JPD/JICA Task Force
Columbia, NY, Feb. 19-20 2015

ECONOMIC COMPLEXITY

Measuring the Intangible Growth Potential of Countries

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Web Page: http://pil.phys.uniroma1

SAPIENZA UNIVERSITÀ DI ROMA

istituto dei sistemi complessi

CRISISLAB
ANALYTICS FOR CRISIS PREDICTION AND MANAGEMENT

ECONOMICS:

From ”the dismal science” (Thomas Carlyle)

to…..

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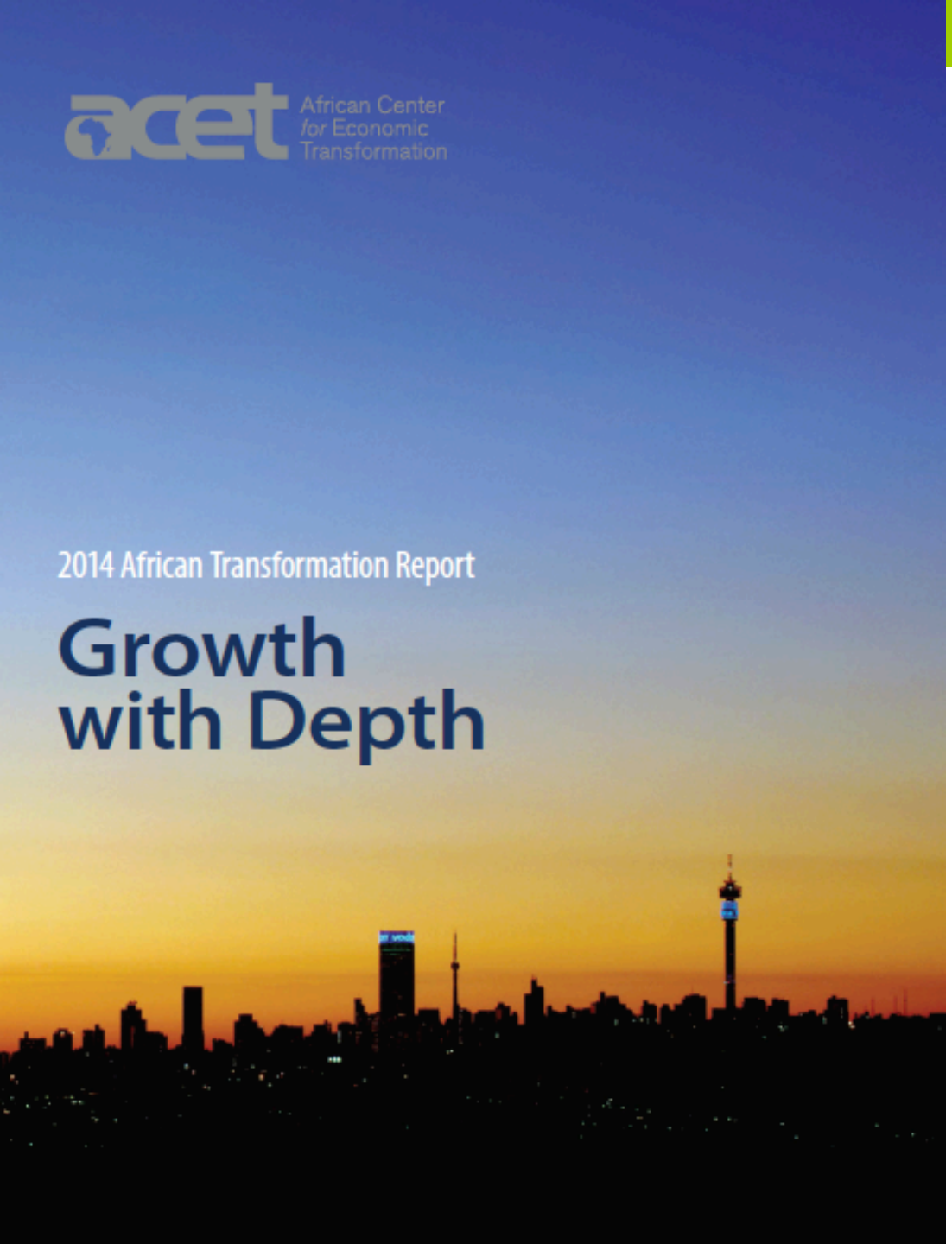
to…..



