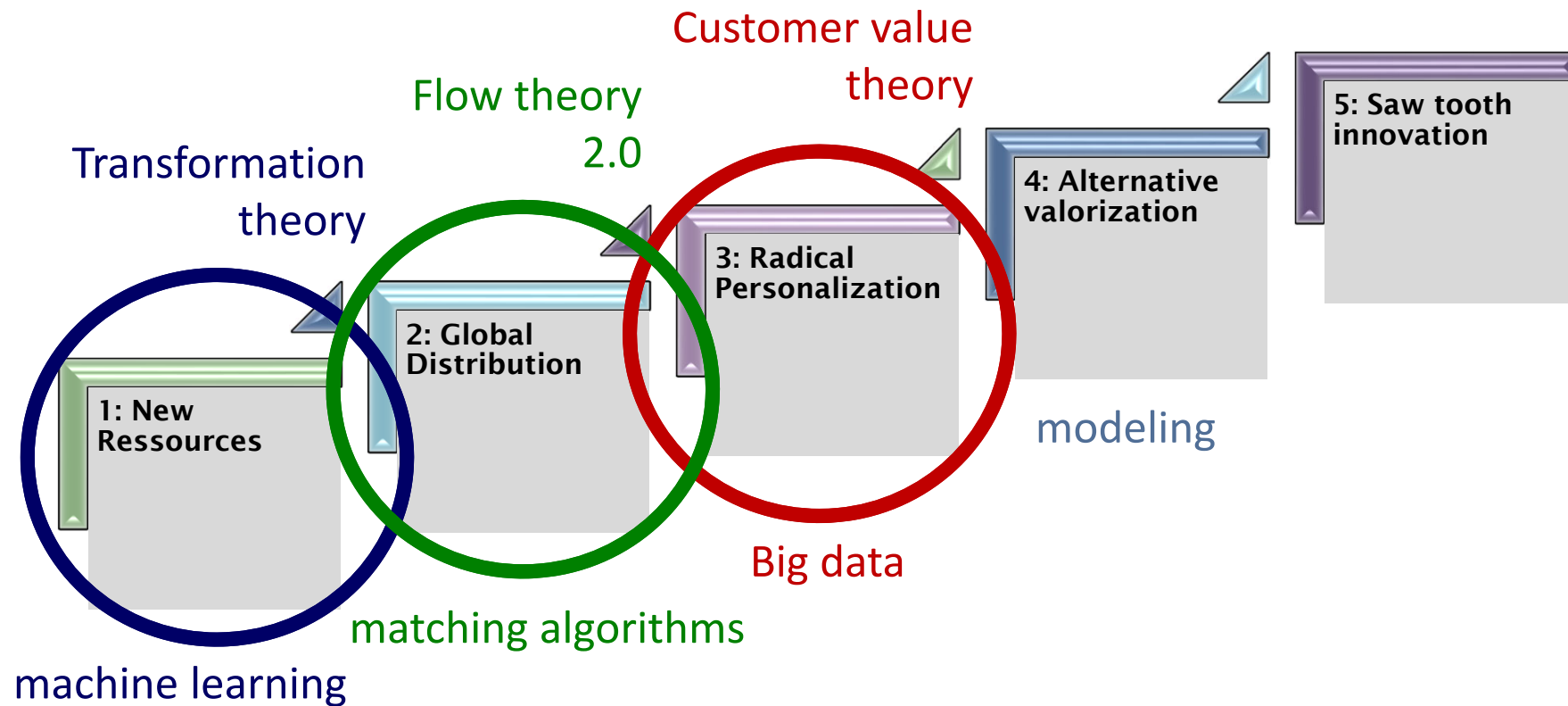
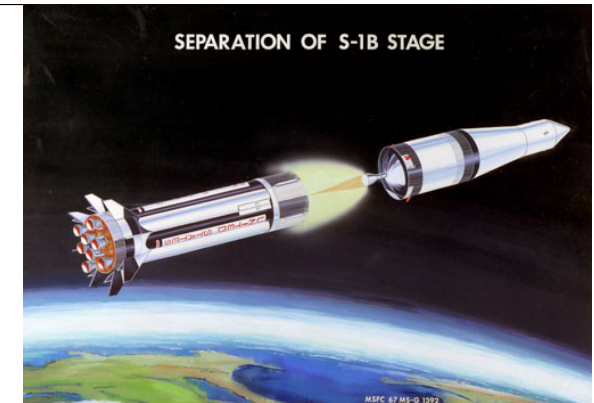


