AV60 Conference
Roma, Sept. 22, 2014

ECONOMIC COMPLEXITY

Measuring the Intangible Growth Potential of Countries

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CRISISLAB
ANALYTICS FOR CRISIS PREDICTION AND MANAGEMENT

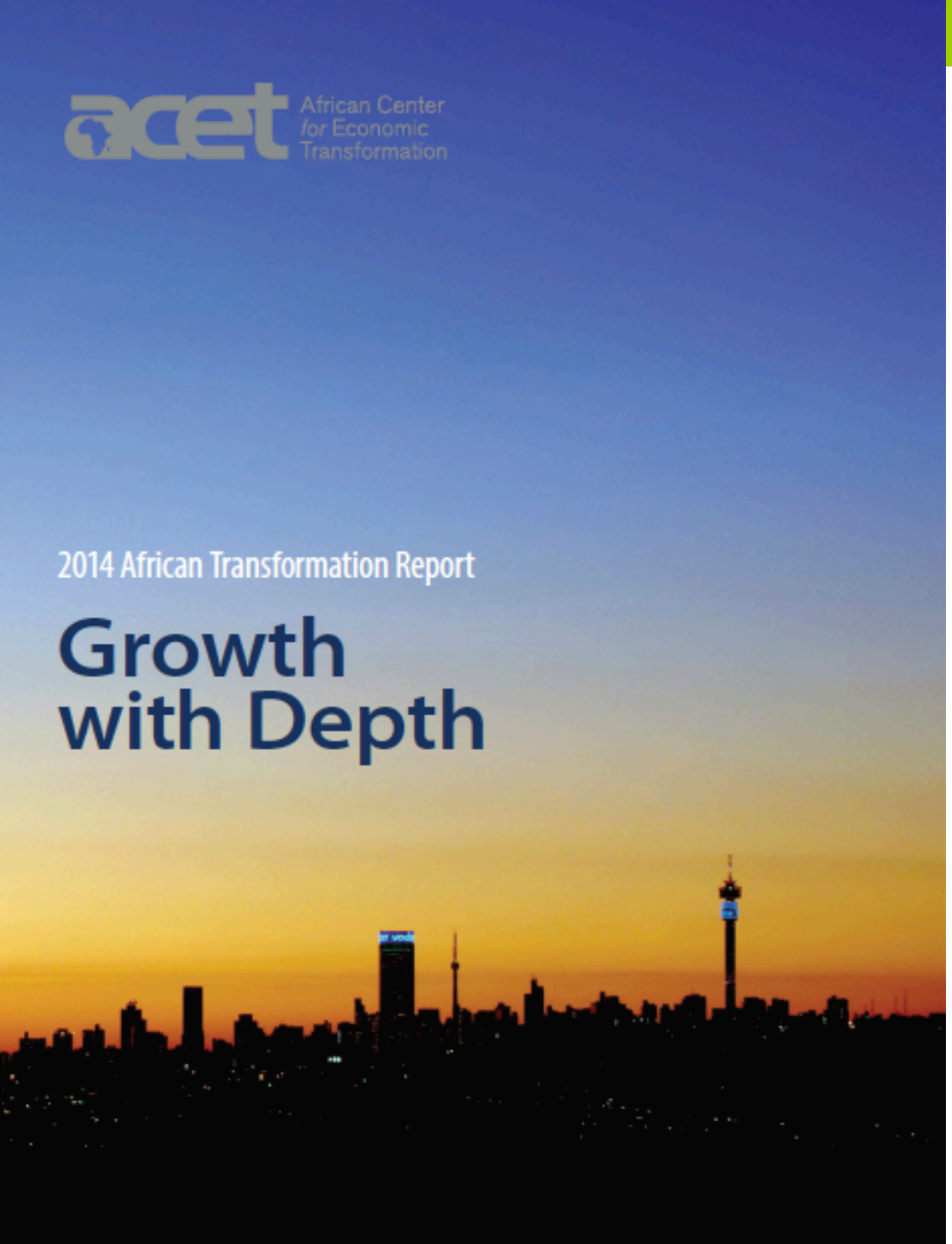
Economic Complexity

In the wake of the financial crisis and its subsequent spillover into the economy one of the major challenges is to rekindle the very foundations of economics and finance.

New economic theories should be strongly data driven in order to provide a more concrete scientific grounding to economics, so as to expand the realm of quantitative methods into socio-economic sciences (in the spirit of Google Page Rank).

This new grounding for economic disciplines is aligned with the mission of the Institute for New Economic Thinking (INET)

Quantitative macro economic scenarios for long term country growth



Amman conference, June 2014

Stiglitz's Task Force on Industrialization:

Yau Ansu:
ACET Report (221pages)

Comparison of economic data between 12 african countries and other countries (mostly asiatic) which went through industrialization In the recent past.

- Aggregated data for the two groups of countries
- Interesting information but sometimes conflicting
- Difficult to get a unified comprehensive picture

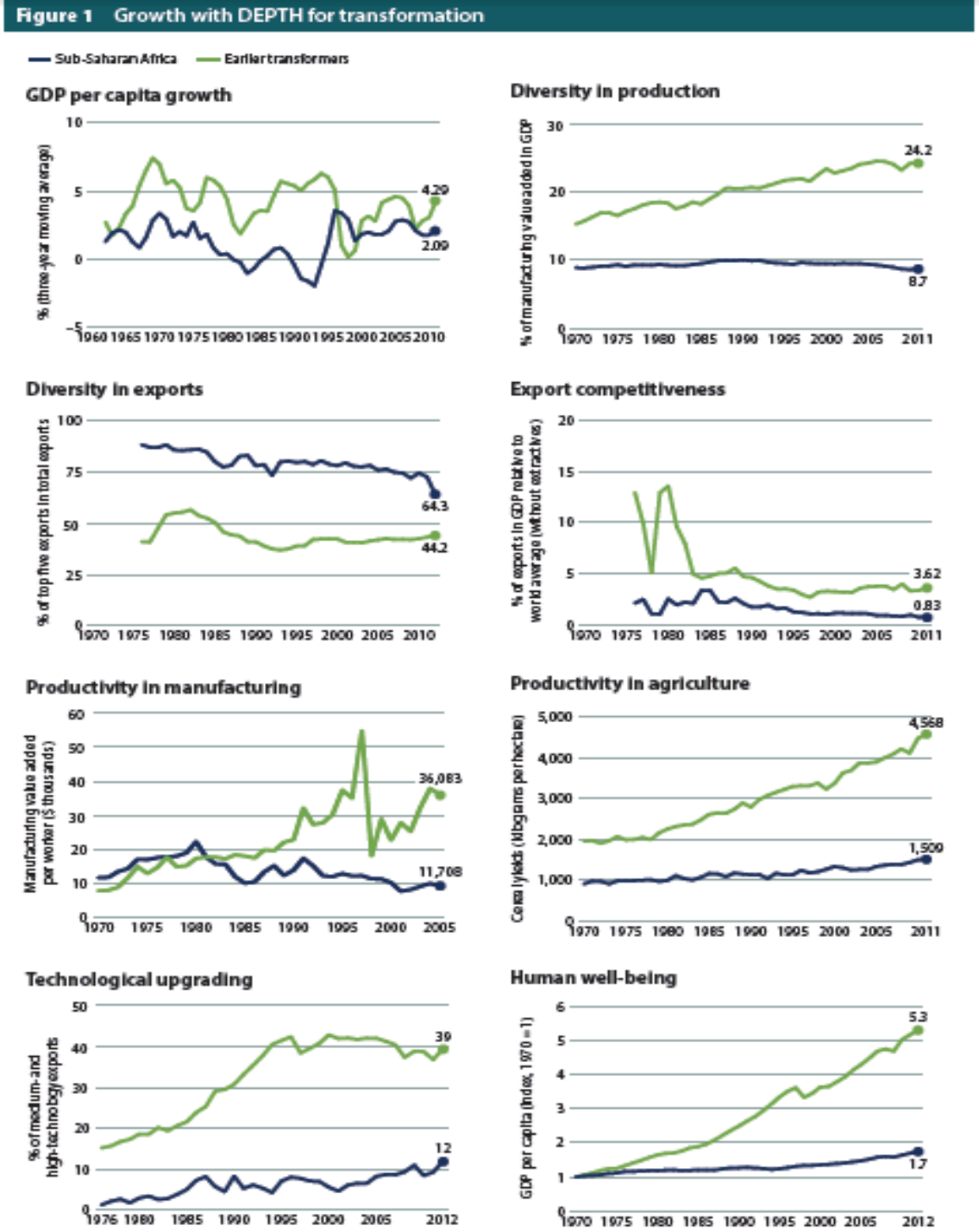


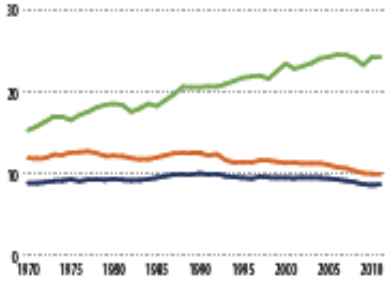
Figure 1.2 How Sub-Saharan Africa fares in relation to eight earlier transformers

The figures here show how Sub-Saharan Africa is performing in relation to eight earlier transformers on various indicators of depth.

ACET 15
Sub-Saharan Africa
Earlier transformers

a Diversity: production

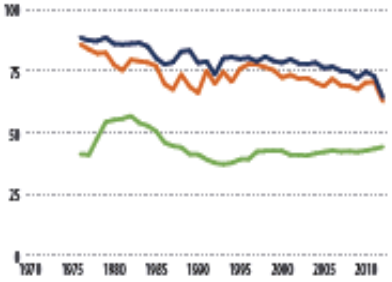
% of manufacturing in GDP



Source: World Development Indicators (database).

b Diversity: exports

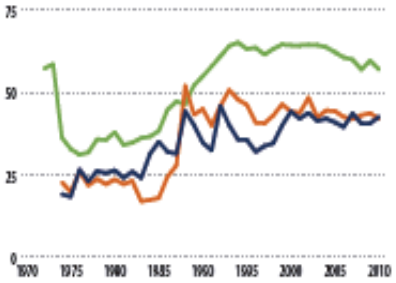
% of top five exports in total exports



Source: UN Comtrade, Revision 2, Digit 3.

c Diversity: exports of manufactures and services

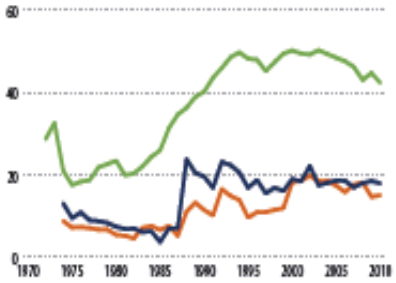
% of total goods and services exports



Source: World Bank staff estimates; World Trade Organization; IMF.

d Diversity: exports of manufactures

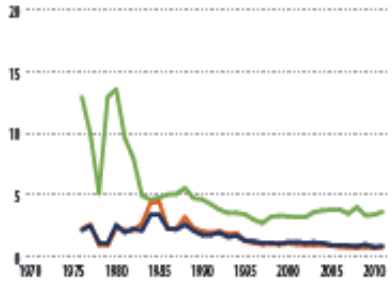
% of total goods and services exports



Source: World Bank staff estimates; World Trade Organization; IMF.

e Export competiveness: export market share without extractives

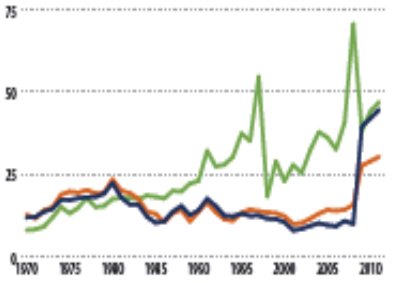
% of exports in GDP relative to world average (without extractives)



Source: World Development Indicators (database); UN Comtrade, Revision 2, Digit 3.

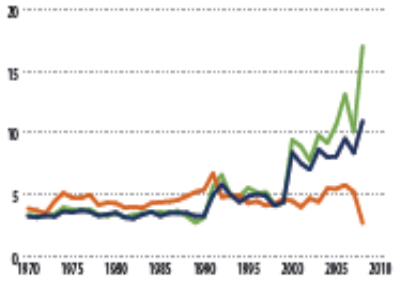
f Productivity: manufacturing value added per worker

Manufacturing value added ($ thousands)



Source: UNIDO, Revision 3, Digit 2.

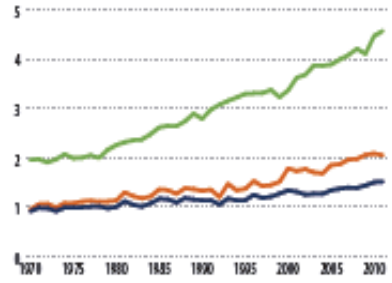
g Productivity: ratio of labor productivity to the average wage in manufacturing



Source: UNIDO, Revision 3, Digit 2.

h Productivity: cereal yields

Kilograms per hectare (thousands)



Source: World Development Indicators (database).

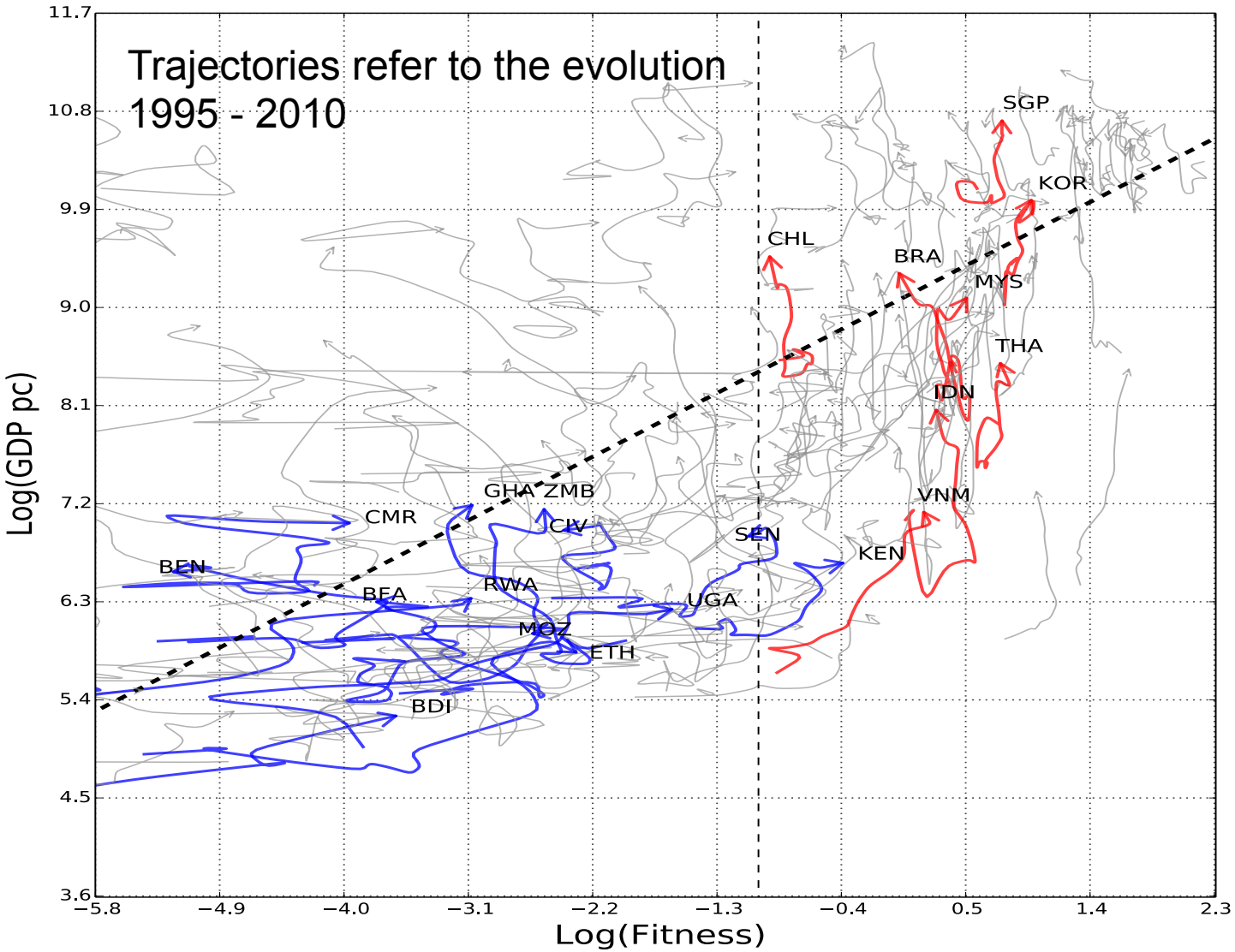
More and more data but difficult to draw a clear conclusion ???