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

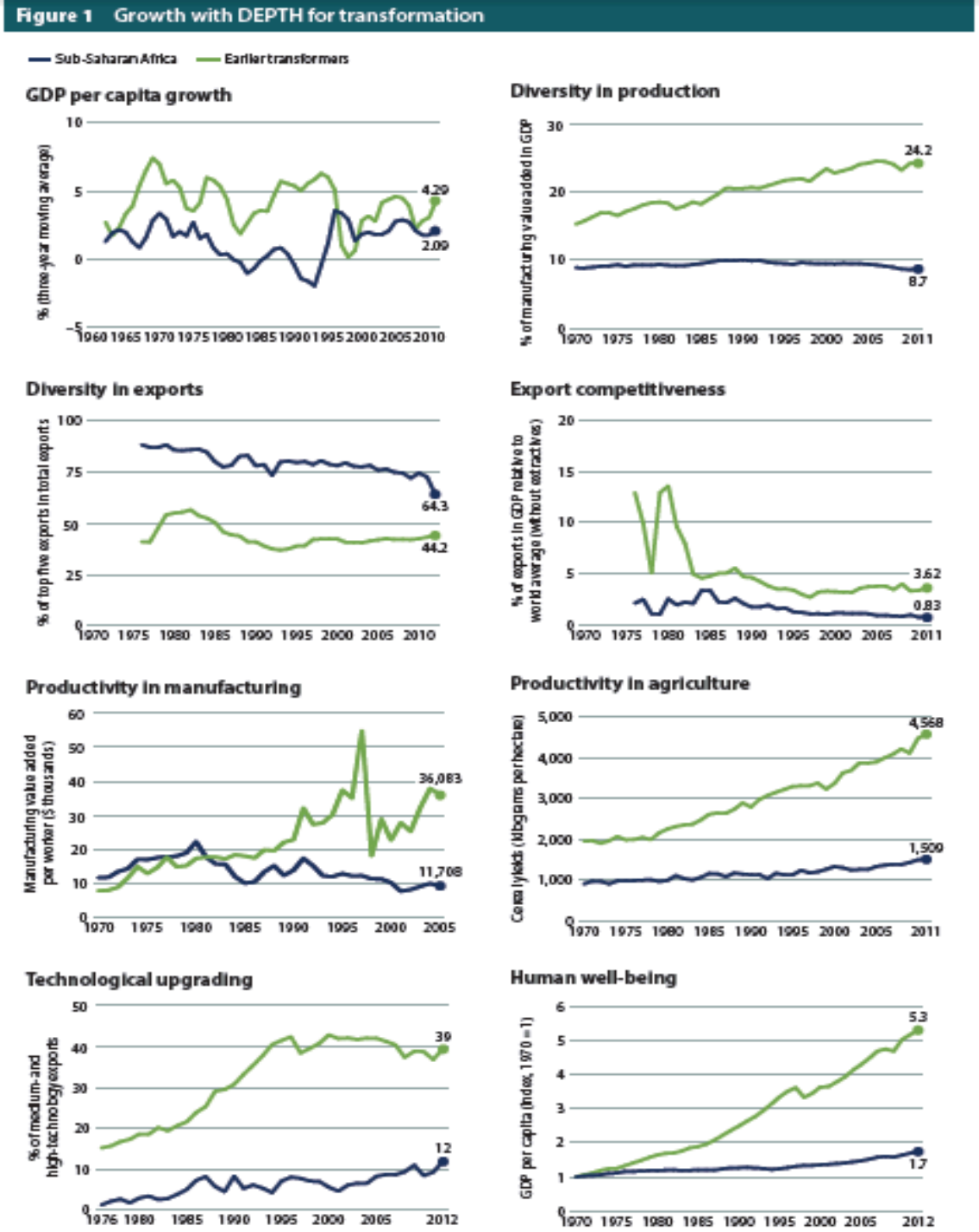


Figure 2 How countries rank on transformation

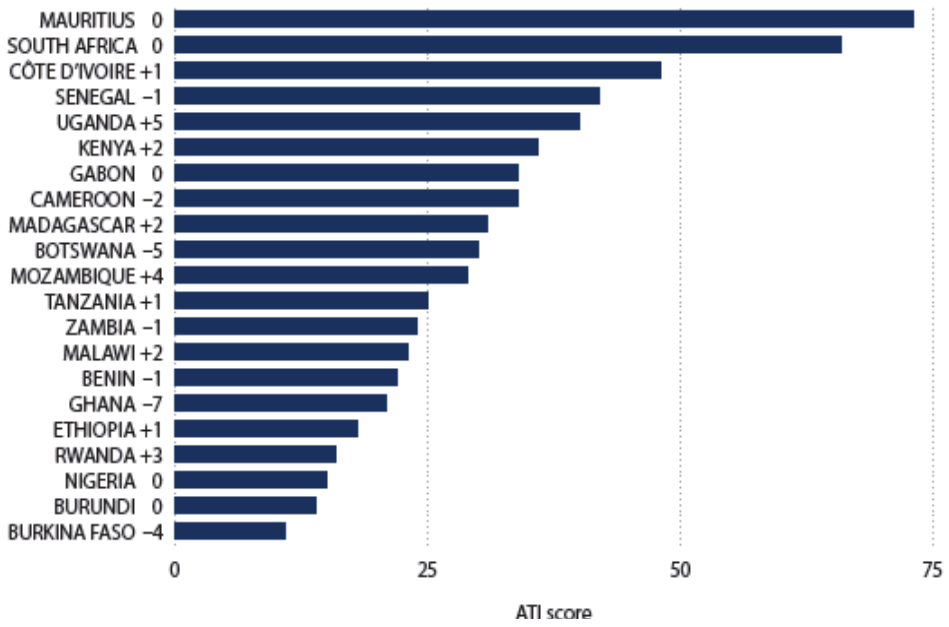
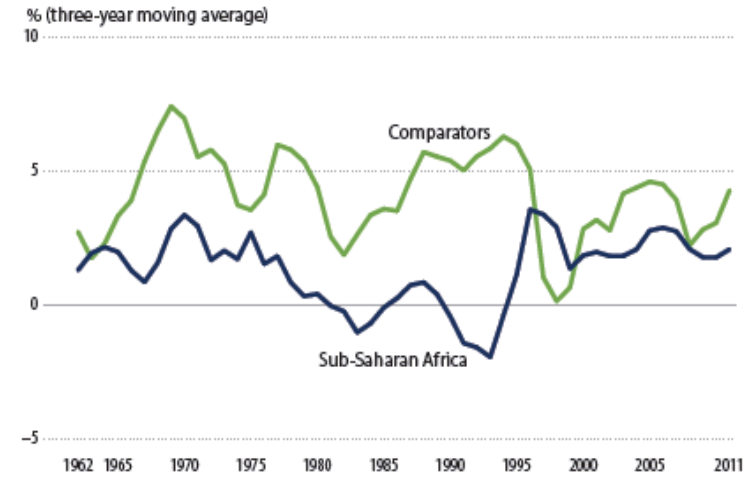


Figure 1.1 Growth In GDP per capita, 1962–2011



Source: World Development Indicators (database).

Although growth has resumed in Sub-Saharan Africa, progress on the other aspects of economic transformation is lagging, and this demands greater attention from policymakers

Figure 1.4 How 21 African countries rank on transformation and depth

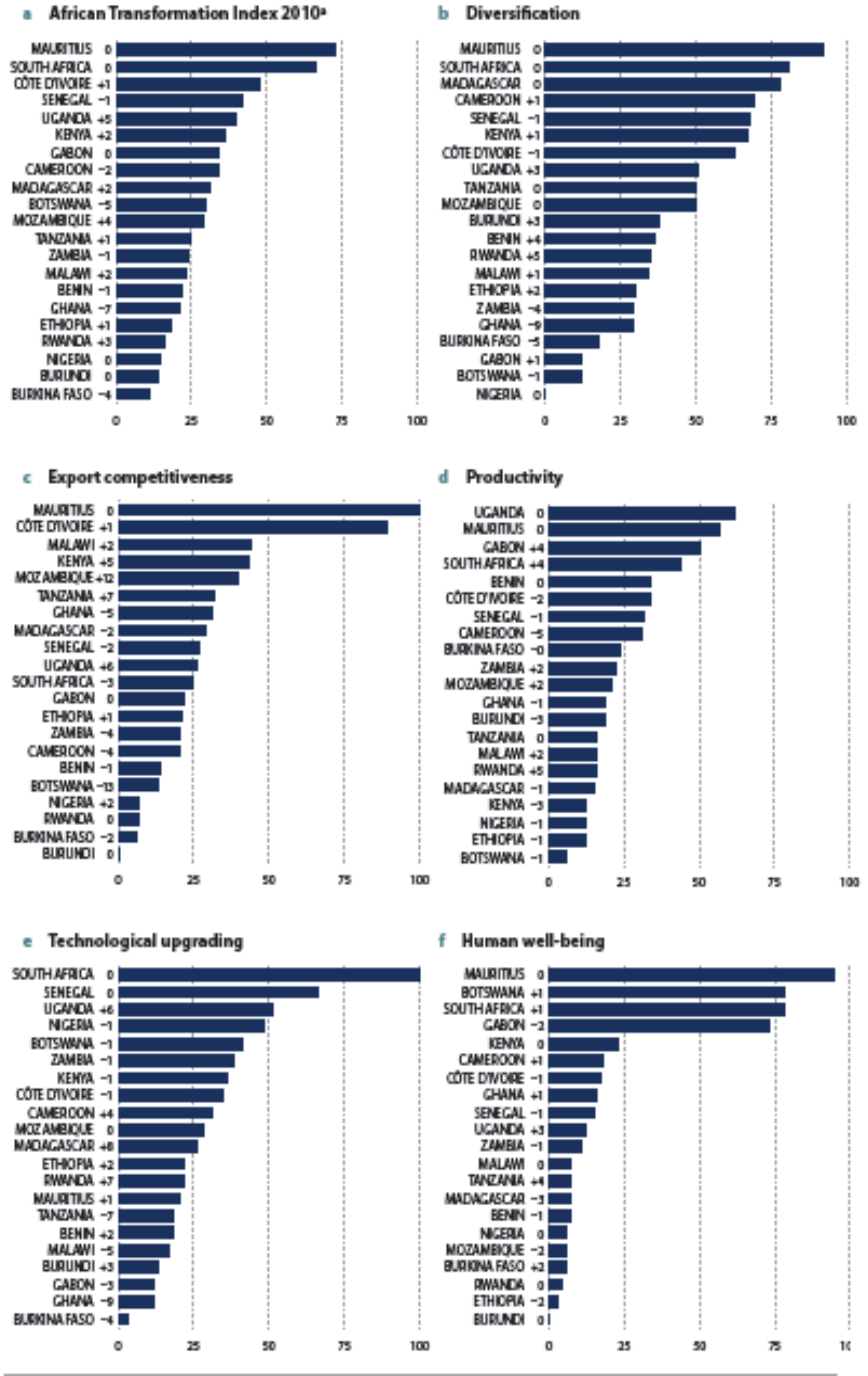


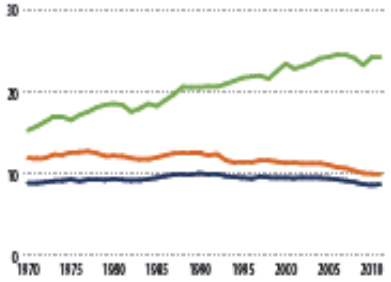
Figure 1.2 How Sub-Saharan Africa fares in relation to eight earlier transformers