In all situations **with defined context and recorded good practice!**

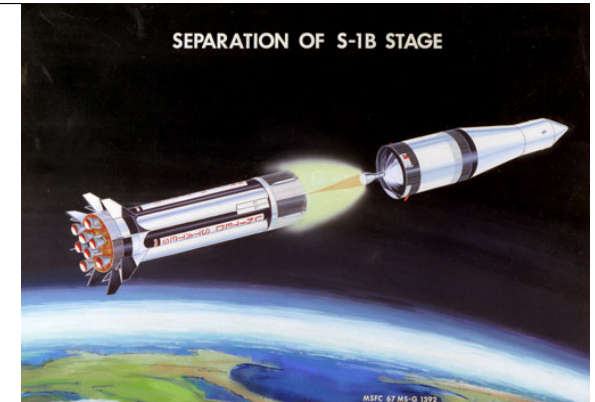
Valorization beyond financial resources becomes a dominant business model



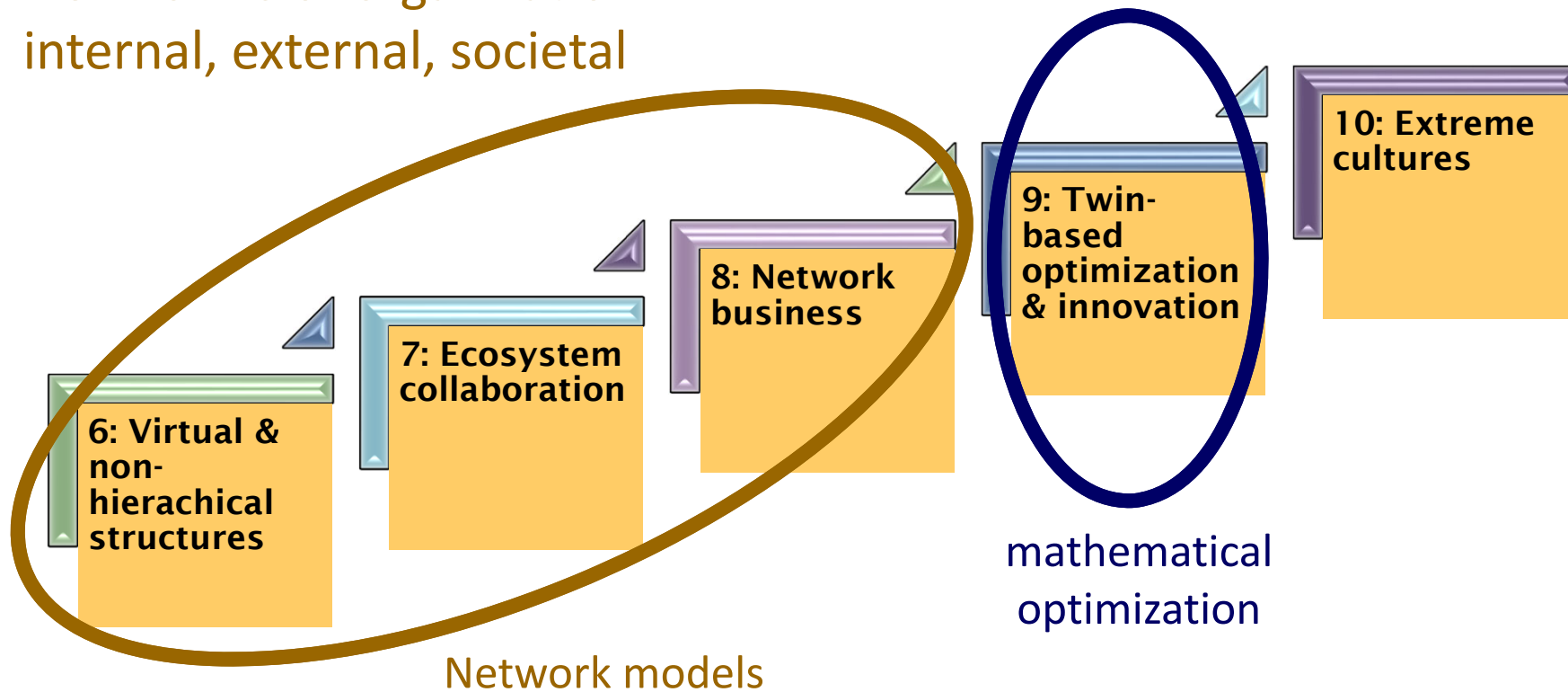
The digitalization rocket will burn 10 stages