And still data are aggregated, no specific information on individual countries

The Economic Complexity answer: New synthetic concepts

Individual country trajectories in the new space

Clear interpretation - Complete information - Visual impact

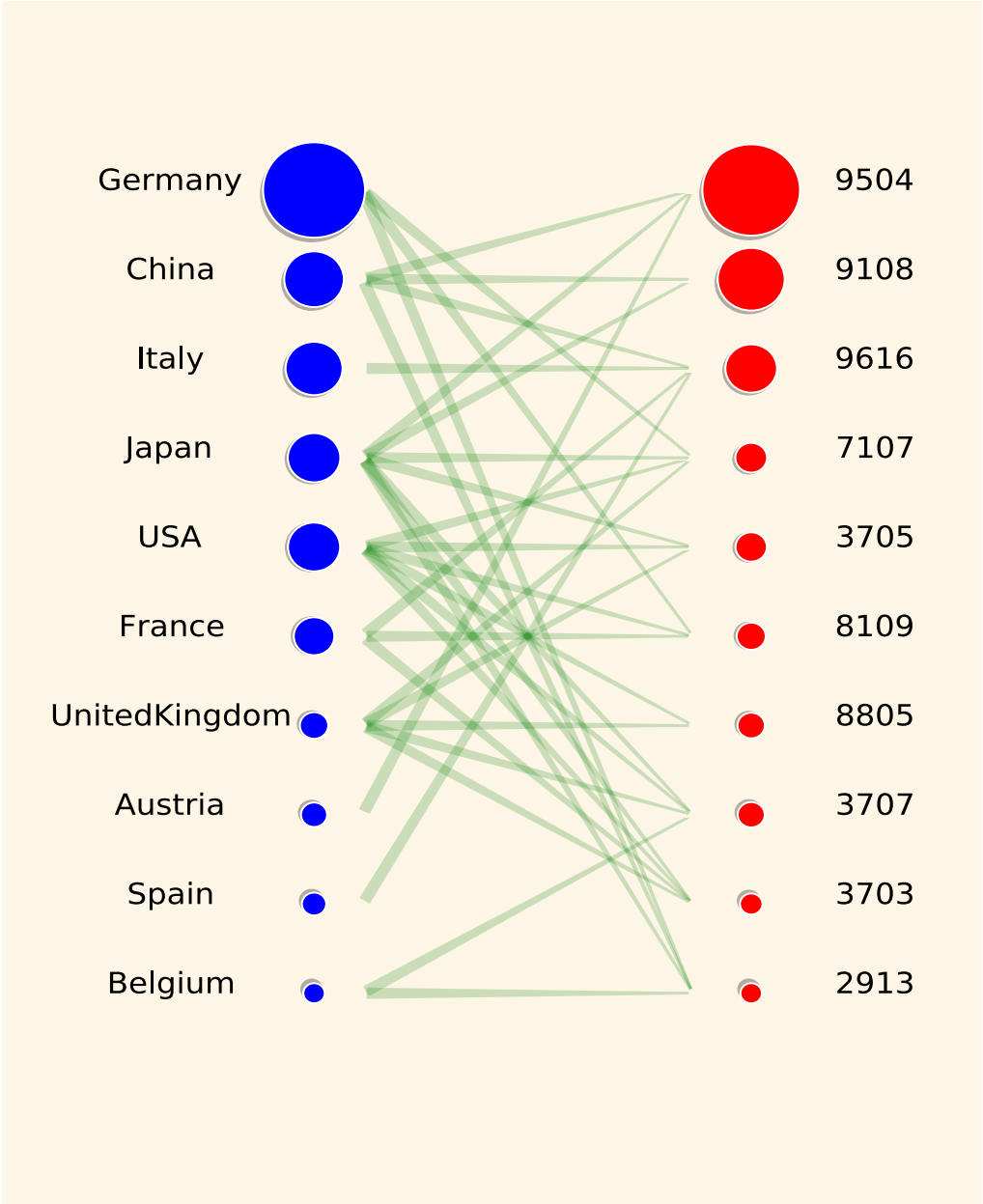


COMTRADE database:
Which country exports which product

Bipartite Network:
New algorithm to extract information for

- Fitness of Countries
- Complexity of Products

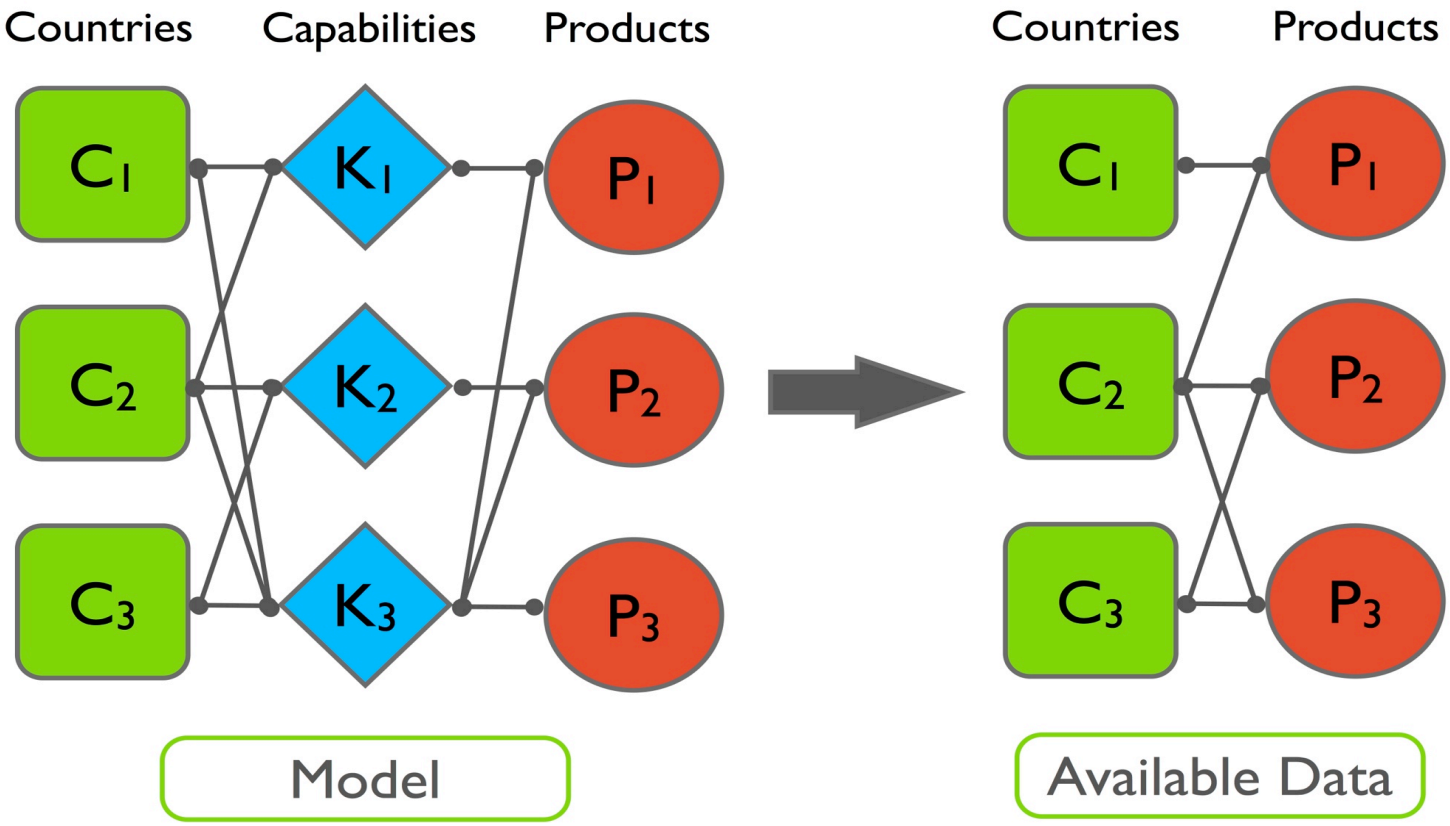
NB: this is not an analysis of the export volumes.
The information is derived from the nature of products



THE THEORY OF HIDDEN CAPABILITIES

A **COUNTRY** IS ABLE TO PRODUCE A **PRODUCT** WHEN IT OWNS ALL THE **CAPABILITIES** NEEDED FOR IT (Hausmann& Hidalgo 2009)

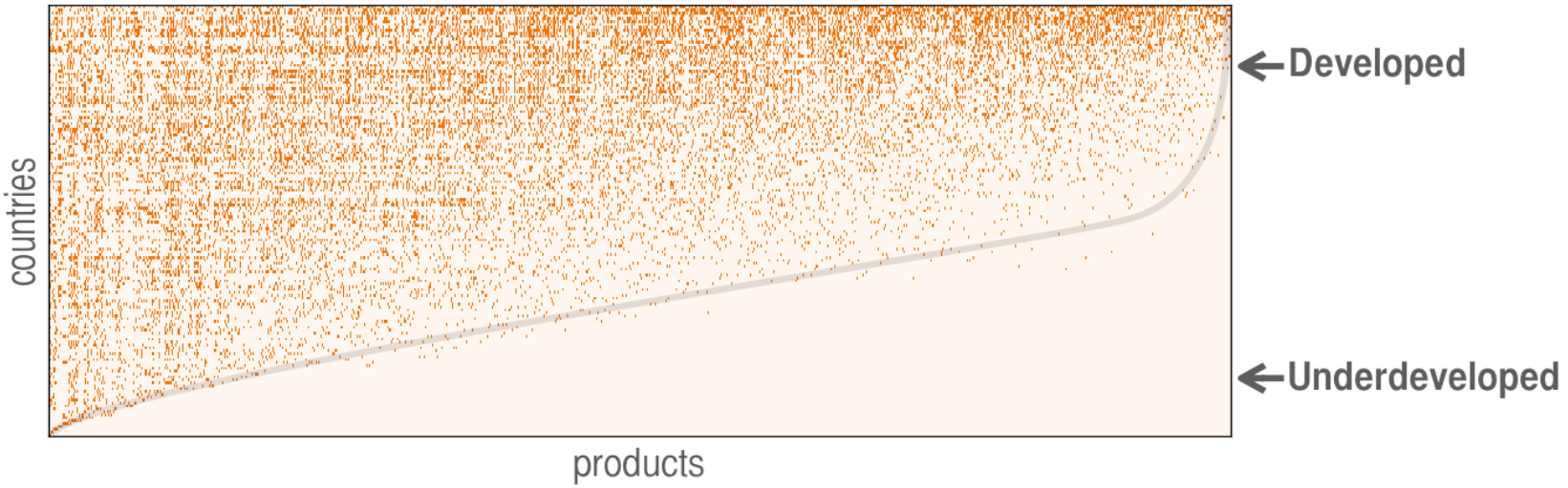
Products discount all the information on capabilities as stock prices should discount all the information on companies (except finance fluctuations)



HOW TO **MEASURE** **CAPABILITIES** FROM THE AVAILABLE DATA?

SPECIALIZATION VS. DIVERSIFICATION

DATA DRIVEN APPROACH:



Evidence for leading role of diversification with respect to competitive advantage (specialization)

- Globalization
- Ecosystems
- Evolvability
- Adaptation

From Qualitative to Quantitative

- Math. Problem: minimal elements to have a triangilar matrix
  Complex Hierarchical structure, nestdness etc.
- For sectors and companies the situation evolves towards specialization

Monetary measures

(GDP, GDP_{pc}, etc)

Metrics for intangibles

NEW INFORMATION

M. Cristelli, A. Tacchella, L. Pietronero, The Heterogenous Dynamics of Economic Complexity (in preparation)

M. Cristelli, A. Tacchella, L. Pietronero, Economic Complexity: Measuring the Intangibles (ebook)

We measure the **Fitness of countries** (DNA/intangibles) and the **Complexity of products** with an iterative **Google-like algorithm** for the bipartite country-product network

Fitness

$$\tilde{F}_c^{(n)} = \sum_p M_{cp} Q_p^{(n-1)}$$

$$F_c^{(n)} = \frac{\tilde{F}_c^{(n)}}{\langle \tilde{F}_c^{(n)} \rangle_c}$$

Complexity

$$\tilde{Q}_p^{(n)} = \frac{1}{\sum_c M_{cp} \frac{1}{F_c^{(n-1)}}}$$

$$Q_p^{(n)} = \frac{\tilde{Q}_p^{(n)}}{\langle \tilde{Q}_p^{(n)} \rangle_p}$$

F_c: diversification weighted by complexity

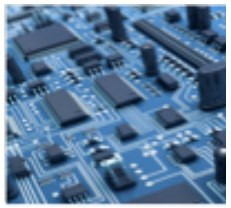
Q_p: Extremal non-linear complexity of products
a single low fitness producer implies low complexity

A. Tacchella et al., *A New Metrics for Countries' Fitness and Products' Complexity,* Scientific Reports 2, 723 (2012)

F_c: diversification weighted by complexity


Platinum
0.0032
+

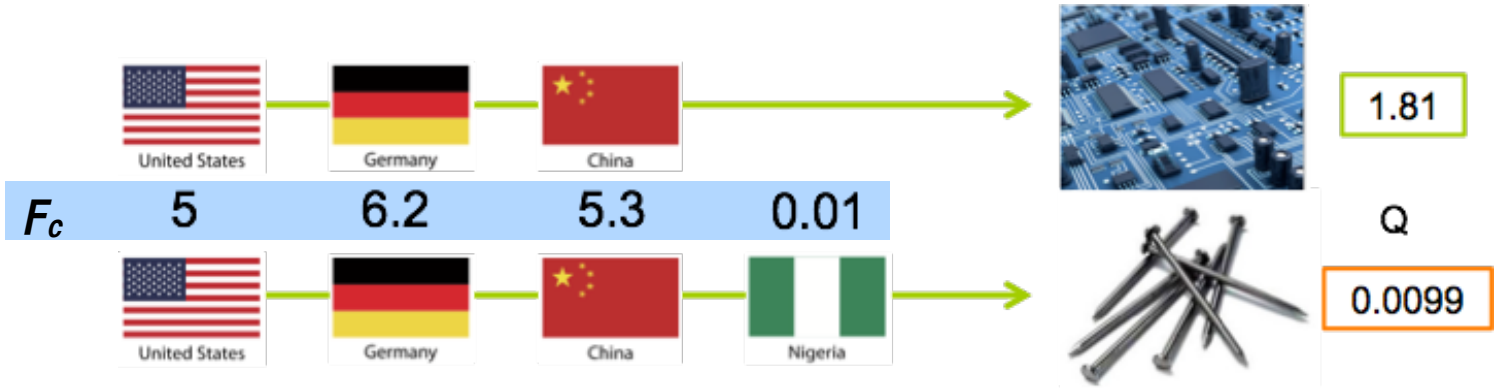
Nails
0.0099
+

Wheat
0.12
+

Chips
1.81
+

Optic Fibers
4.39
=


F_c
6.3331

Q_p: Extremal non-linear complexity of products a single low fitness producer implies low complexity



A. Tacchella et al., *A New Metrics for Countries' Fitness and Products' Complexity,* Scientific Reports 2, 723 (2012)

The Economic Dynamical Ecosystem:
Data driven approach from micro to macro

- Countries: diversified in products
  Countries and Products: Google like approach – Big Data
  Countries: Fitness index
  Products: Complexity index
  Dynamics: Monetary vs Intangible metrics – Hidden potential

- Subsystems: Regions, Districts, Cities (London, Shanghai)

- Industrial sectors: Various levels of grouping
  Evolution of their Complexity
  Policy making: virtual experiments, what if?
  Criteria for optimization

- Companies: specialized in products
  But diversified in terms of Technologies in their control
  (ie patents)

S. Inoua, *On the Complexity Approach to Economic Development*, 2013
http://vixra.org/pdf/1301.0182v1.pdf

How the model works:

1. Probability of having a product with *combinatorial complexity C (number of capabilities)* is

$$p(C) \sim \pi^C$$

Meaning of π: how effective is a country in making more products by combining capabilities