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

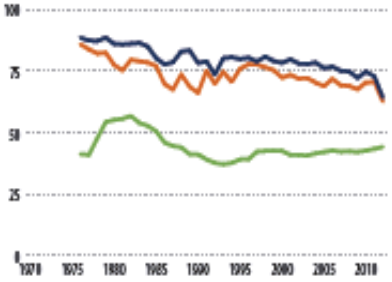
% of manufacturing in GDP



Source: World Development Indicators (database).

b Diversity: exports

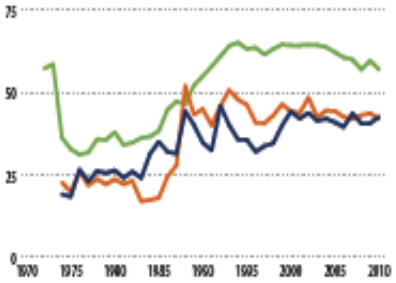
% of top five exports in total exports



Source: UN Comtrade, Revision 2, Digit 3.

c Diversity: exports of manufactures and services

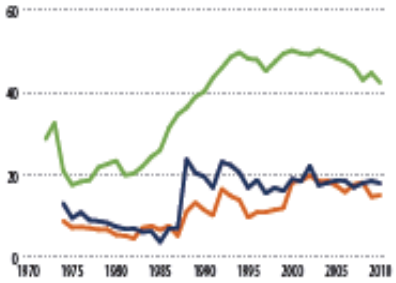
% of total goods and services exports



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

d Diversity: exports of manufactures

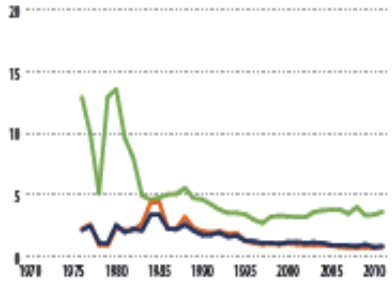
% of total goods and services exports



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

e Export competiveness: export market share without extractives

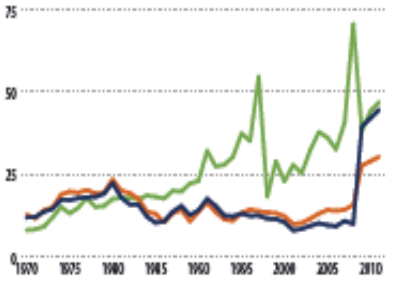
% of exports in GDP relative to world average (without extractives)



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

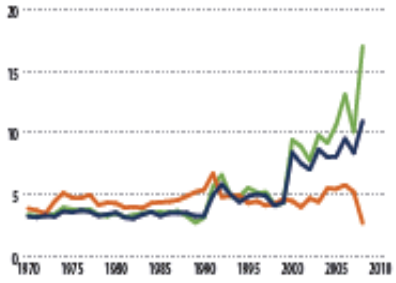
f Productivity: manufacturing value added per worker

Manufacturing value added ($ thousands)



Source: UNIDO, Revision 3, Digit 2.

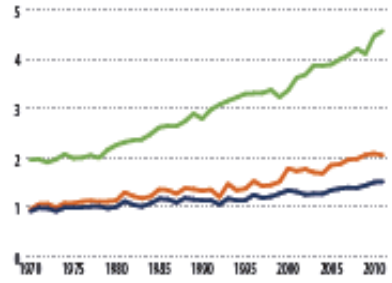
g Productivity: ratio of labor productivity to the average wage in manufacturing



Source: UNIDO, Revision 3, Digit 2.

h Productivity: cereal yields

Kilograms per hectare (thousands)



Source: World Development Indicators (database).

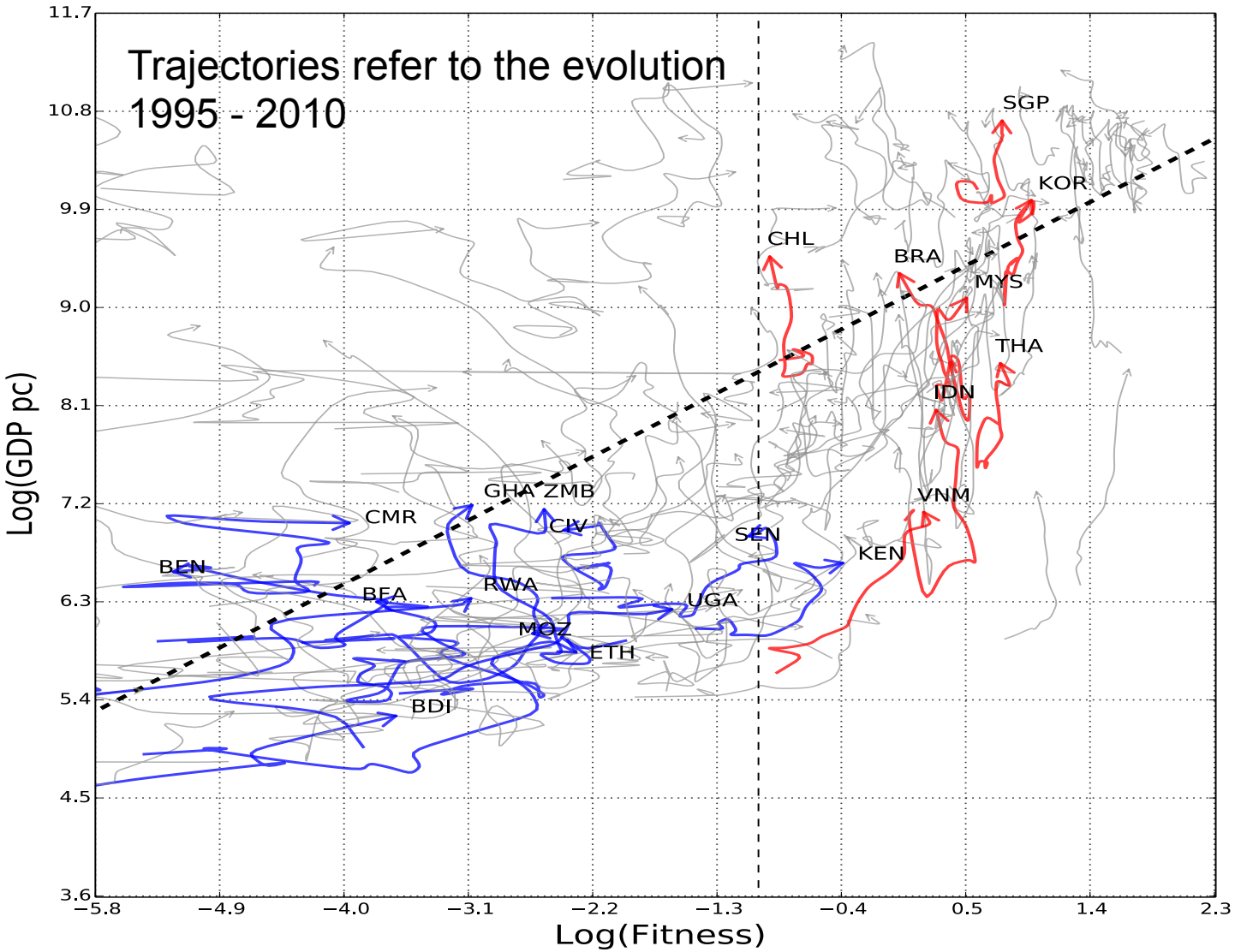
More and more data but difficult to draw a clear conclusion ???