The digitalization rocket will burn 10 stages

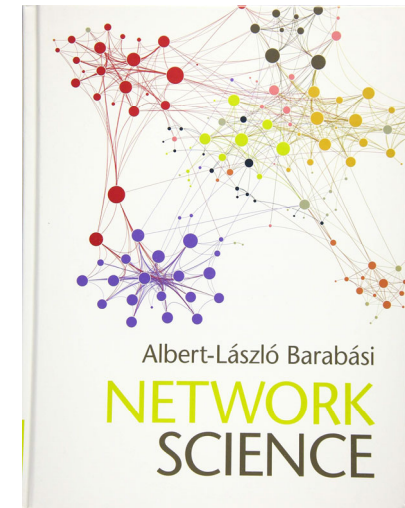
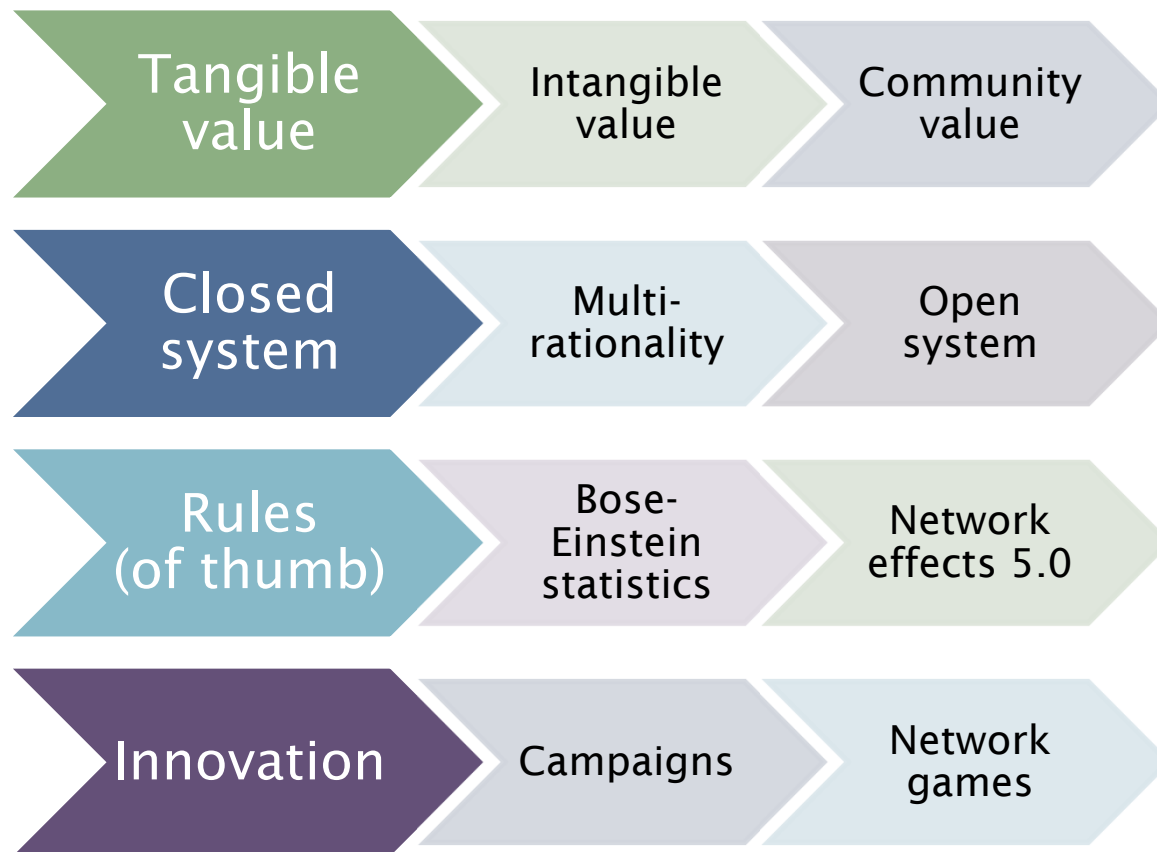