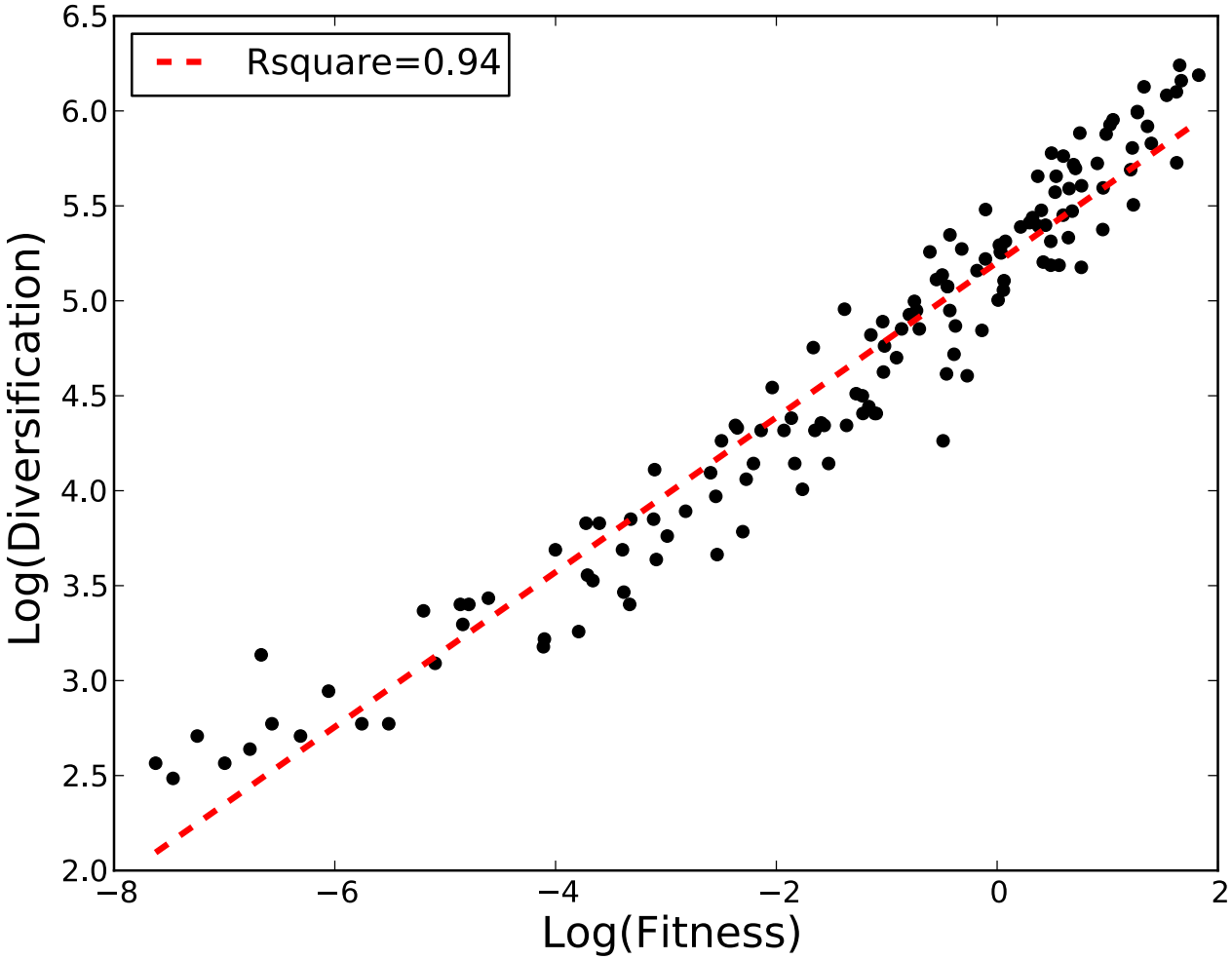
$$d = \sum_{C=1}^{K} p(C) \binom{K}{C} \sim (1+\pi)^K$$

2. The diversification *d* of a country which has *K* capabilities (*K* represents the complexity of that country) is

NB: no loss of generality assuming minimum number of capabilities =1

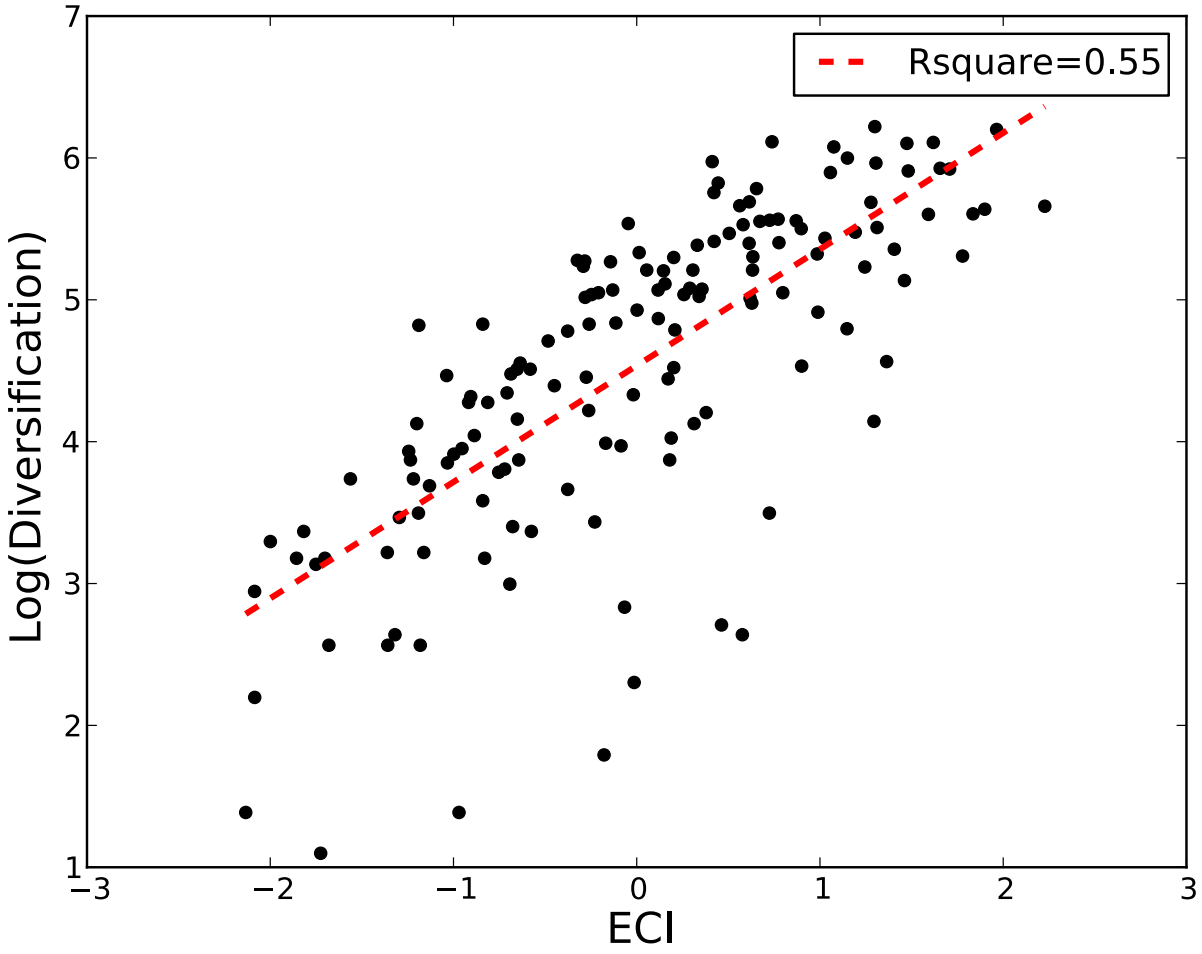
1° Prediction: let's test, as proxy for *K* , *log(Fitness)* and the *Economic Complexity Index* (ECI, C. Hidalgo et al. PNAS, 2009)

log(DIVERSIFICATION) vs log(FITNESS)



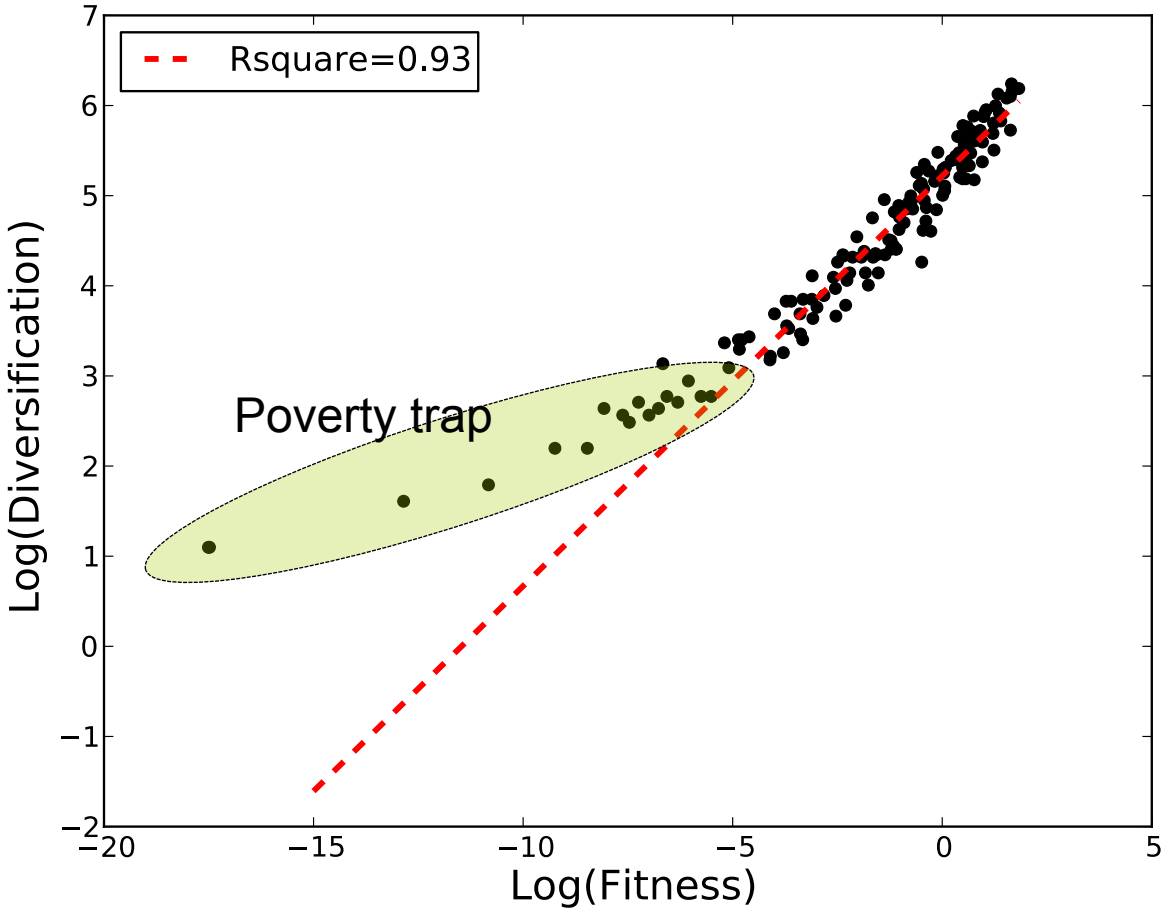
Log(Fitness) is good proxy for the *complexity K* of countries $R^2 \approx 0.92\text{-}0.94$ in the period 1995-2010

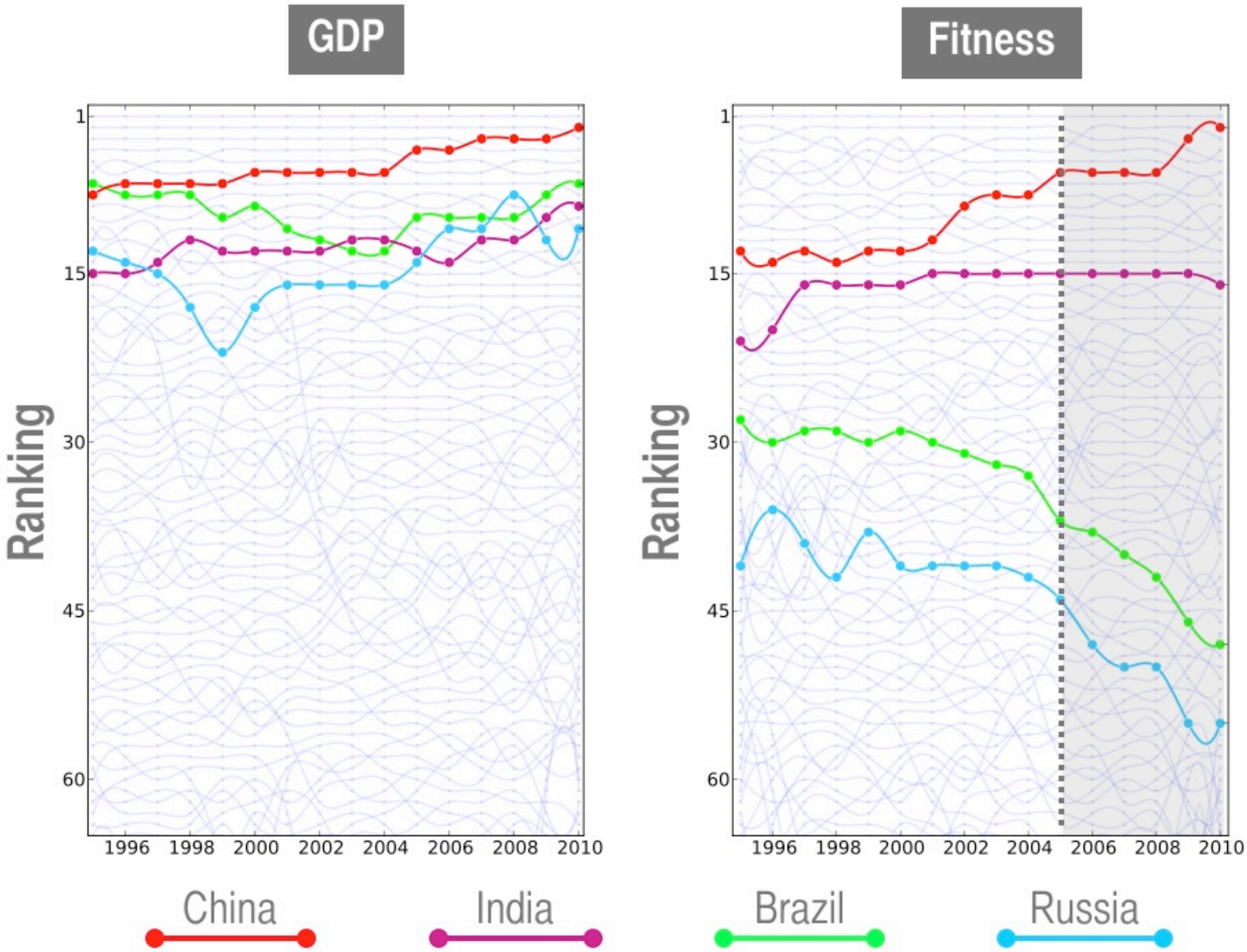
Hausmann & Hidalgo have tried to use exactly the Google algorithm but their ECI is not a good proxy for *complexity K*, $R^2 \approx 0.52\text{-}0.65$ in the period 1995-2010

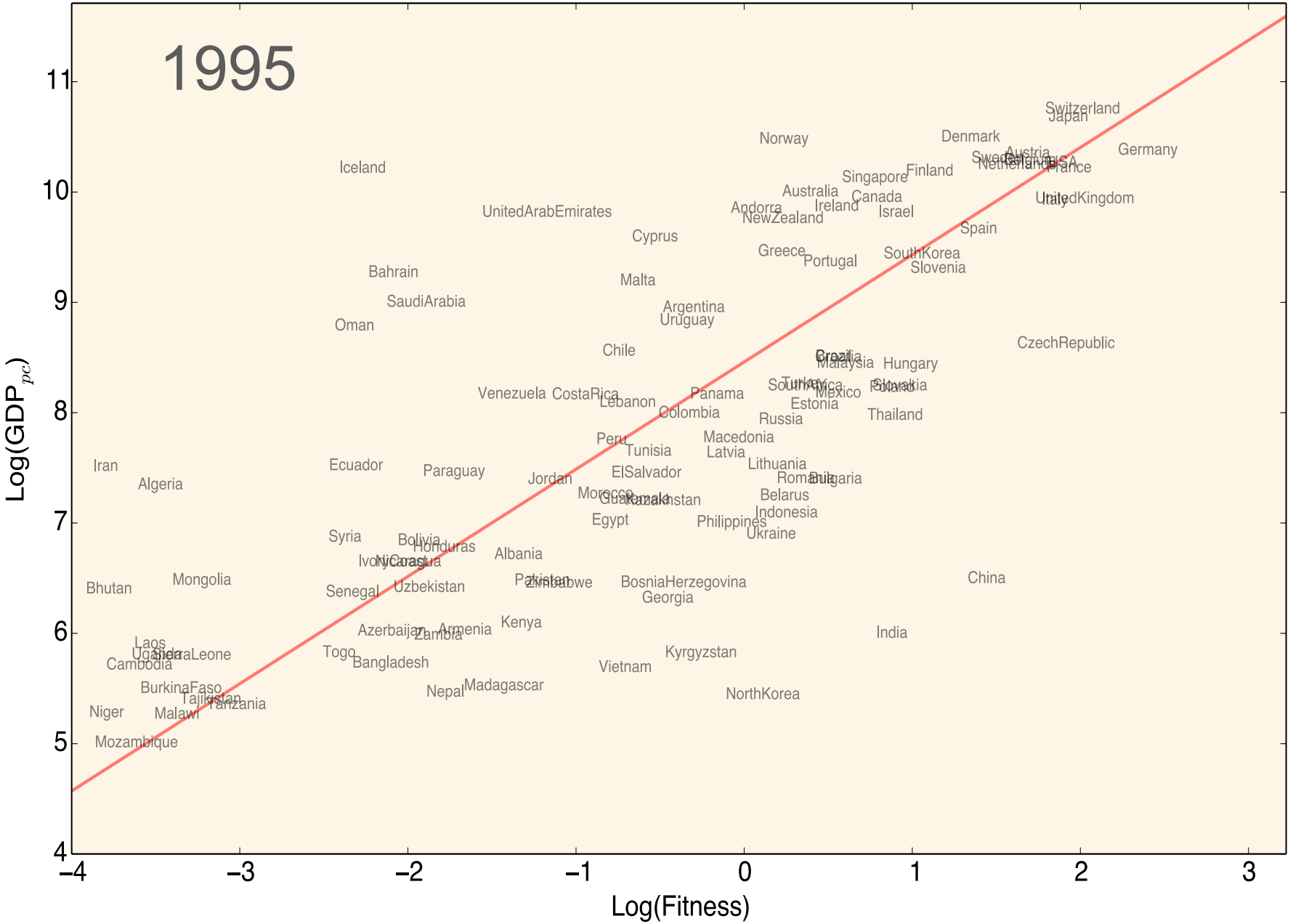


MICRO ORIGIN OF POVERTY TRAP?