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

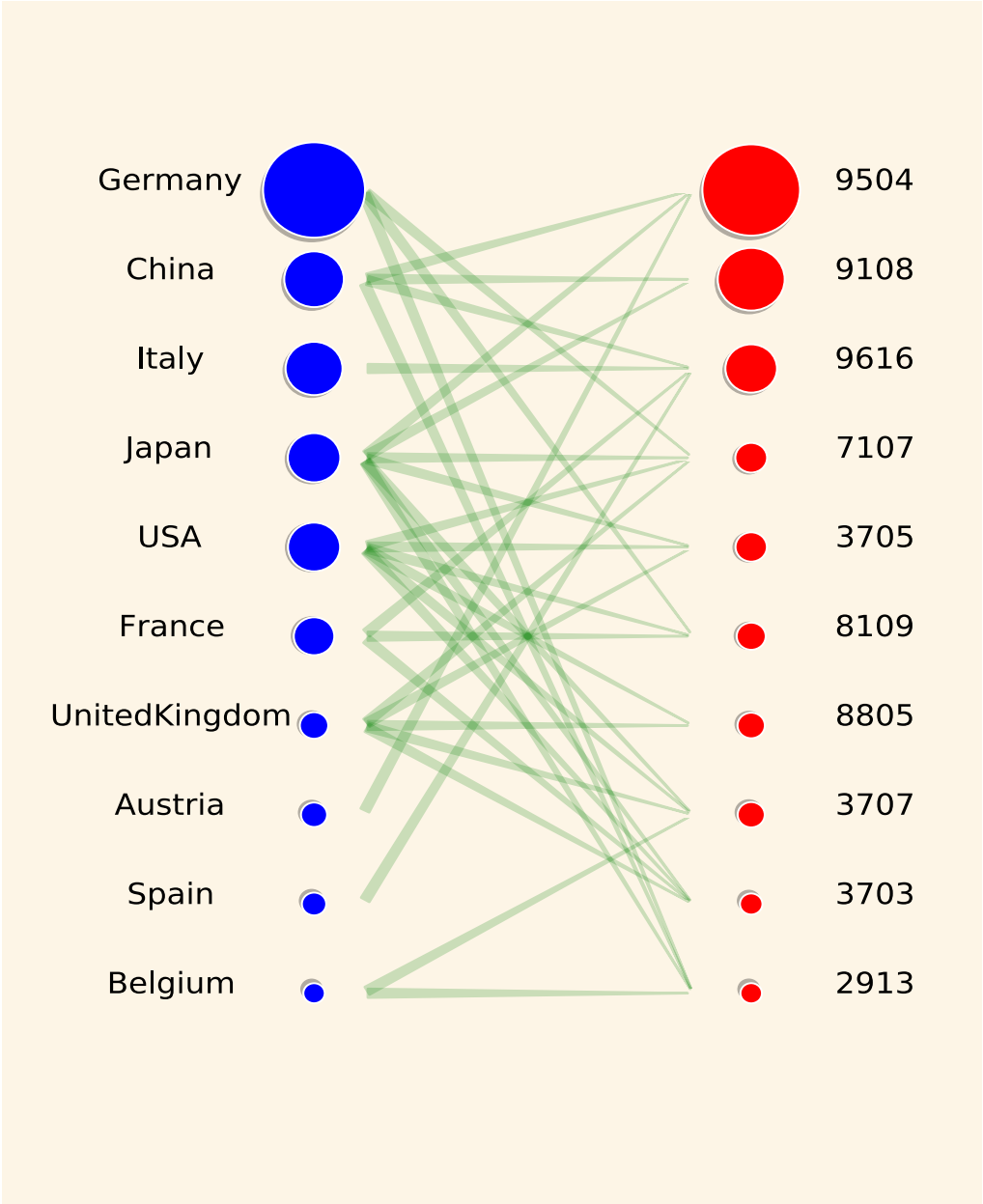


COMTRADE database:
Which country exports which product

Bipartite Network:
New algorithm to extract information for

- Fitness of Countries
- Complexity of Products

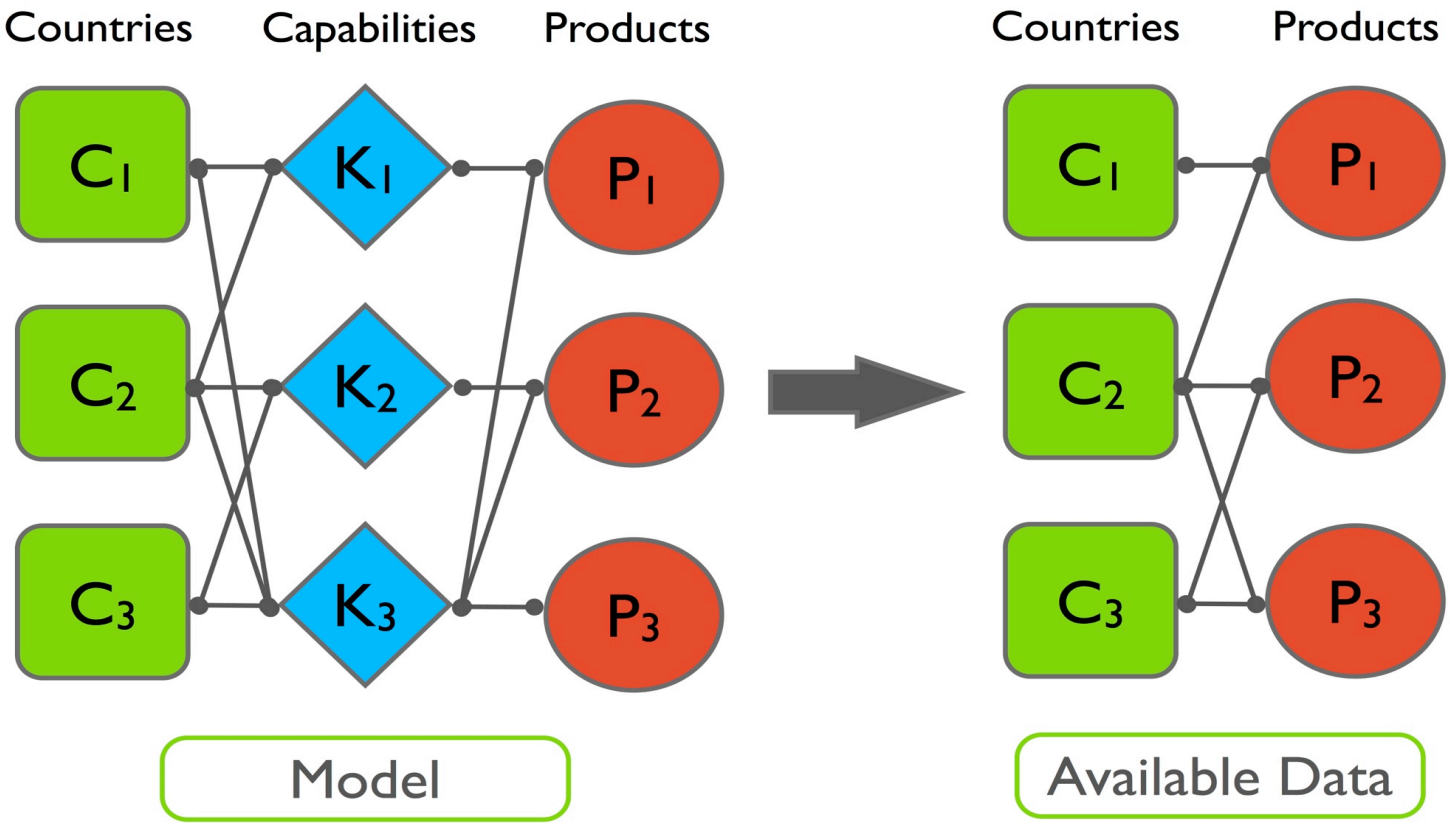
NB: this is not an analysis of the export volumes.
The information is derived from the nature of products



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)