New forms of organization:
internal, external, societal



**7½ of 10 stages of the digital transformation
Rocket are fueled by mathematics**

From ecosystem thinking to networking thinking: networks, attention, popularity



Viral communication is fake meta-news

Networks exhibit some interesting phenomena known from physics

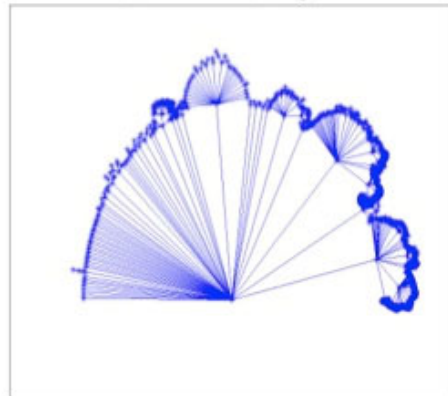
Bose-Einstein condensation in complex networks

The average degree of the nodes with energy ε follows the Bose-Einstein statistics

$$\langle [k_i - 1] | \varepsilon \rangle = \frac{1}{e^{\beta(\varepsilon - \mu)} - 1}$$

Scale-Free phase

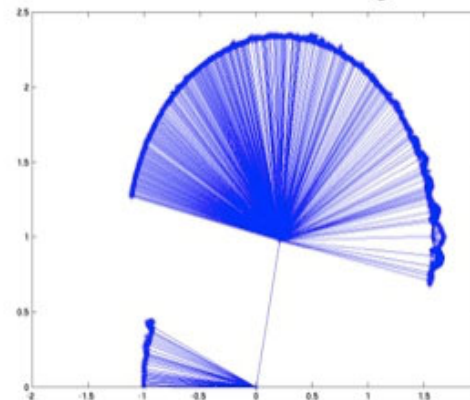
$$\beta < \beta_c$$



G. Bianconi, A.-L. Barabási 2001

Bose-Einstein condensate phase

$$\beta > \beta_c$$



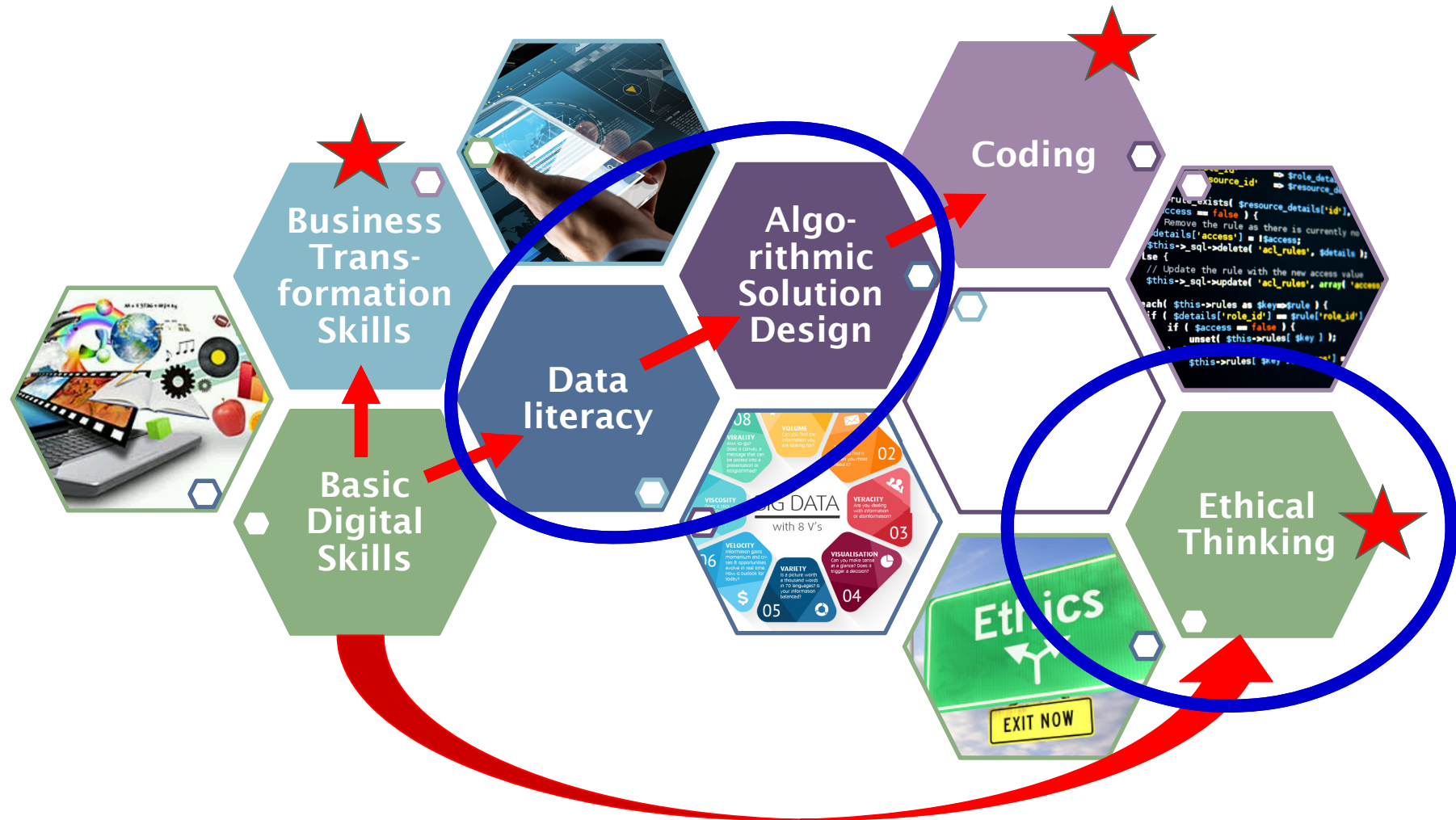
Why do we need mathematics here?