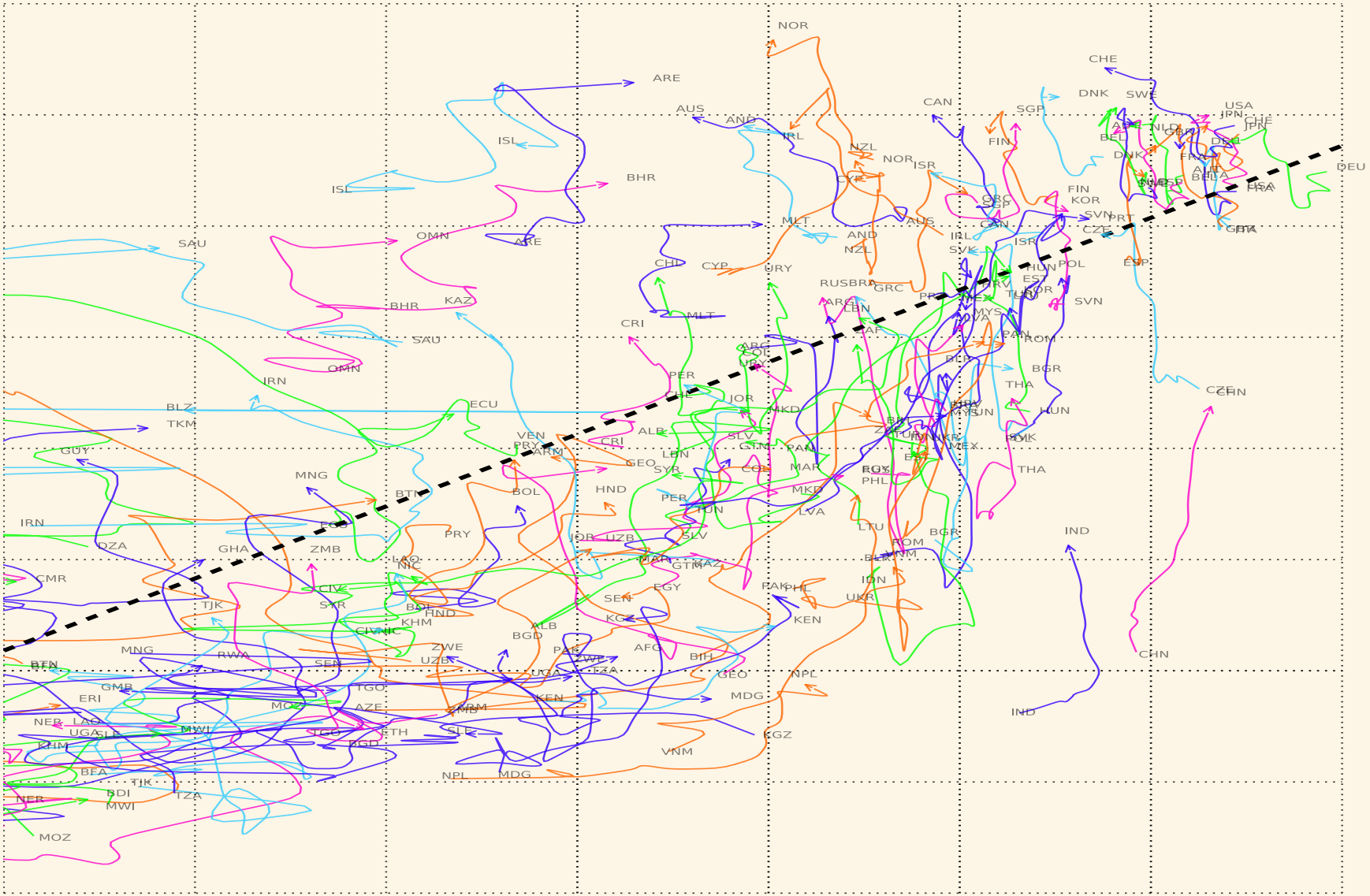
No longer exponential relationship btw *diversification* and *complexity* (i.e. *Log(Fitness)*)

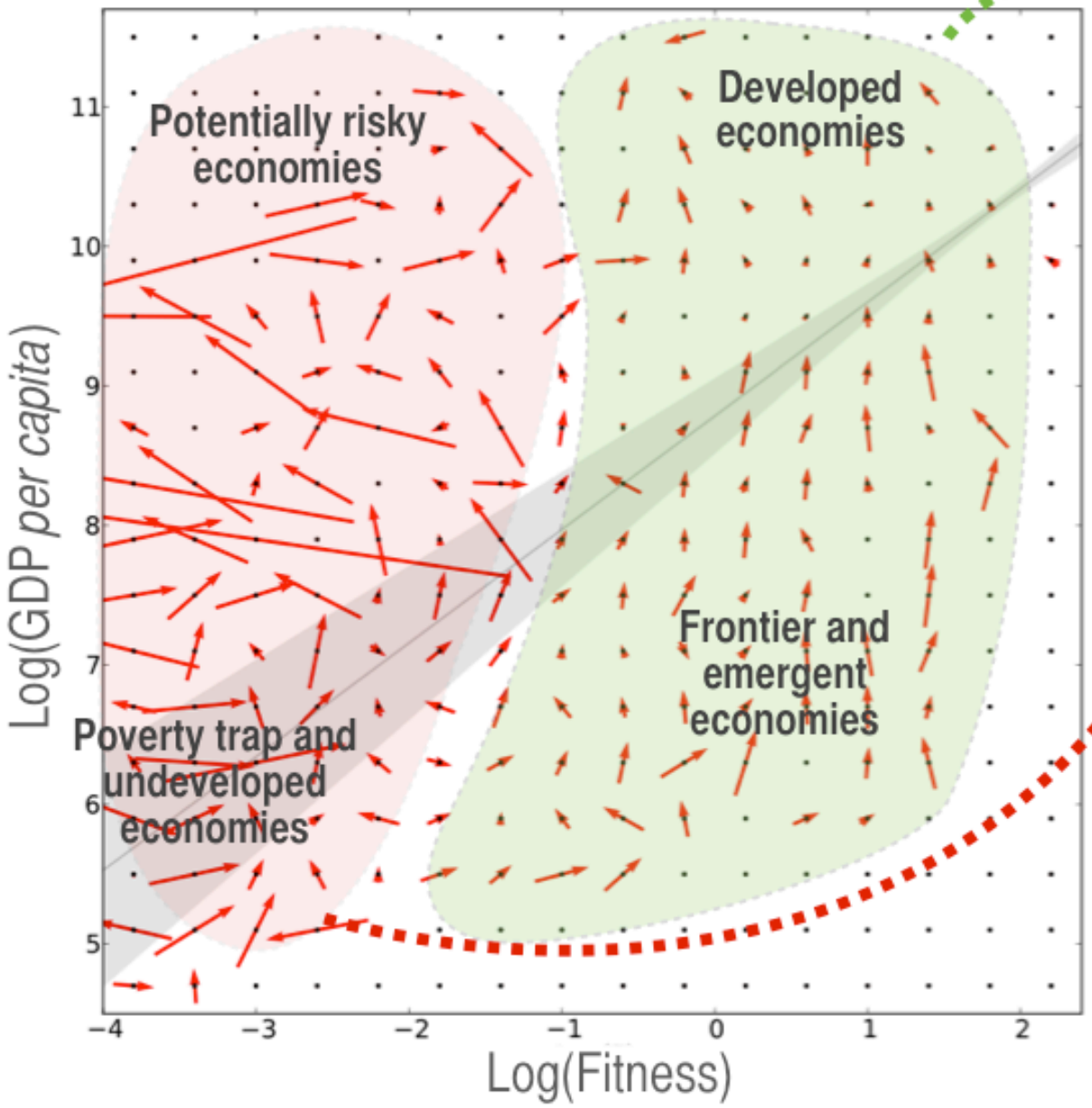



GDP
Fitness
Ranking
Ranking
1
15
30
45
60
1996
1998
2000
2002
2004
2006
2008
2010
China
India
Brazil
Russia


1995
Log(GDP$_{pc}$)
Log(Fitness)
11
10
9
8
7
6
5
4
−4
−3
−2
−1
0
1
2
3
Switzerland
Japan
Norway
Denmark
Germany
Iceland
Singapore
Finland
Australia
Canada
UnitedKingdom
UnitedArabEmirates
Andorra
Ireland
Israel
NewZealand
Spain
Cyprus
Greece
Portugal
SouthKorea
Slovenia
Bahrain
Malta
SaudiArabia
Argentina
Uruguay
Oman
Chile
CzechRepublic
Malaysia
Hungary
Venezuela
CostaRica
Panama
Mexico
Estonia
Lebanon
Colombia
Russia
Thailand
Peru
Macedonia
Tunisia
Latvia
Iran
Ecuador
Paraguay
Lithuania
Algeria
Jordan
ElSalvador
Bulgaria
Morocco
Belarus
Egypt
Indonesia
Philippines
Ukraine
Syria
Bolivia
Honduras
Albania
Mongolia
China
Bhutan
Senegal
Uzbekistan
BosniaHerzegovina
Georgia
Kenya
Azerbaijan
Armenia
Zambia
India
Laos
Togo
Kyrgyzstan
Cambodia
Bangladesh
Vietnam
BurkinaFaso
Madagascar
Nepal
NorthKorea
Niger
Malawi
Mozambique

ECONOMIC DYNAMICS IS HETEROGENEOUS





Laminar regime

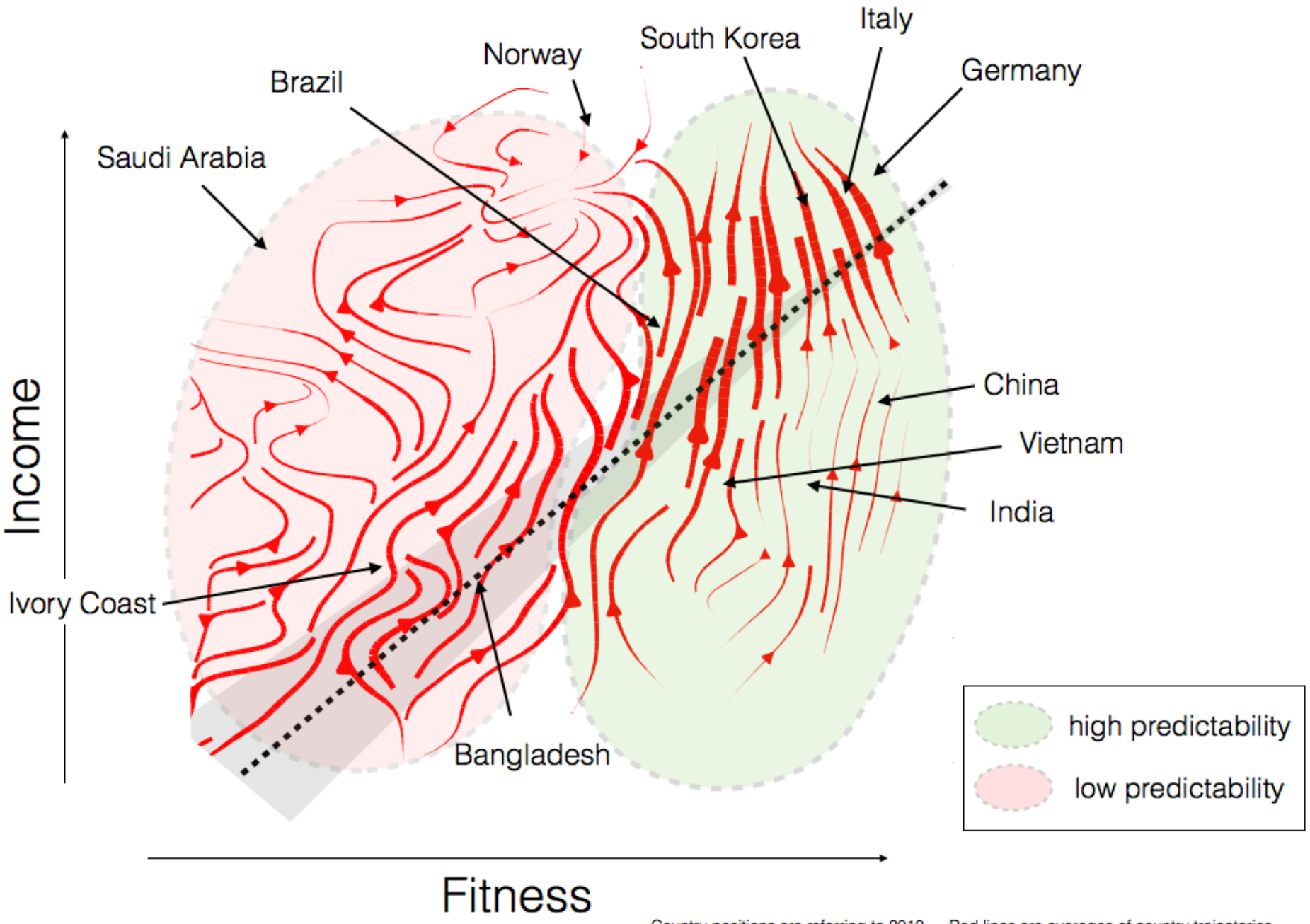
Fitness is the relevant and driving variable for the economic dynamics in this regime

high predictability

Chaotic regime

Dynamics is ruled by several other exogenous factors competing with Fitness

low predictability



Country positions are referring to 2010 — Red lines are averages of country trajectories
Income is measured by Gross Domestic Product *per capita*, PPP (current international $)

Predictability – Forecasting (Beyond Regressions)