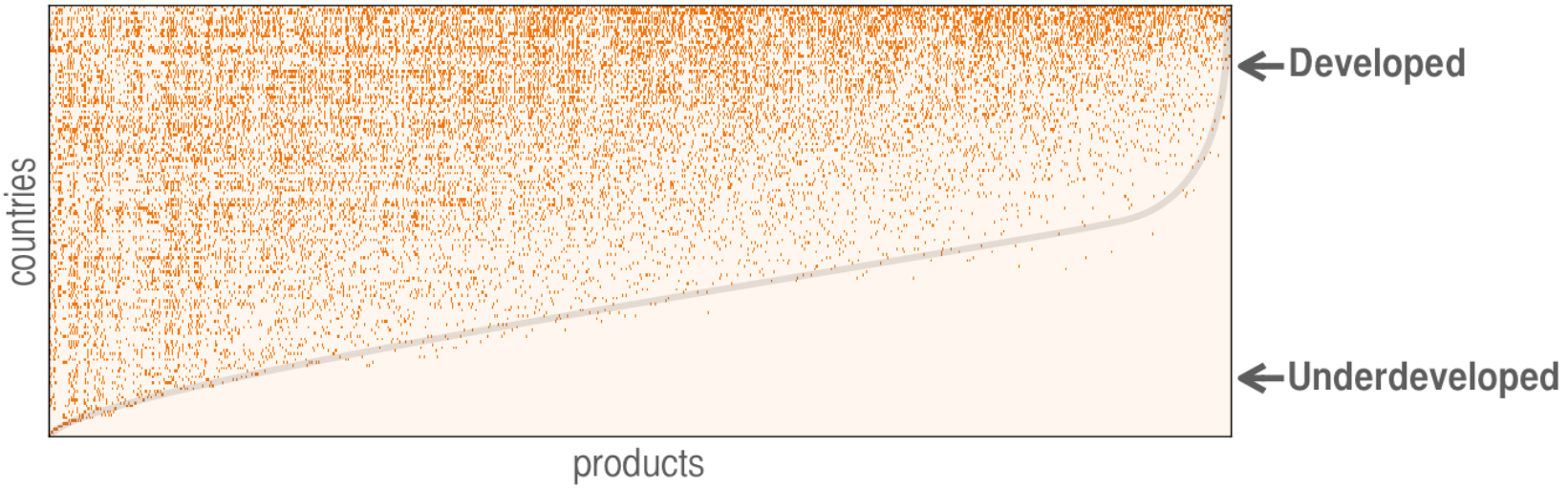
Products discount all the information on capabilities as stock prices should discount all the information on companies (except finance fluctuations)



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

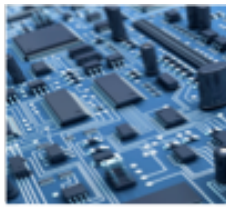
Q_p: Extremal non-linear complexity of products
a single low fitness producer implies low complexity

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
+

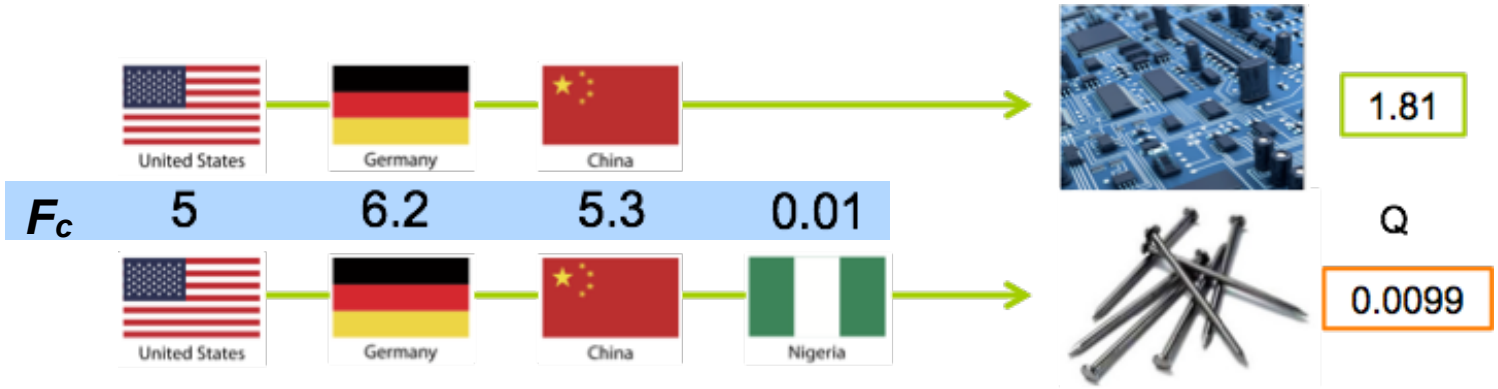
Nails
0.0099
+

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

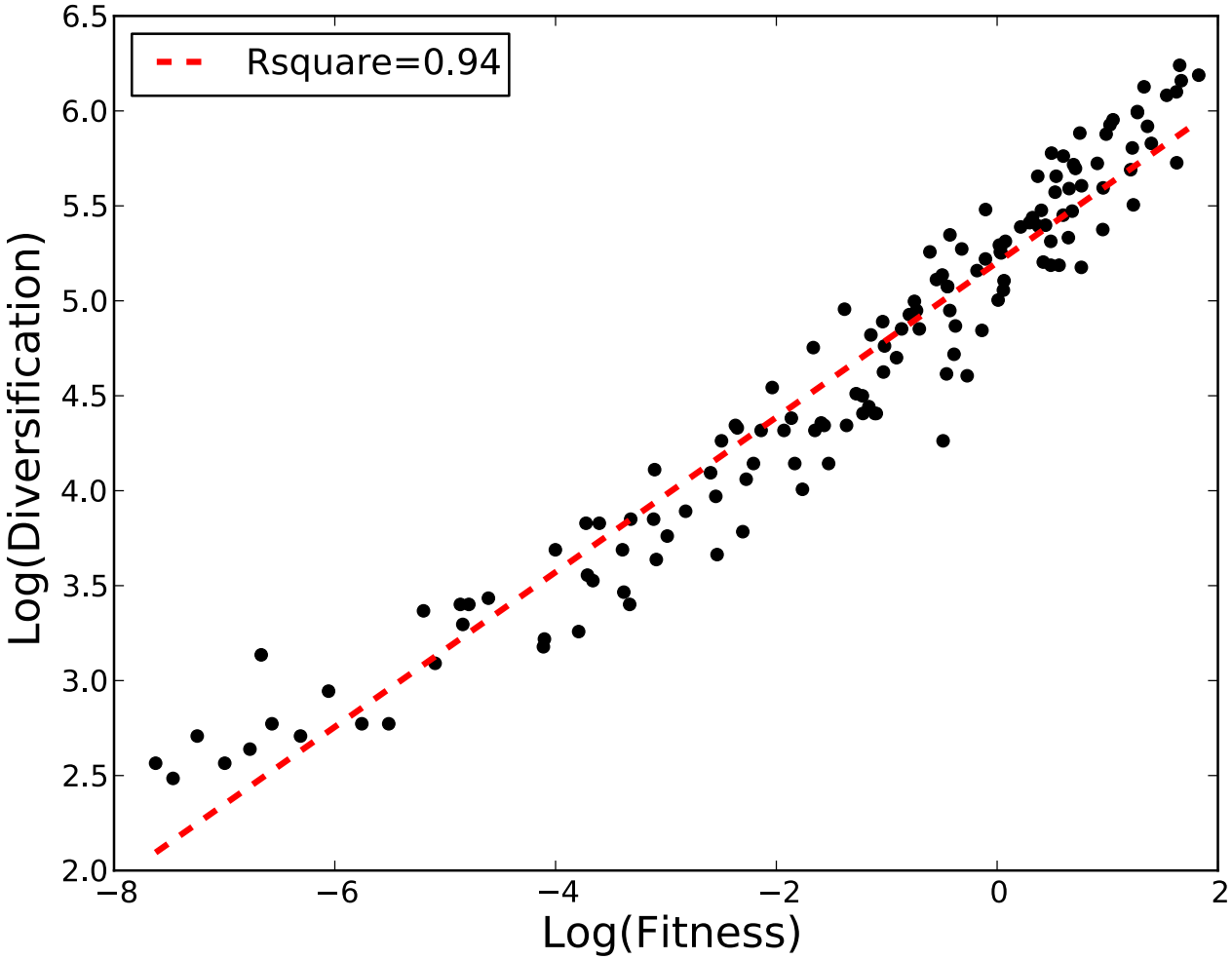
$$d = \sum_{C=1}^{K} p(C) \binom{K}{C} \sim (1+\pi)^K$$