1. Necessity to understand properties of a diverse set of networks:
 - ▶ *Down to earth business*: Social media marketing
 - ▶ *Advanced business*: Ecosystems around products
 - ▶ *Basic research*: Entrepreneurial spillover-effects in urban centers and in the digital hinterland
2. Creation of structures and input data for simulations:
 - ▶ E.g. networks with specified properties
 - ▶ E.g. large sets of customer behavior data
3. Lots of open questions around big data and machine learning:
 - ▶ To improve and classify algorithms
 - ▶ To identify explanatory structures
 - ▶ To design secure containers
 - ▶ To evaluate inference uncertainty

Computational social science
is becoming a key discipline –
it relies on physics & **mathematics!**

III. Let us look at the precondition: “digital skills”

Problem solving involves mathematics in several aspects



Mathematics will play a key role in future disciplinary work

➤ Criminal investigations



➤ Forecasting



➤ Security



➤ Strategy work



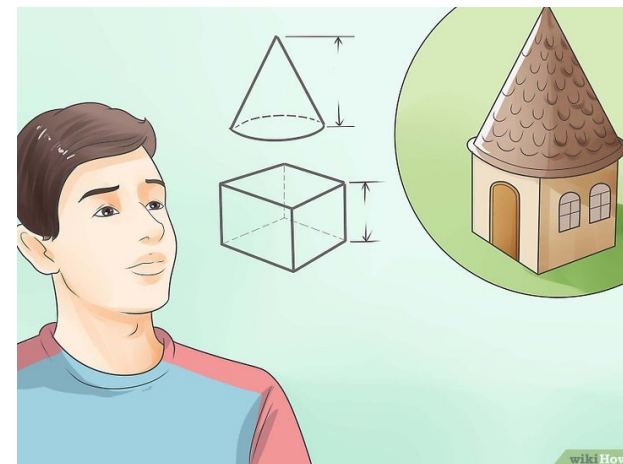
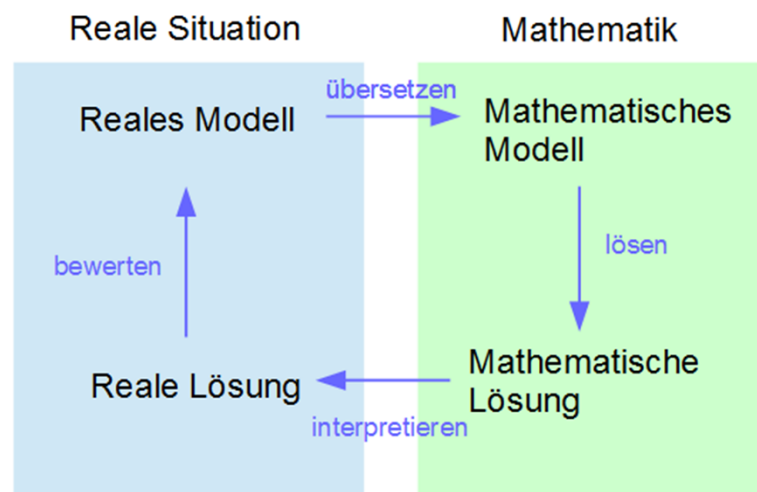
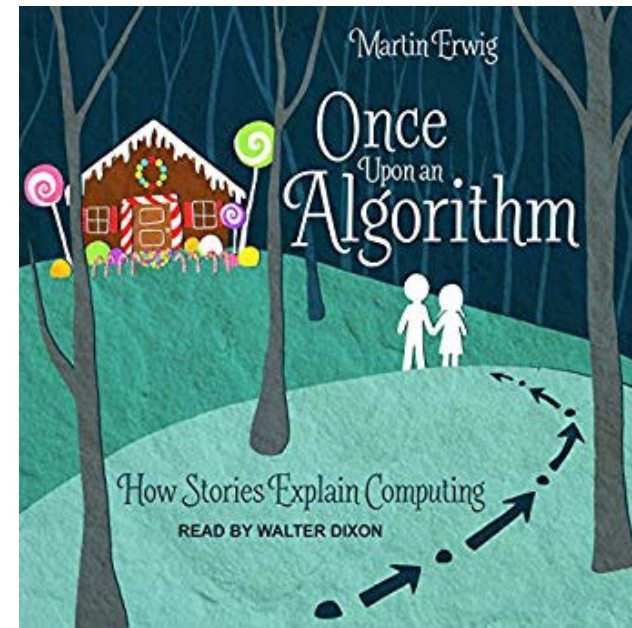
Algorithms are also key for everyday problem solving