Heterogeneous Growth Dynamics: Selective Predictability

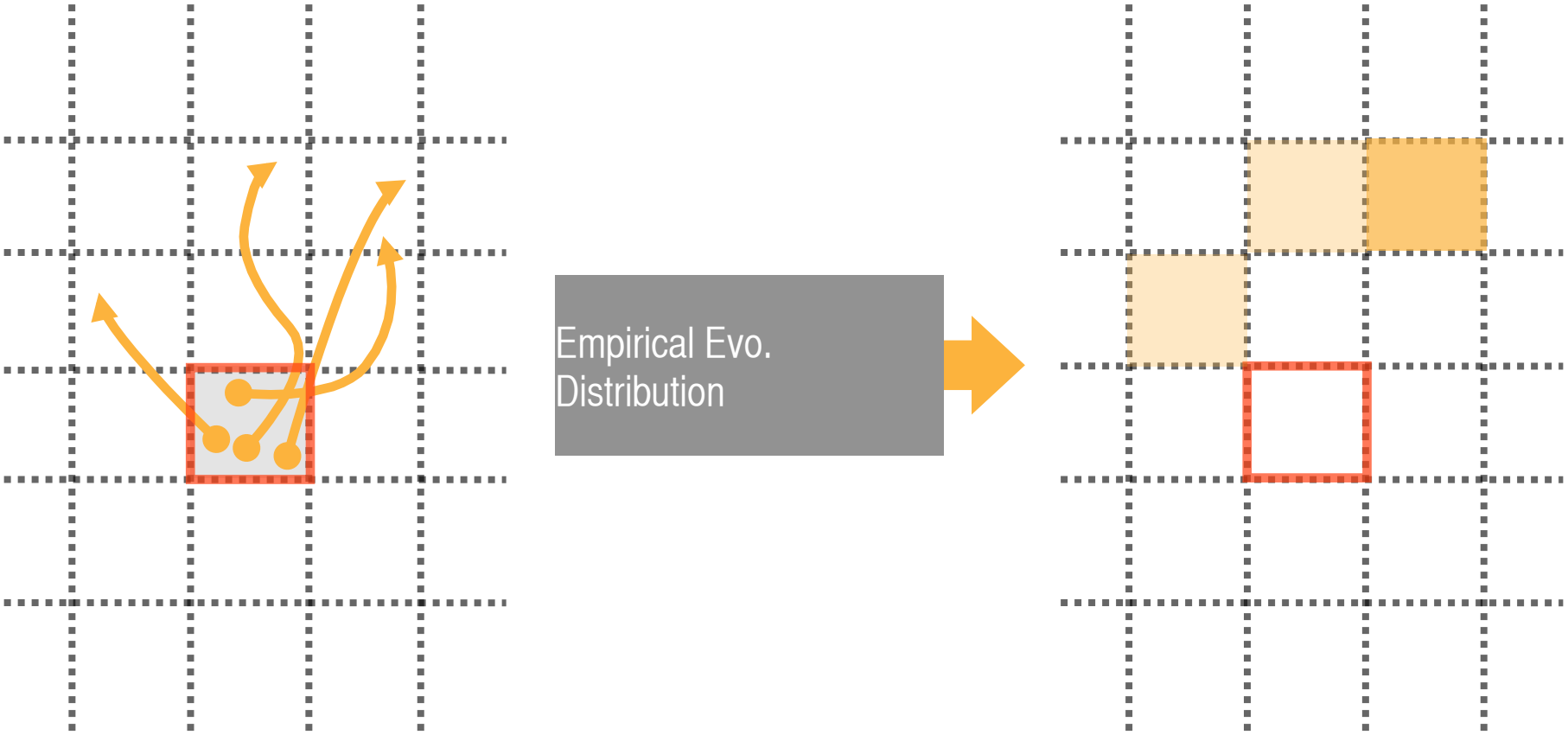
Overview of scienfic predictions:

- If one KNOWS the equation of motion:
  - Linear dynamics: full predictability. Sun raises tomorrow at 06:22
    Halley comet will come back in 121y, 237days, 13h, 45 min, 12 sec
  - Nonlinear chaotic dynamics: Lyapunov exponents
    Weather forecasts, limit of 3 – 7 days
    BUT: don't buy a calendar for more than 5 million years

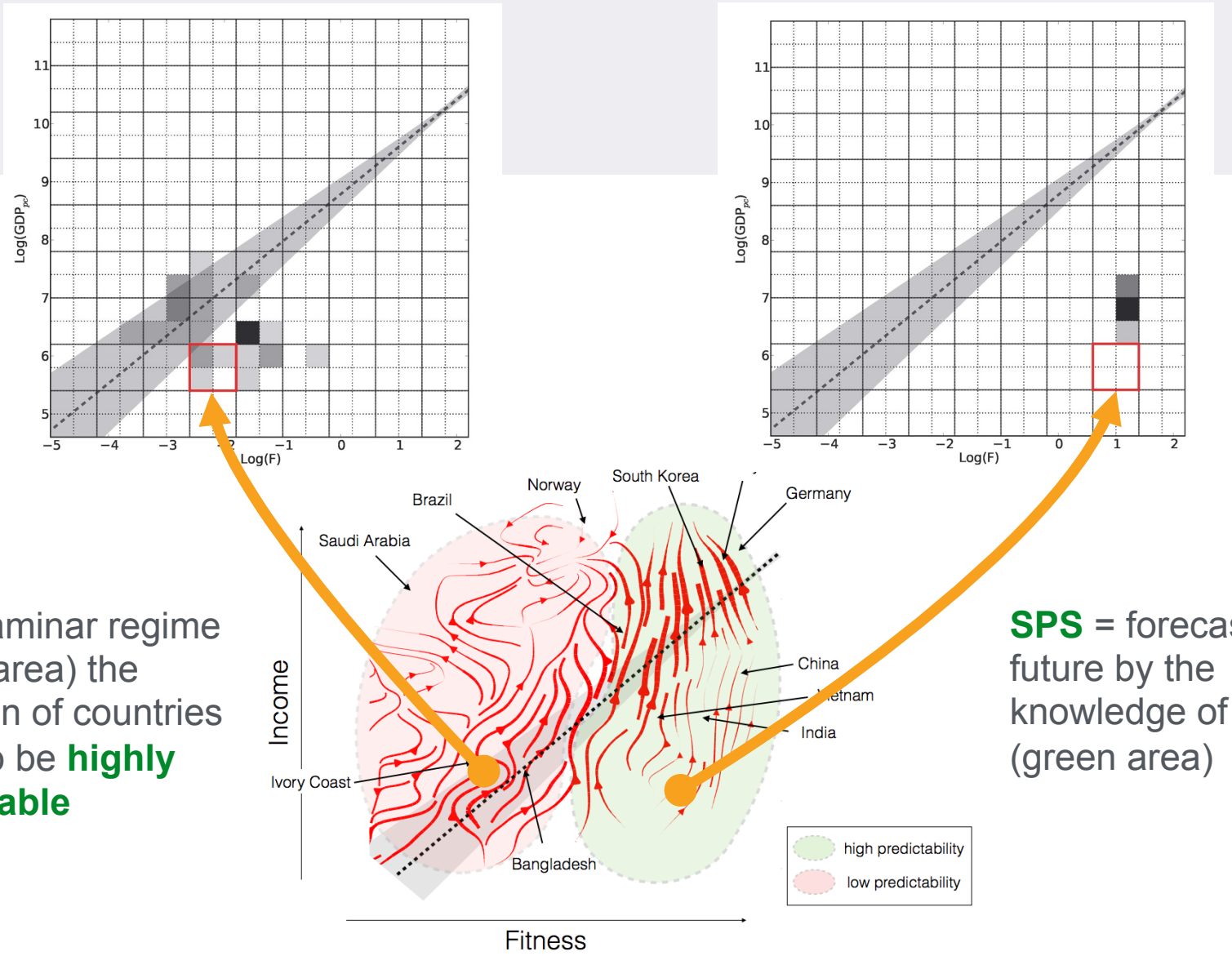
- If one DOES NOT KNOW the equation of motion:
  Method of Analogous: dynamical system approach; effective dimension of phase space. New in economics; concretely data-driven

- Method of Regressions: cause-effect relation; homogeneity of response etc.

Method of Analogs: forecasting the future by the knowledge of the past



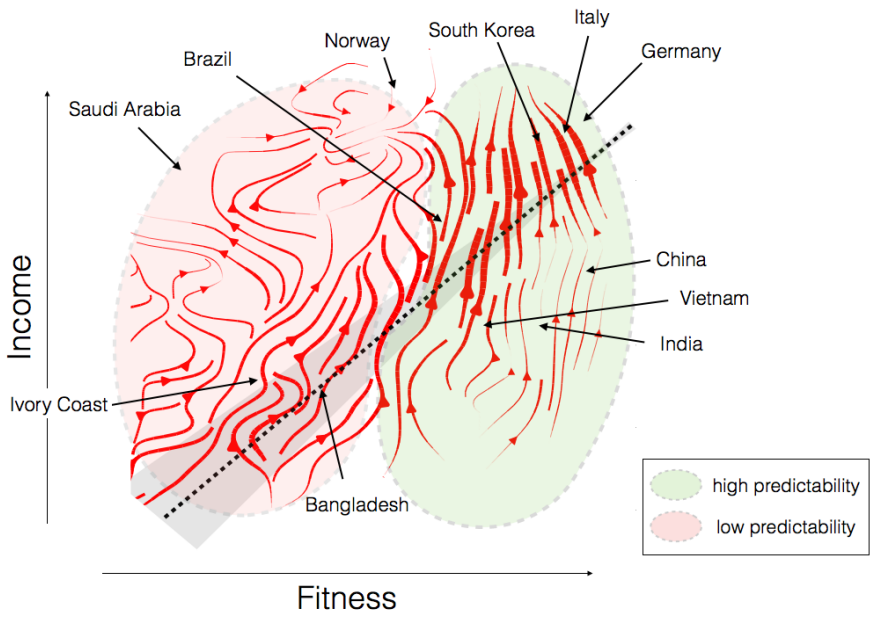
The Selective Predictability Scheme (SPS)



In the laminar regime (green area) the evolution of countries tends to be **highly predictable**

SPS = forecasting the future by the knowledge of the past (green area)

We propose scenarios for medium and long term evolution of countries from the laminar regime according to their position in the **Fitness-Income plane** in 2012 with the SPS



Datasets and Methodology

- Dataset of export volumes (source UN Comtrade)
- GDP_{pc} in current USD (source World Bank)
- Training window for the SPS from 1995 to 2012

Results

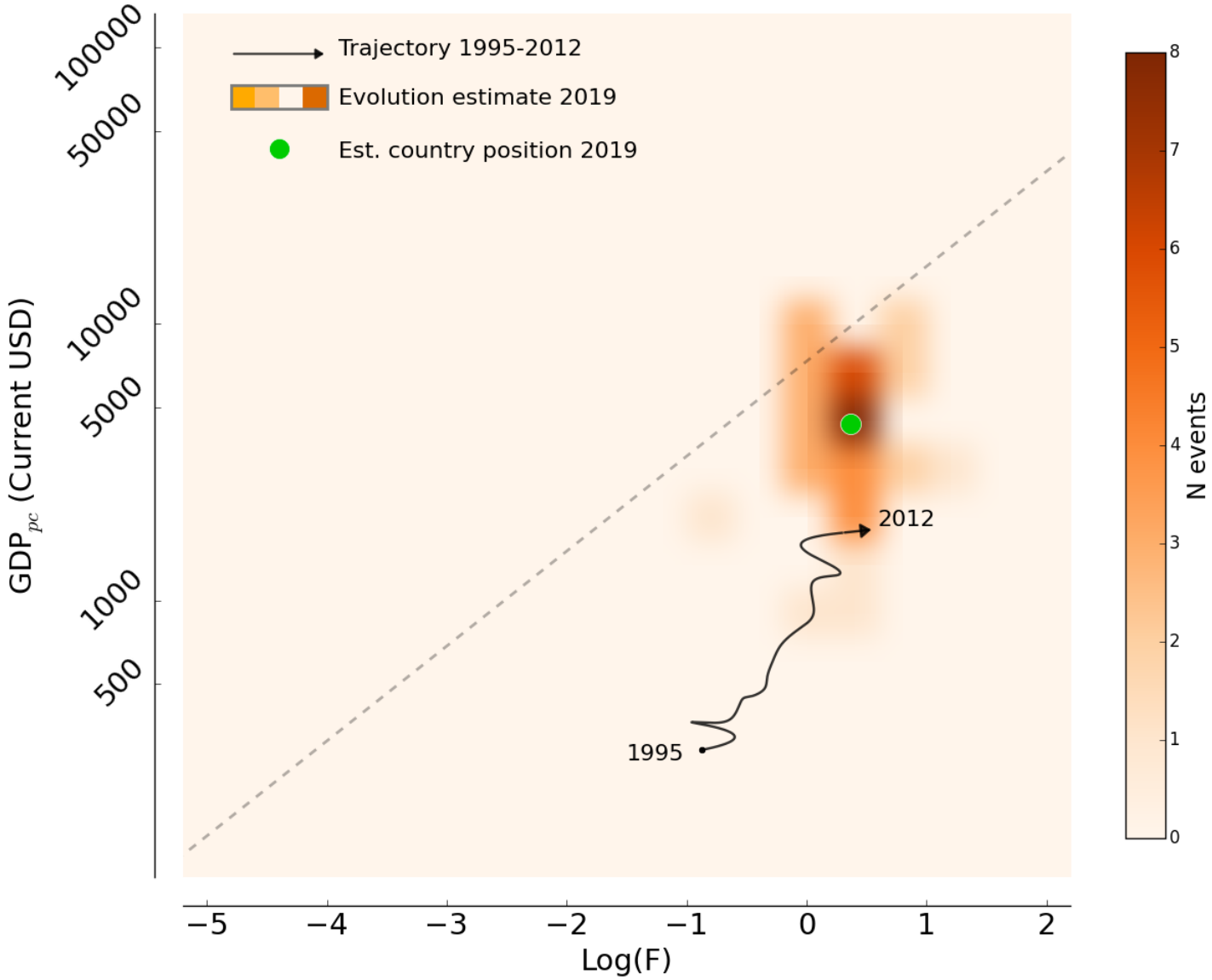
- 7 years growth scenario: 2012-2019
- laminar regime + predictability > 0.6

Country 2

Predictability 0.667

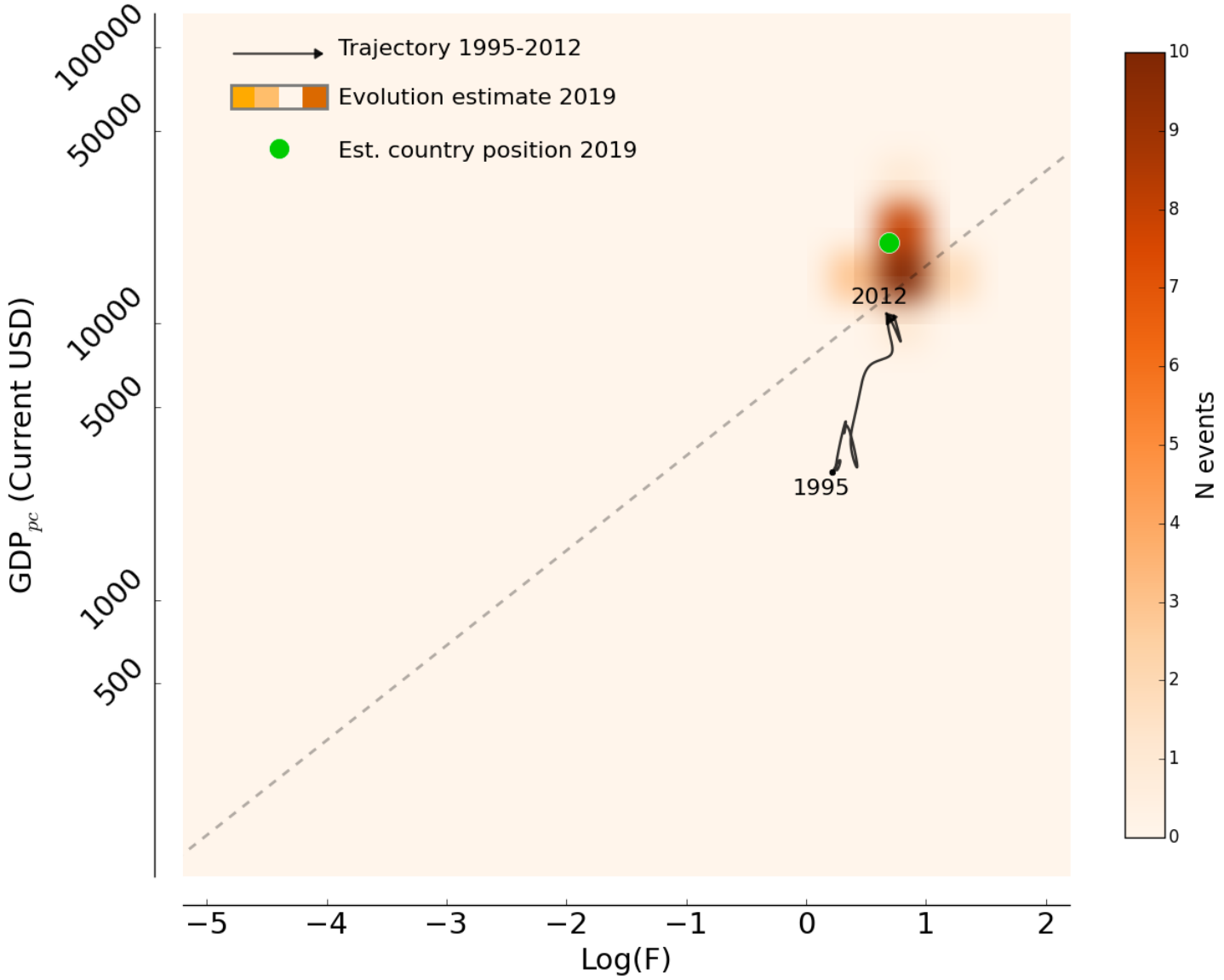
Fitness 1.343 (2012)

GDP $_{pc}$ 1755 Current USD (2012)