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

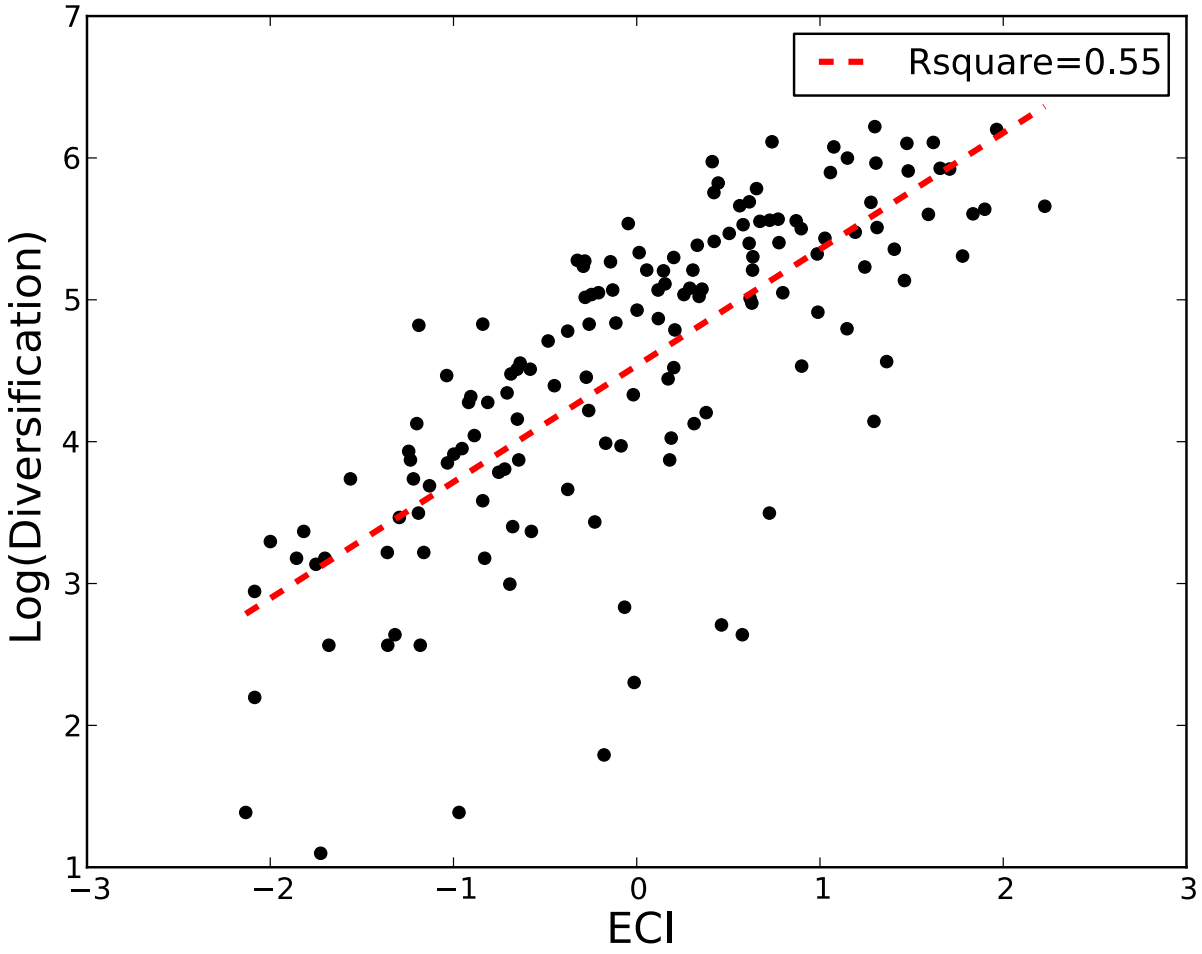
1° Prediction: let's test, as proxy for *K* , *log(Fitness)* and the *Economic Complexity Index* (ECI, C. Hidalgo et al. PNAS, 2009)

log(DIVERSIFICATION) vs log(FITNESS)



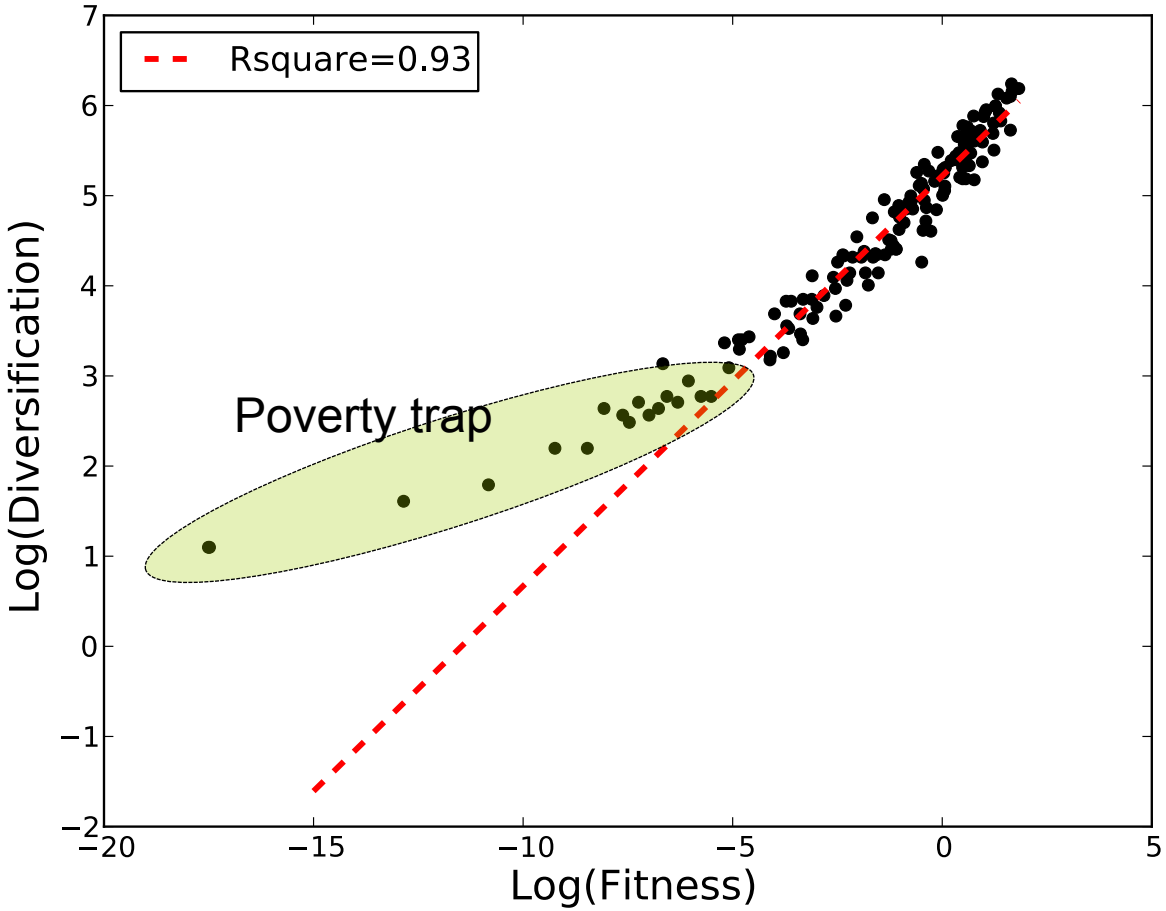
Log(Fitness) is good proxy for the *complexity K* of countries $R^2 \approx 0.92\text{-}0.94$ in the period 1995-2010