- They do not only work in sports, they even improve common sense practice
 - Purchasing
 - Organizing
 - Selecting team members
 - Search for the missing
 - ... including: searching for missing information



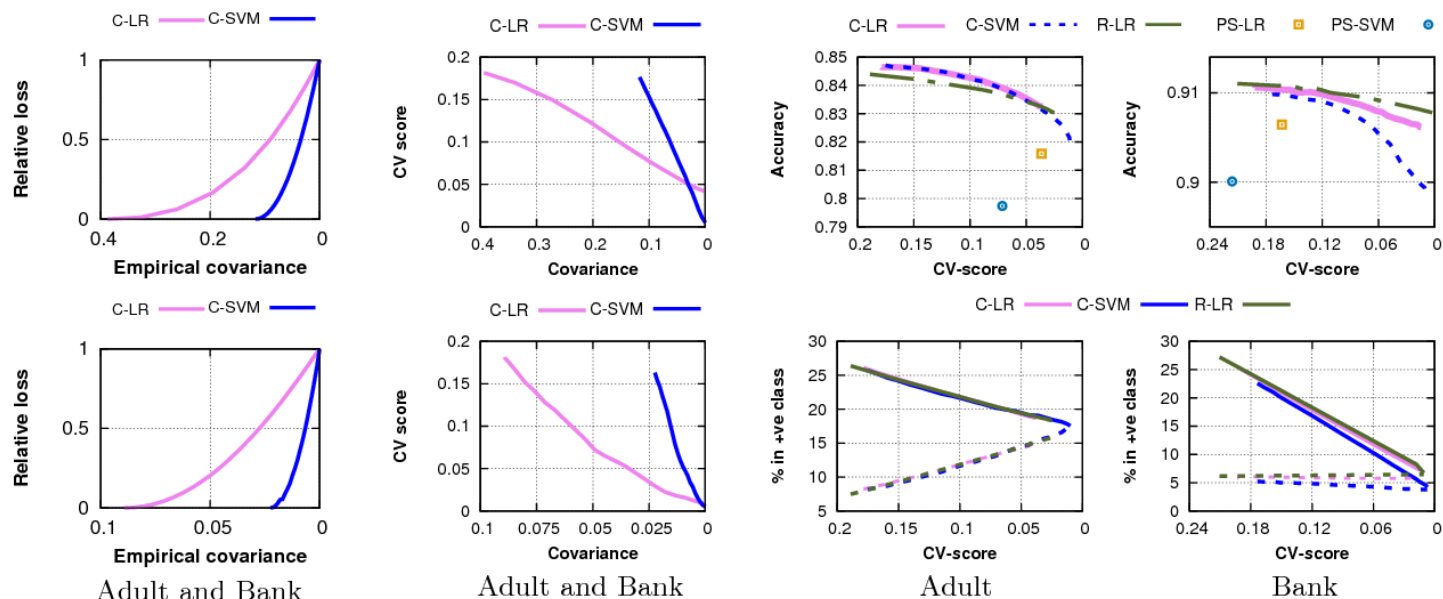
Mathematics is the «design science» supporting computational thinking

- Designing models
- Designing algorithms
- Designing the procurement of data
- Designing the code
- Designing the business
- Designing the business optimization



«No-discrimination» is impossible if you ignore discrimination parameters – data show surprising effects ...