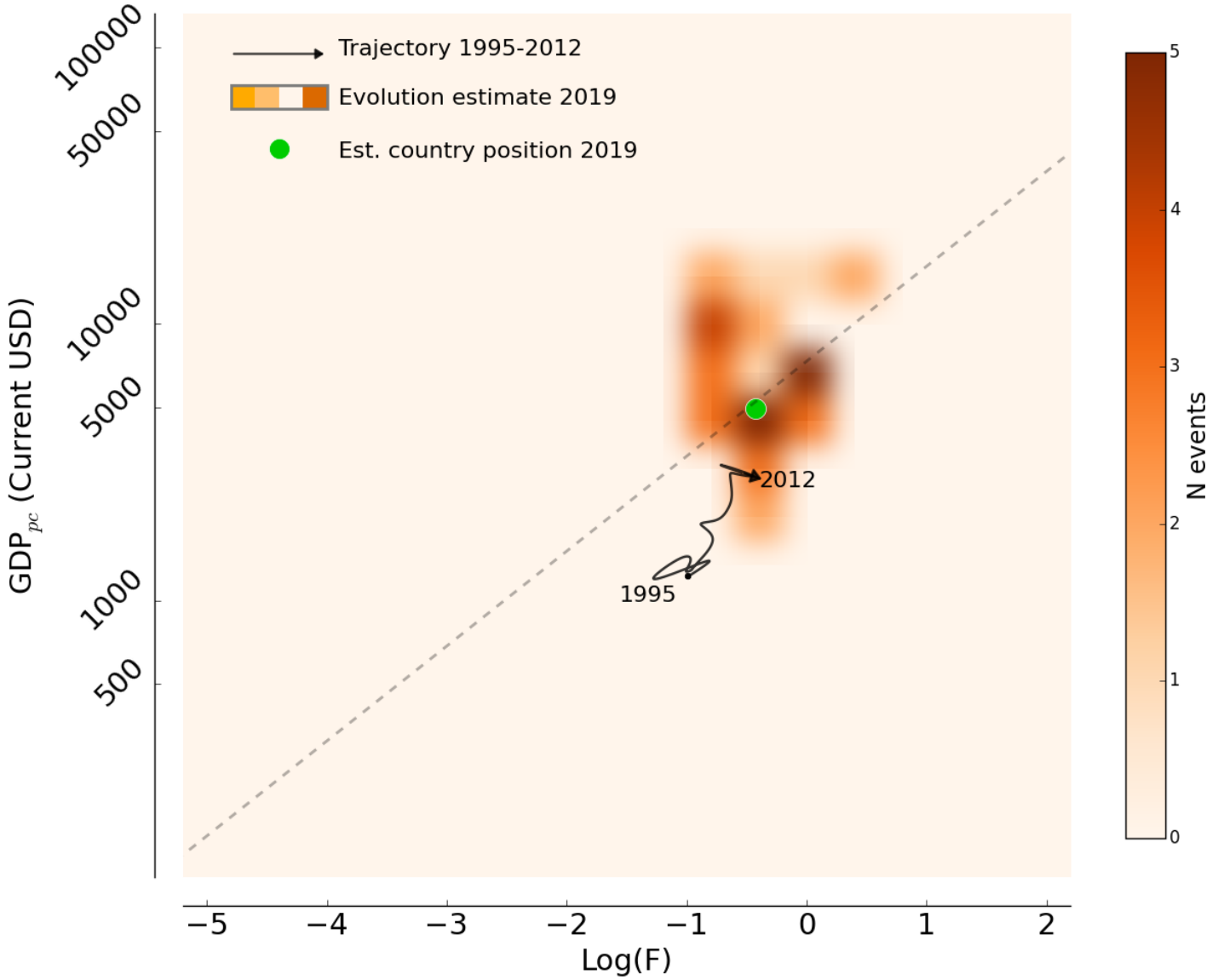
Country 13 Predictability 0.802

Fitness 1.987 (2012) GDP $_{pc}$ 10661 Current USD (2012)



Country 15 Predictability 0.649

Fitness 0.582 (2012) GDP $_{pc}$ 2902 Current USD (2012)



Scenario: 2012-2019

Countries from laminar regime Log(F) >-1 and degree of predictability >0.6 (min 0, max 1). Countries are ordered with respect to the estimate CAGR of the GDP_{pc} from 2012 to 2019. *Population variations are neglected. Growth Rate are not discounted with inflation rate.*

Country	Predictability	GR GDPpc 2012-19	CAGR GDPpc 2012-19	N Events	Log(Fitness) (2012)	GDPpc (2012)	Est. GDPpc (2019)
Country 1	0.667	147%	13.82%	45	-0.119	1255	3106
Country 2	0.667	147%	13.82%	45	0.295	1755	4343
Country 3	0.711	113%	11.37%	10	1.854	6093	12948
Country 4	1.083	108%	10.99%	4	1.017	1503	3119
Country 5	0.828	91%	9.65%	99	-0.034	3873	7381
Country 6	0.828	91%	9.65%	99	-0.018	4396	8377
Country 7	0.828	91%	9.65%	99	-0.082	3256	6205
Country 8	0.828	91%	9.65%	99	0.195	3551	6768
Country 9	0.828	91%	9.65%	99	0.219	4197	7999
Country 10	0.752	87%	9.38%	24	1.093	2587	4846
Country 11	0.802	84%	9.11%	25	0.705	7022	12928
Country 12	0.802	84%	9.11%	25	0.611	10432	19206
Country 13	0.802	84%	9.11%	25	0.686	10661	19627
Country 14	0.802	84%	9.11%	25	0.809	5480	10089
Country 15	0.649	70%	7.91%	37	-0.541	2902	4946