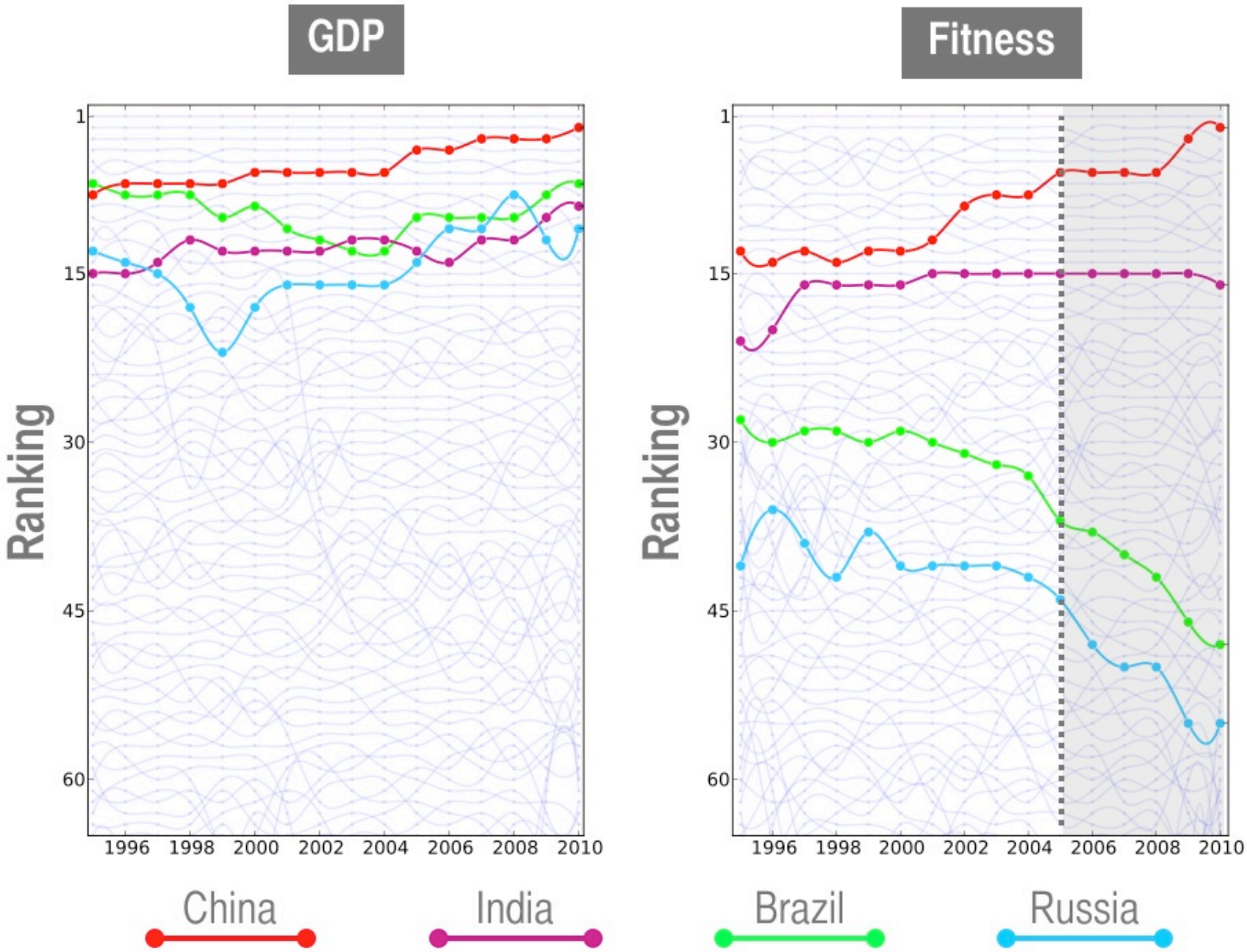
Hausmann & Hidalgo have tried to use exactly the Google algorithm but their ECI is not a good proxy for *complexity K*, $R^2 \approx 0.52\text{-}0.65$ in the period 1995-2010

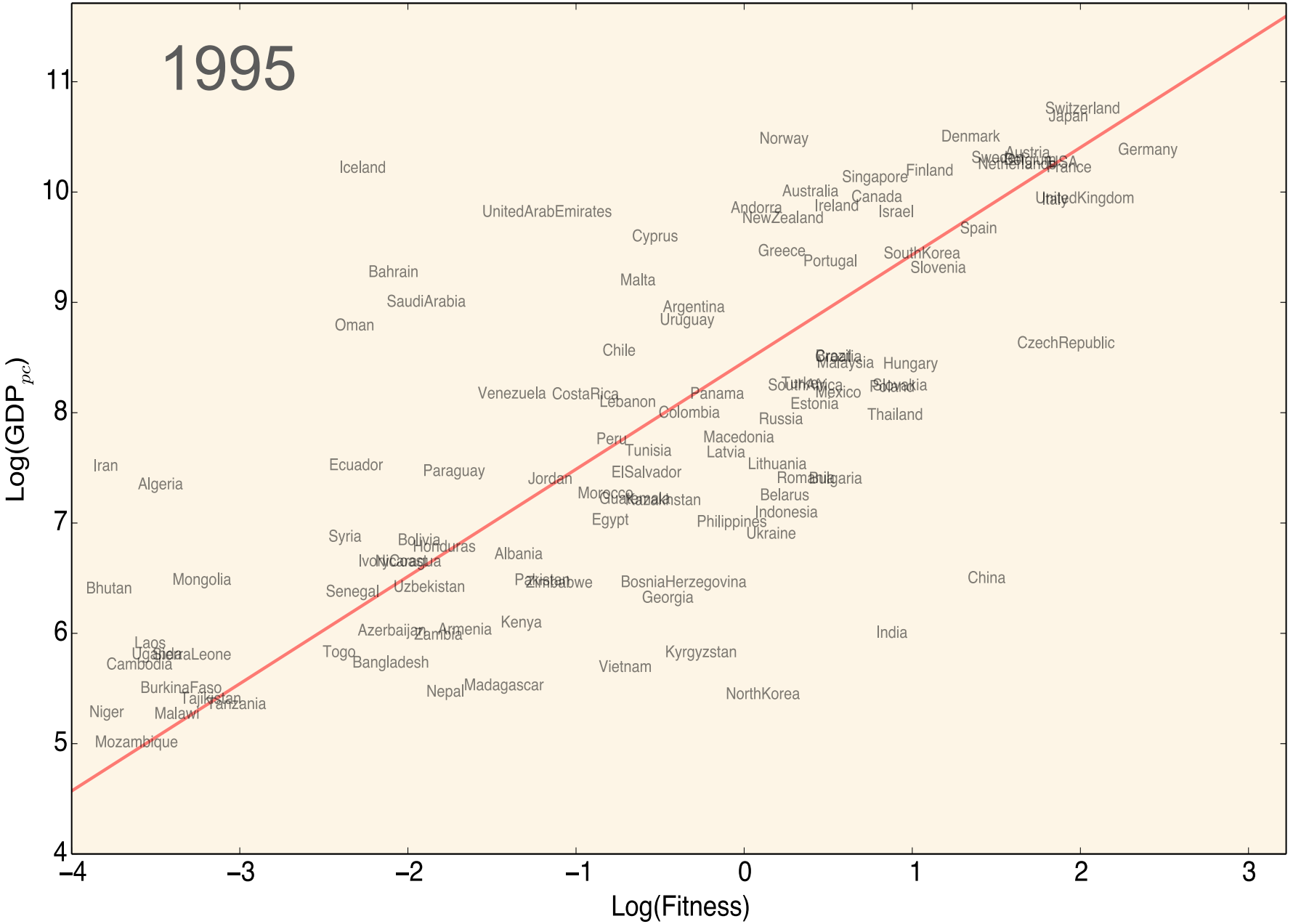


MICRO ORIGIN OF POVERTY TRAP?