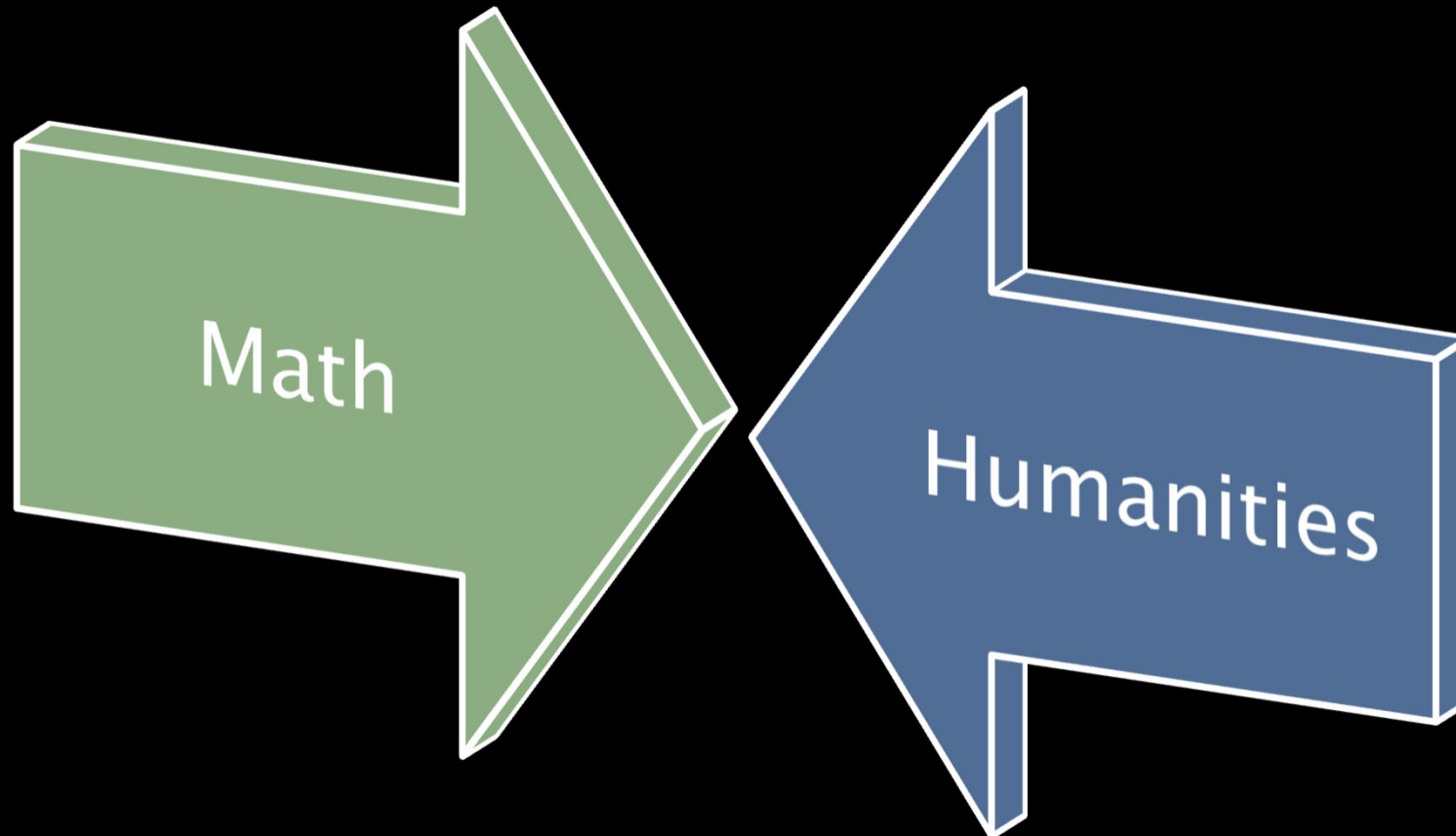
Asian/Pacific-Islander	934	369	1,303
White	28,696	10,207	38,903
Black	3,694	534	4,228
Other	308	45	353
Total	34,014	11,208	45,222