Average GR world 2012-19 = 67%

*GDP_{pc} are expressed in Current USD

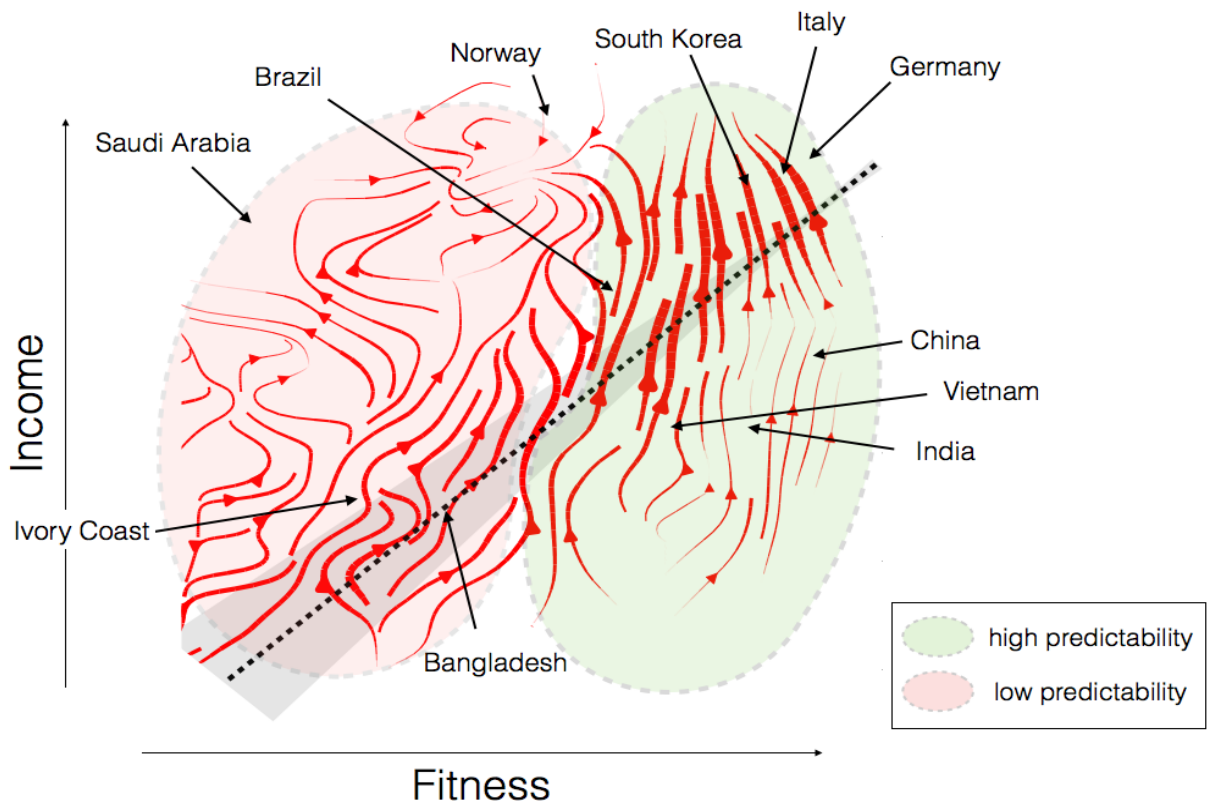
Backtesting

Forecast of GDP_{pc}

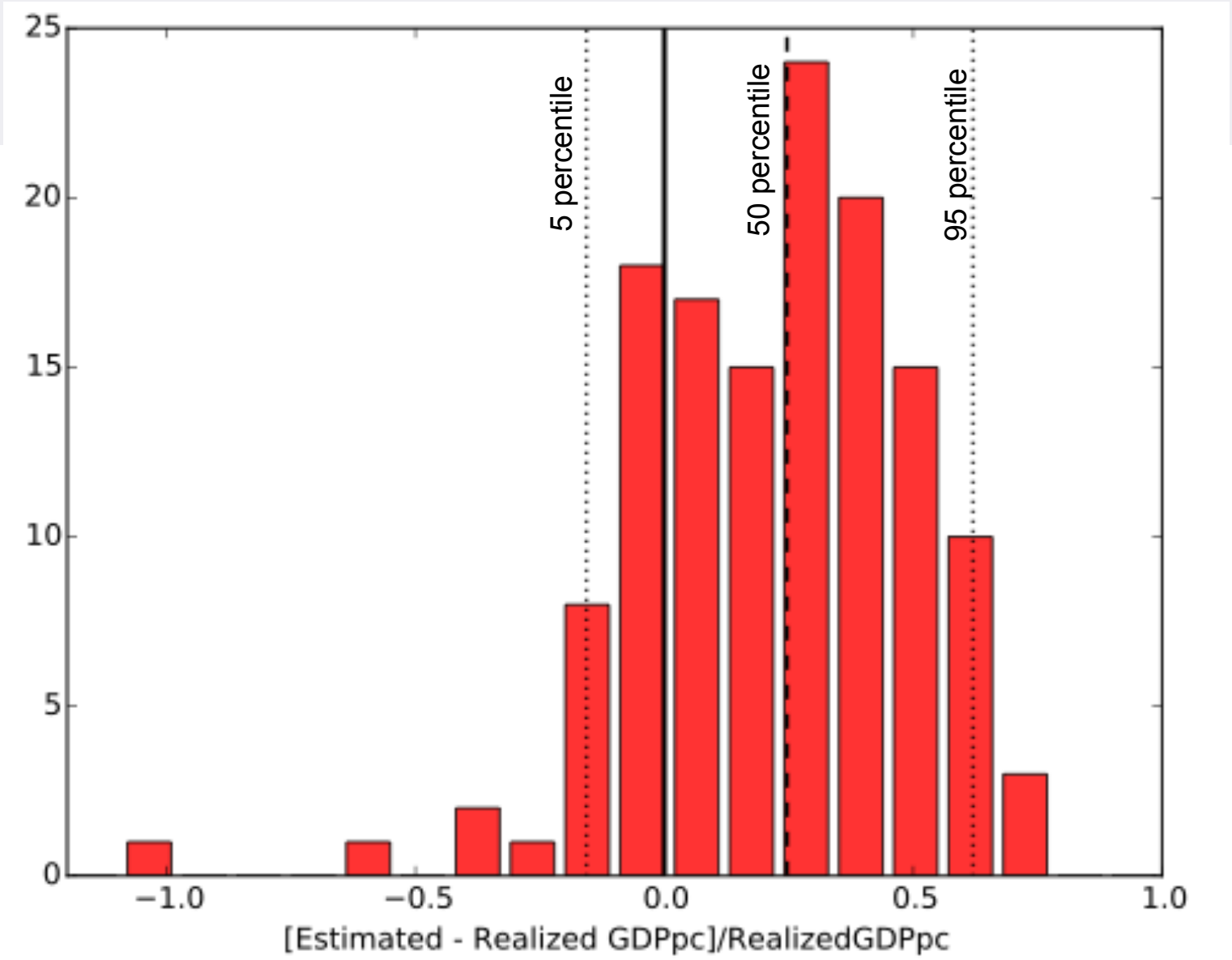
1995 Training set for SPS 2005 2012

Case 1: red and **green** areas, laminar and chaotic regime

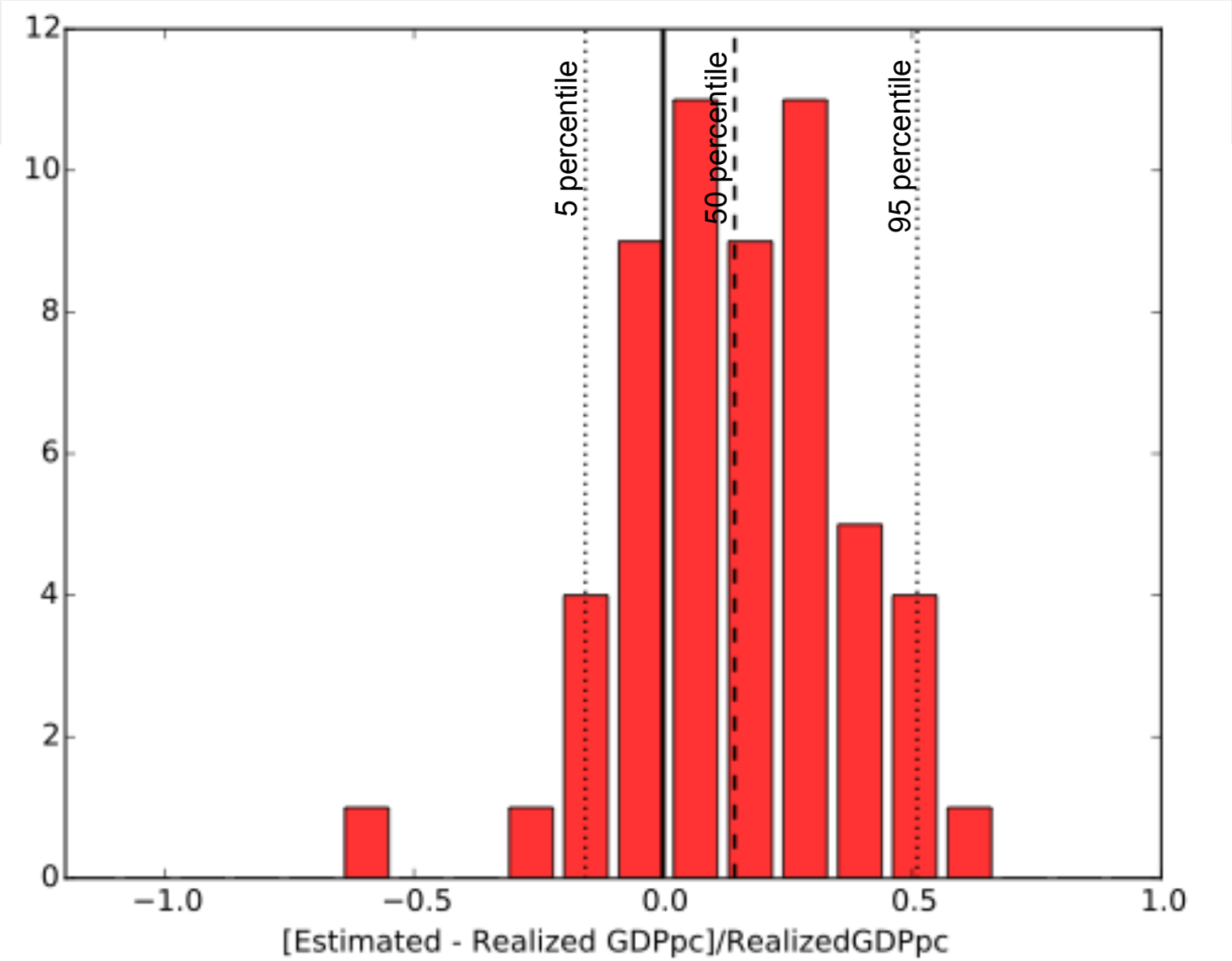
Case 2: green area, only laminar regime



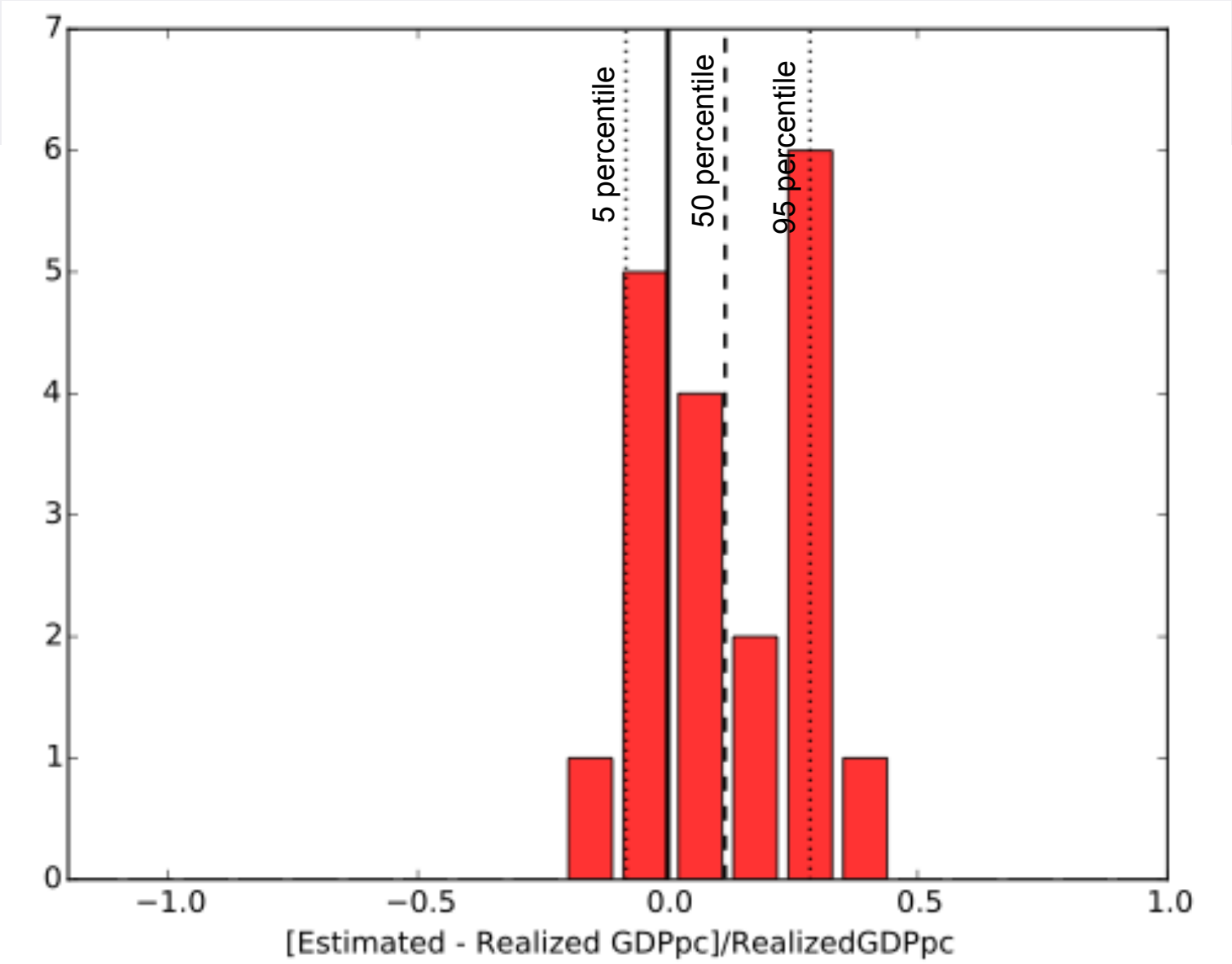
Case 1: laminar and chaotic regime (135 countries)



Case 2: laminar regime (56 countries)



Case 2bis: laminar optimized (19 countries)



Case 2ter: laminar regime Top 10

Top 10 countries in 2005 ordered by expected GR

Average error 10%

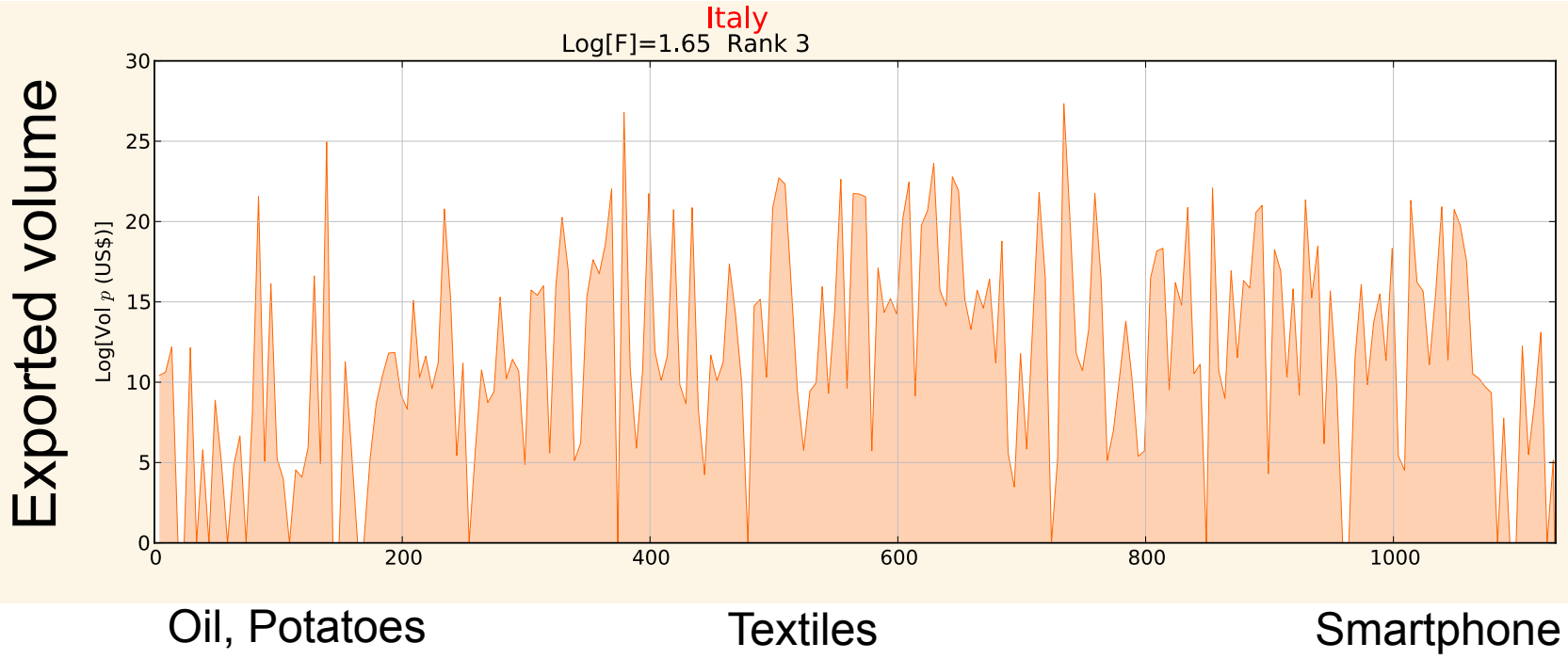
Country	Est. GDPpc 2012	GDPpc 2012	Relative error
Country A	1427	1503	5.1%
Country B	4144	5480	24.4%
Country C	54070	52409	-3.2%
Country D	98697	99636	0.9%
Country E	41309	38680	-6.8%
Country F	10037	10661	5.9%
Country G	14205	13159	-7.9%
Country H	10087	13947	27.7%
Country I	14449	16887	14.4%
Country J	11014	9818	-12.2%

*GDP_{pc} are expressed in Current USD

NB: Top 10 countries selected in 2005 are different from the ones previously proposed for the 2012-2019 period

COUNTRY SPECTROSCOPY

- Products appear clustered in Quality Space
- The revanche of specialization – Industrial sectors and individual companies tend to be reasonably specialized



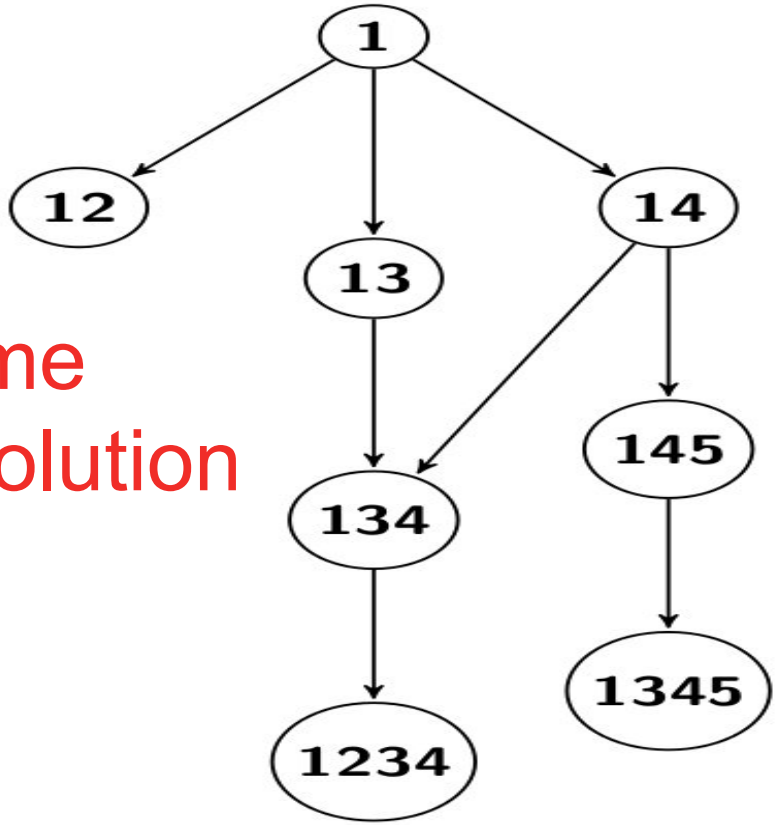
New directions 2014

- Extended database from 1963: 60 years instead of 15.
- Analysis of Dynamics and predictability test much improved
- How to get out of the poverty trap
- Evolution of Products Complexity
- Economic Cycles etc

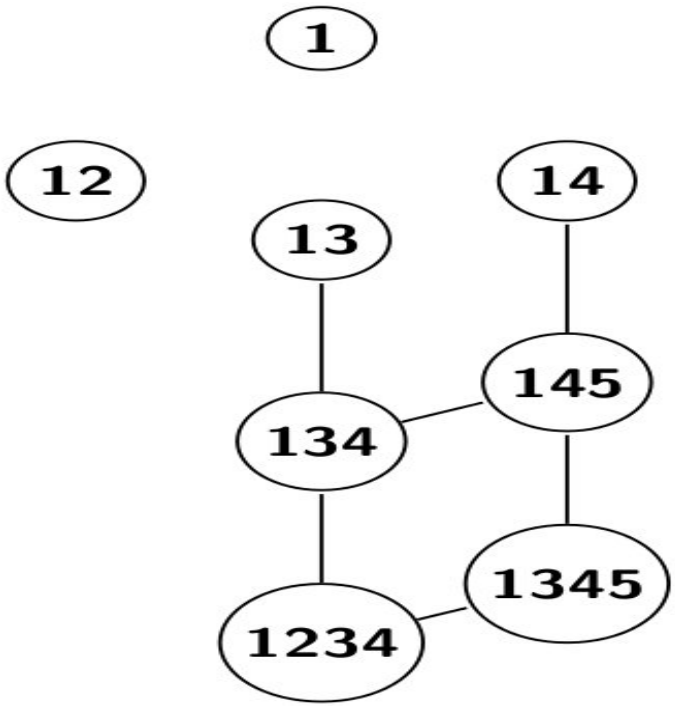
- Systematic construction of the Product Space
- Analysis of Sectors. Focus on countries with an appreciable hidden potential, look at emerging sectors (before RCA) and look at their position in Product Space
- Invasion of the Product Space in succesful cases of industrialization