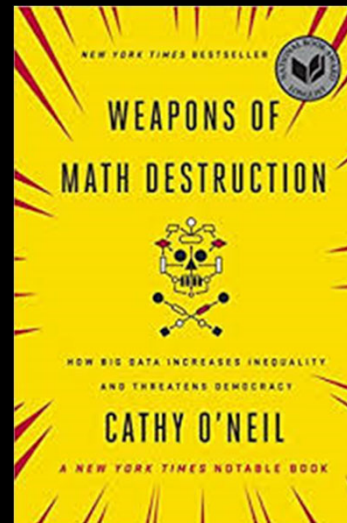
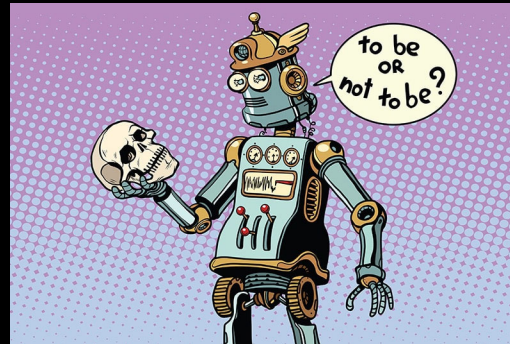
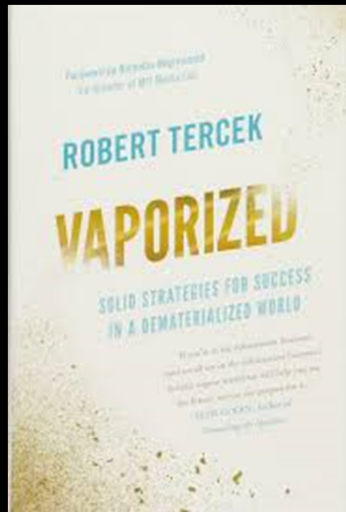
(a) Loss vs. Cov. (b) Cov. vs. CV score (c) Single binary sensitive attribute
Figure 6: [Maximizing accuracy under fairness constraints: single, binary sensitive attribute] Panels in (a) show

There is no **ethics** without
mathematics!

Formal and traditional philosophy are the corner stones of computational business thinking



We have to improve education on both!





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Bern University of Applied Sciences

Merci!

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www.societybyte.swiss

BFH-Center Digital Society



- ▶ **The WHY:** The digital transformation shall be an *enabler* for people, disciplines, business, and government!
- ▶ **The HOW:** We help actors to *speed up the appropriation of digital tools!*
- ▶ **The WHAT:**
 - ▶ Methods: sustainable design & applied data science
 - ▶ Topics: Identity, privacy, and cybersecurity
 - ▶ Areas: digital health & smart cities

www.societybyte.swiss

Personal Background

- ▶ Dipl. Ing. in engineering mathematics from Johannes Kepler University Linz
- ▶ Dr. phil. from the University of Zurich for a thesis on the interplay of function theory, analytic and stochastic potential theory, and Banach space geometry entitled «*Geometric Properties of Composition Operators on Hardy Spaces*»
- ▶ Research on Computer Science & related disciplines
 - ▶ Research on performance optimization, sustainable & secure system design, legal informatics, and e-Government / e-Business
 - ▶ Visiting associate professor for *High Performance Computing* at the University of Rostock
 - ▶ Visiting full professor for *System Software, Communication, and Distributed Systems* at the University of Zurich
 - ▶ Chief architect in two European R&D projects on *E-Government and* representative of Switzerland in the large scale pilot STORK 2.0
- ▶ Research on Business Administration & Economics
 - ▶ Research on team work in high performance teams, socio-technological ecosystems, the digital single market (DSM), and the digital transformation of disciplines and sectors (with focus on healthcare, agriculture, and sports)
 - ▶ Research professor at BFH Business School – currently Co-Director of *IDEA – Institute for Digital Enabling* and Head of the transdisciplinary *BFH Center Digital Society*

Personal Background

▶ Business activities

- ▶ Technological consulting (IT solutions, IT-security, market potential) & leadership consulting (development of IT departments, digital transformation)
- ▶ Co-founder and member of the board of all-acad.com AG
- ▶ Member of the board of 3L Informatik AG
- ▶ Jury president «Public Affairs» in BOSW-Award

▶ Further past activities

- ▶ Member of the Swiss National Advisory Board for E-Government
- ▶ Co-Founder and Vice-President of E-Government Symposium Switzerland

▶ Further current activities

- ▶ President of Swiss Informatics Society (SI) & member of the presidium of GI
- ▶ President of ISCM Bern (IGNM Bern)
- ▶ Treasurer of Praevenire (www.Praevenire.at)
- ▶ Member of the steering committee of NRP 75 “Big Data”
- ▶ Member of the steering committee of TA Swiss
- ▶ Member of the board of eJustice.ch
- ▶ Member of the advisory board of Ifib GmbH (University of Bremen)
- ▶ Editor-in-chief of www.societybyte.swiss