The Complex Taxonomy of Products

Time evolution

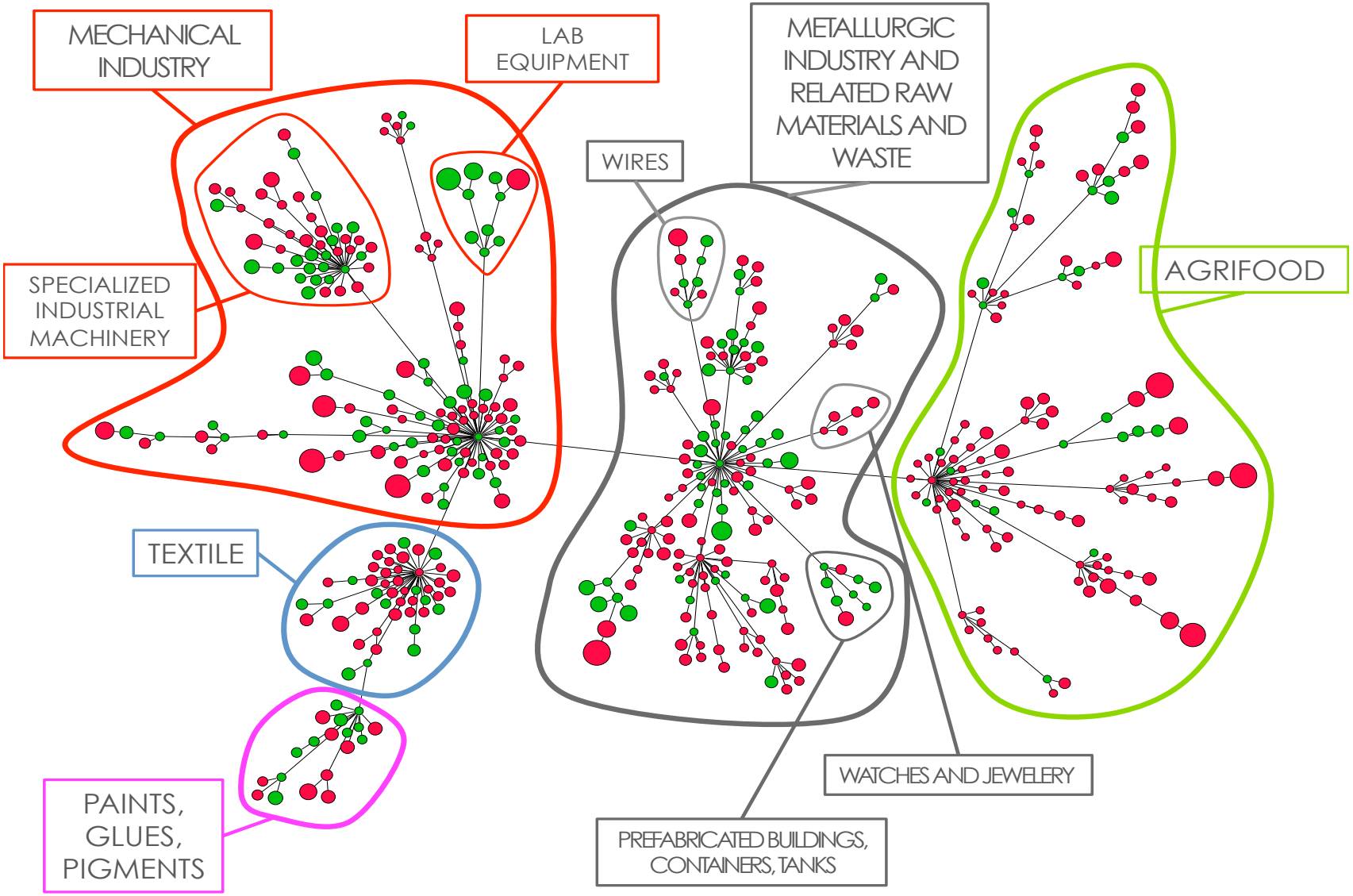


Vicinity

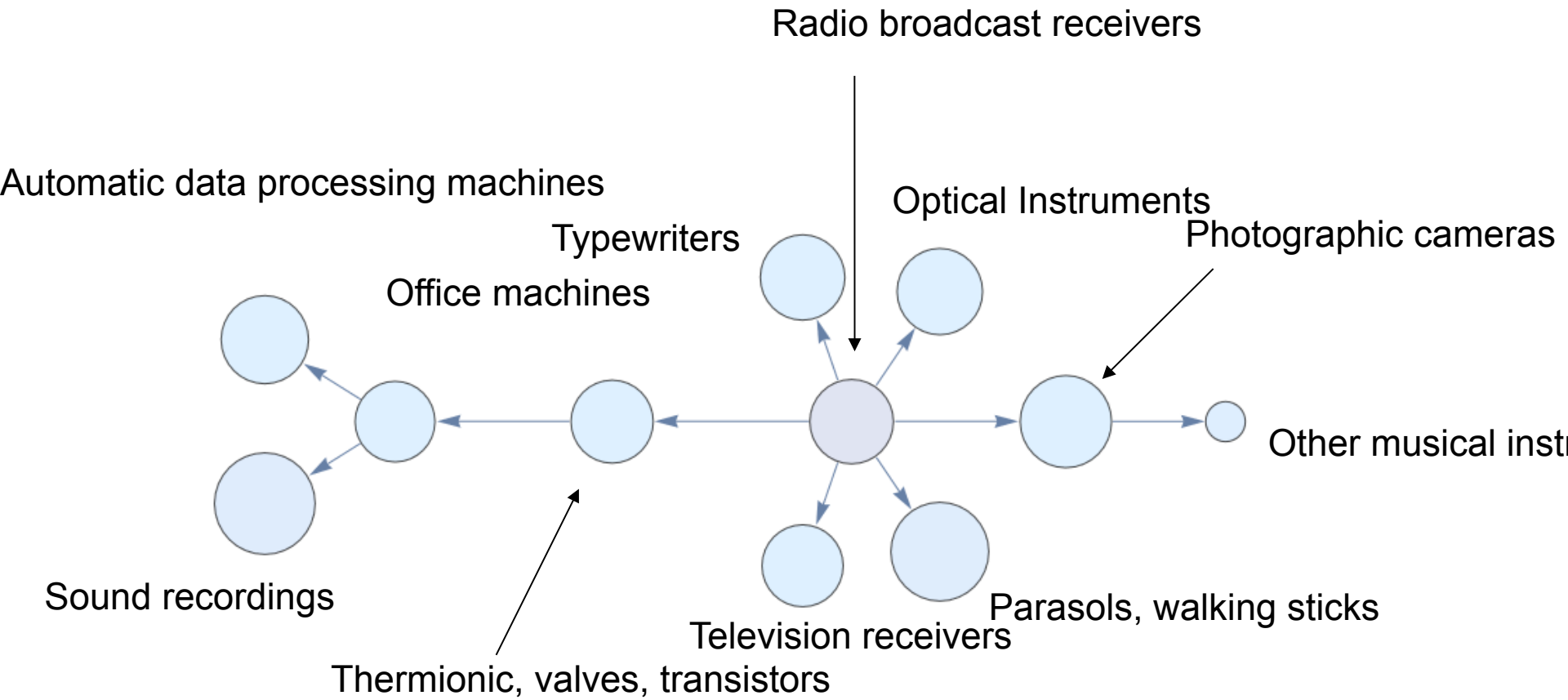


- Definition of products in terms of the needed capabilities
- Hierarchical, tree-like structure
- Directed vs undirected edges (time evolution)
- Possibility to understand and forecast development

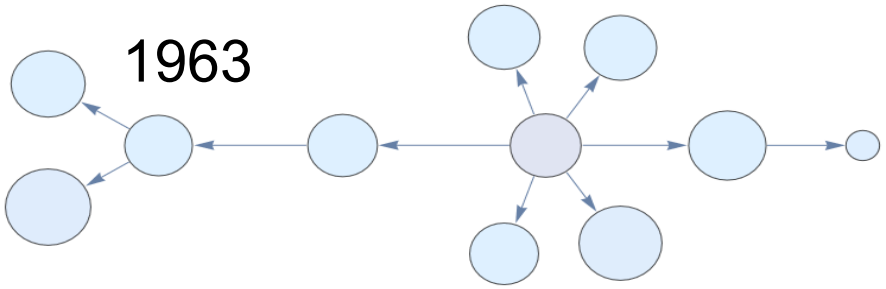
SWEDEN: PORTION OF THE PRODUCT SPACE



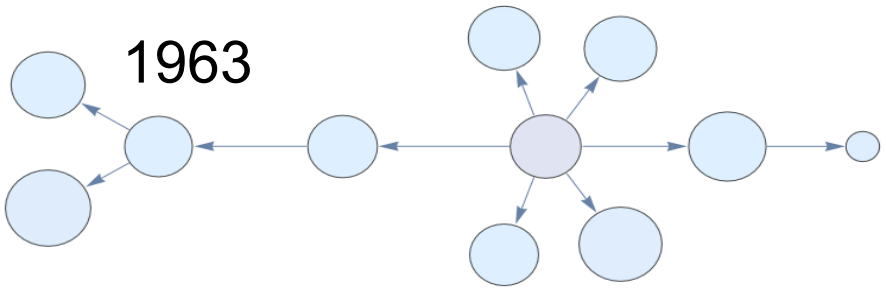
Example: SK 81 detailed products

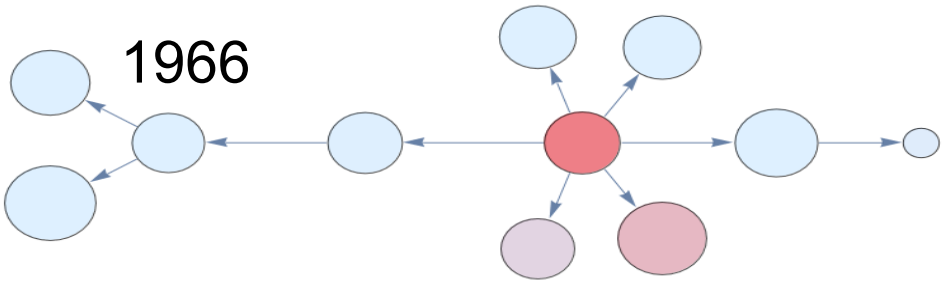


Diffusion of South Korea 1963-2000

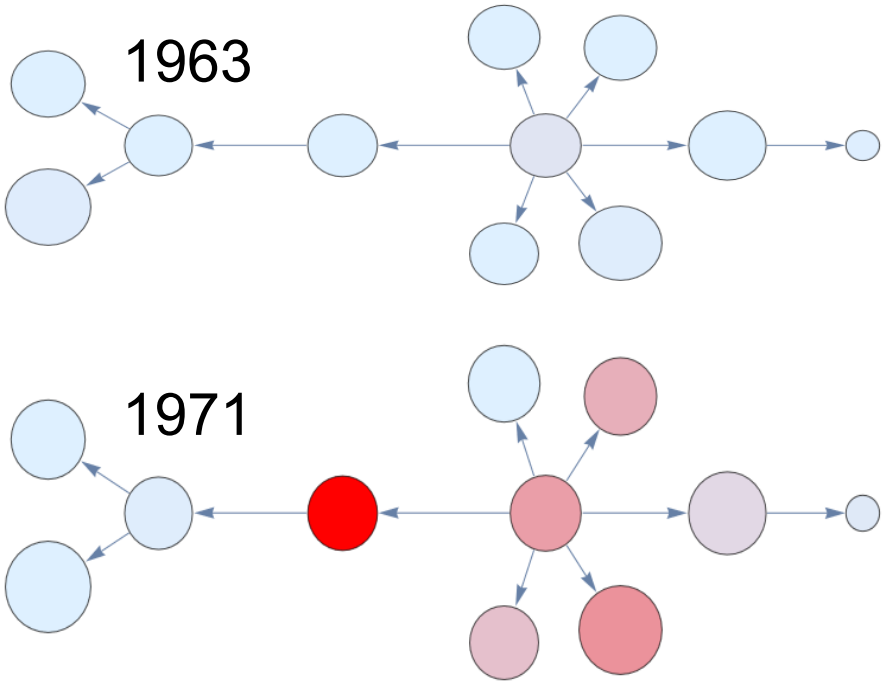


Example: Diffusion of SK 1963-2000

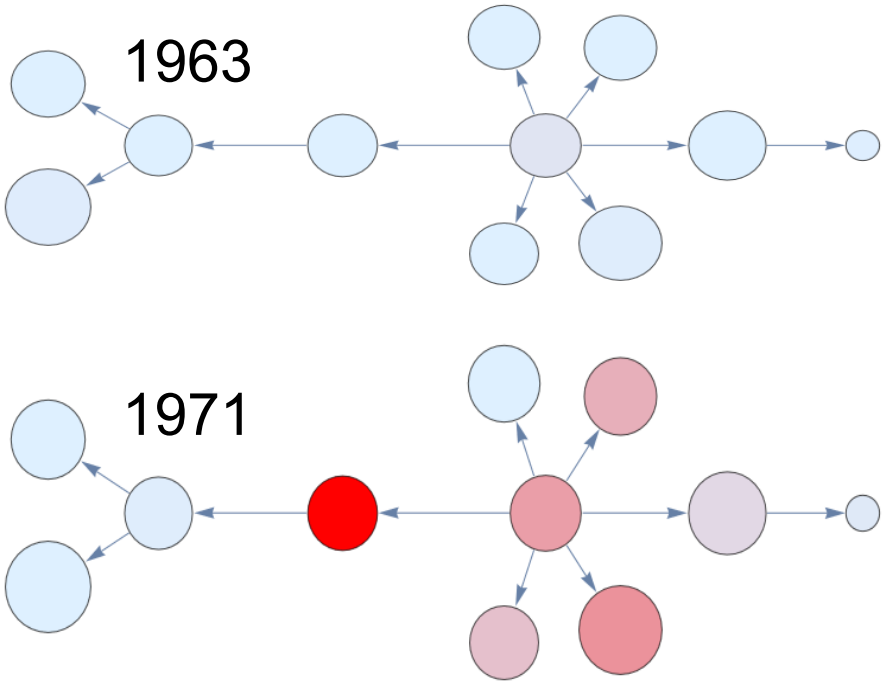




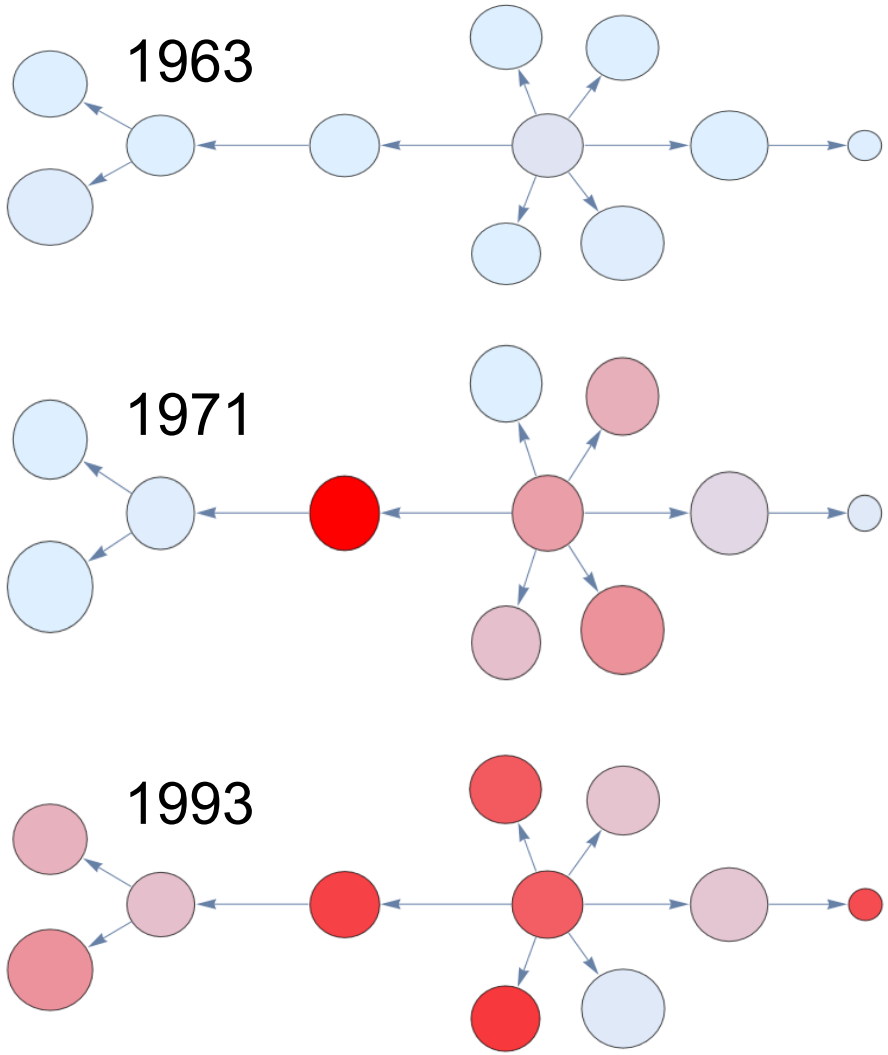
Example: Diffusion of SK 1963-2000



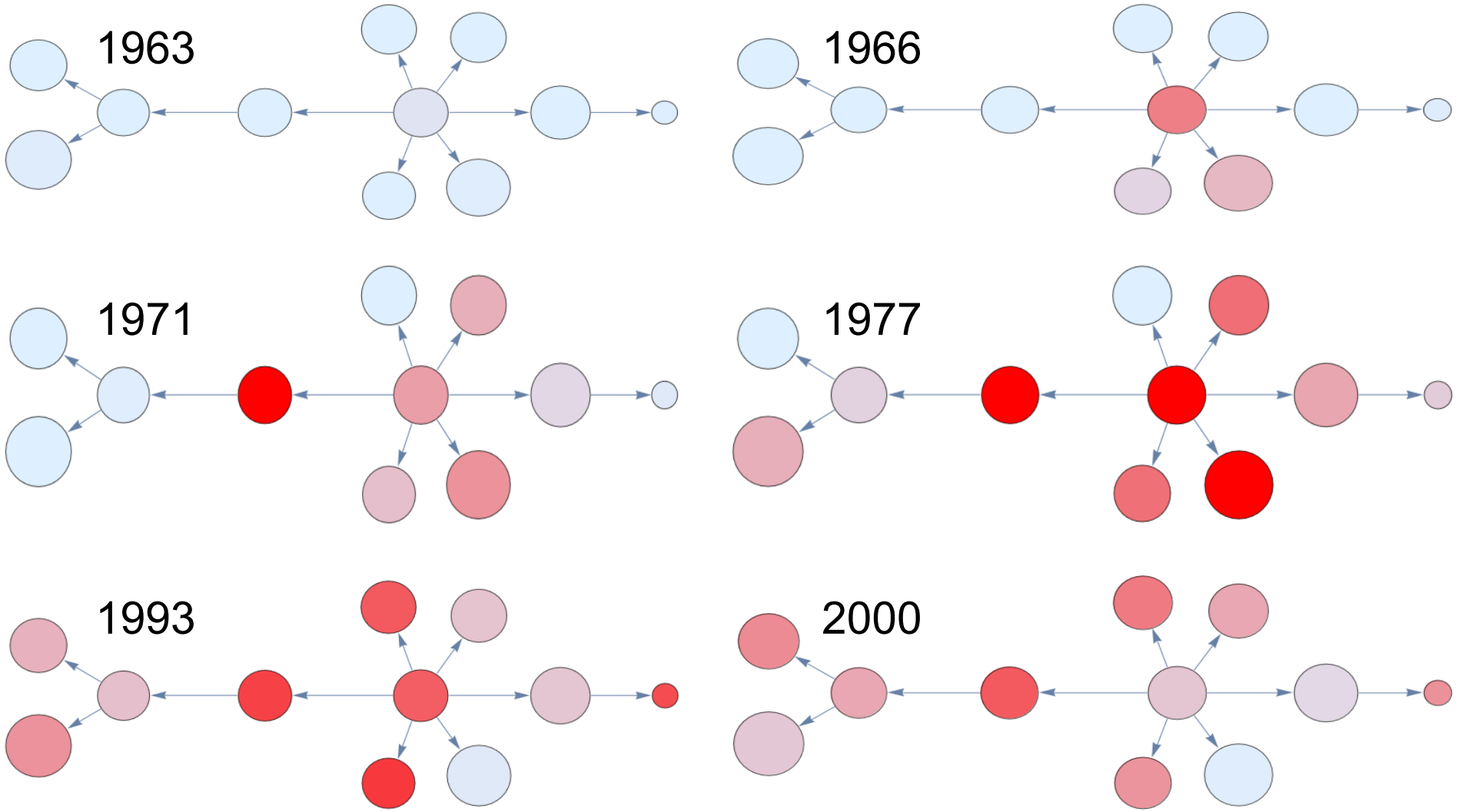
Example: Diffusion of SK 1963-2000



Example: Diffusion of SK 1963-2000



Example: Diffusion of SK 1963-2000



Consulting activity

- Institute for New Economic Thinking (G. Soros, J. Stiglitz)
- The Boston Consulting Group (New York)
  Report on Sweden (2013)
- Royal Dutch Shell (NL), Report on South Africa (2014)
- Institute for Public Policy Research (UK), Report for UK government on UK industrial competitiveness (2014)
- Alibaba Complexity Research Center (Hangzhou, China)
- Azimut private bank, Asset allocation project (2014)