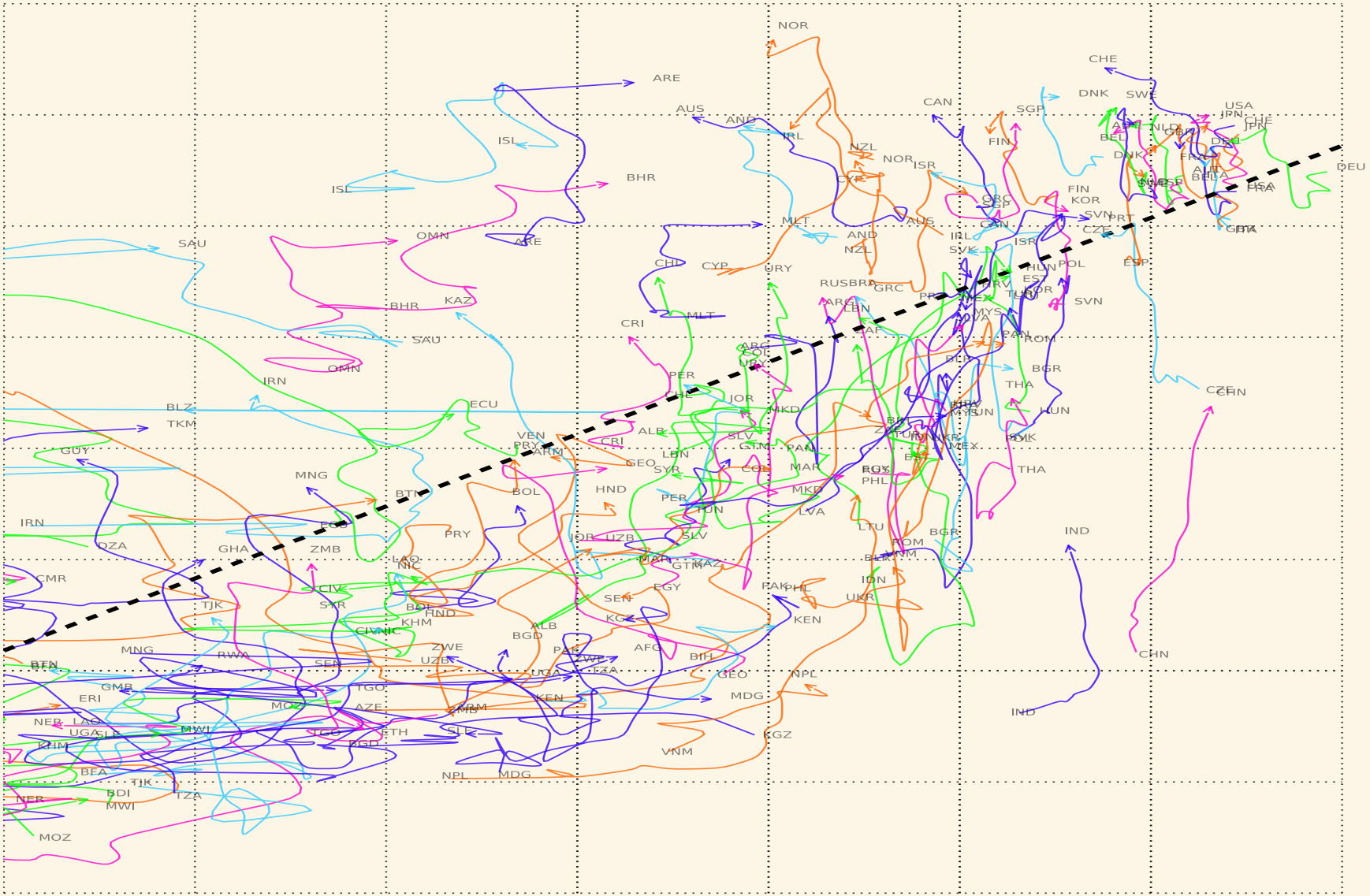
No longer exponential relationship btw *diversification* and *complexity* (i.e. *Log(Fitness)*)

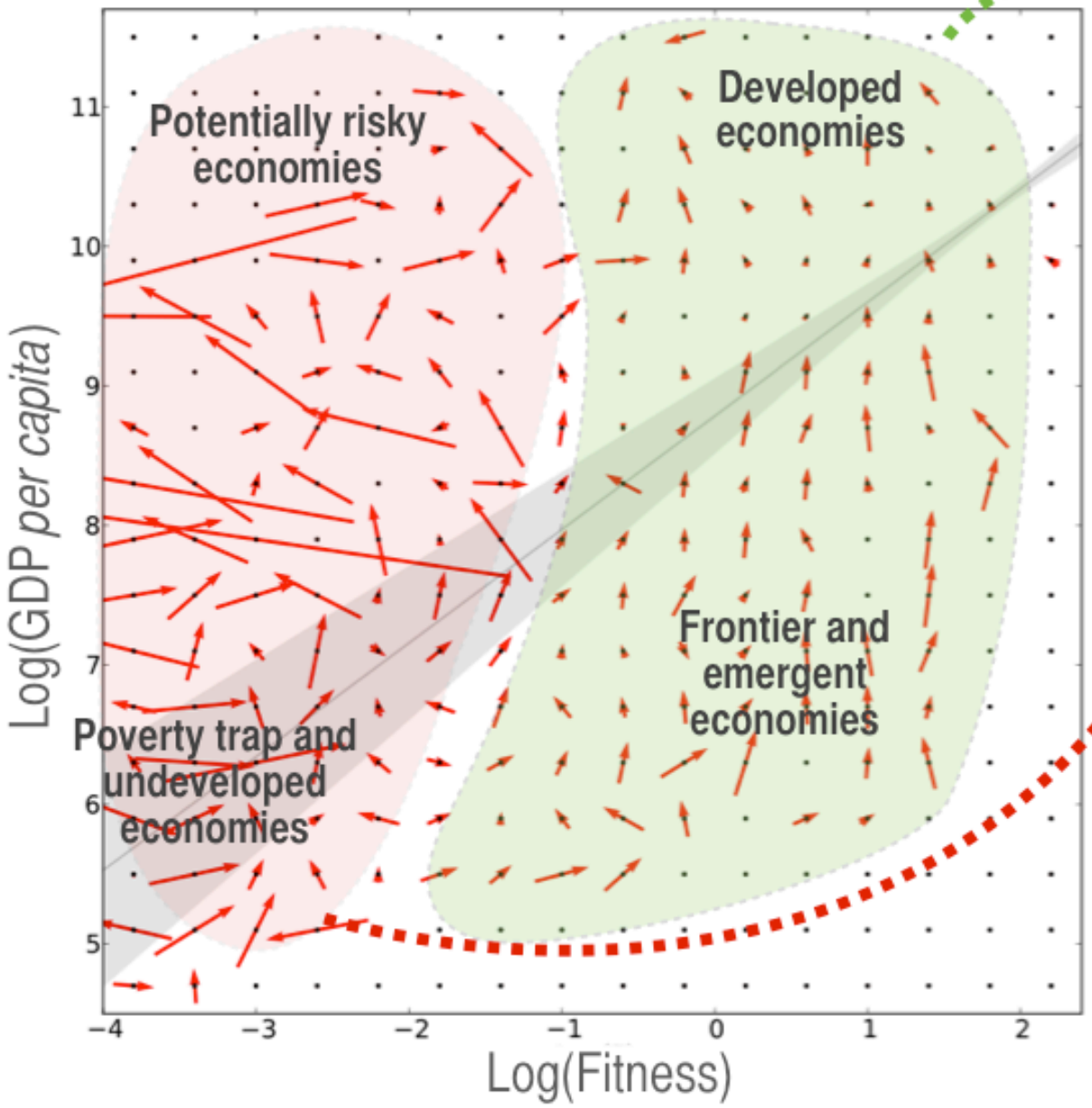



GDP
Fitness
Ranking
Ranking
1
15
30
45
60
1996
1998
2000
2002
2004
2006
2008
2010
China
India
Brazil
Russia


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

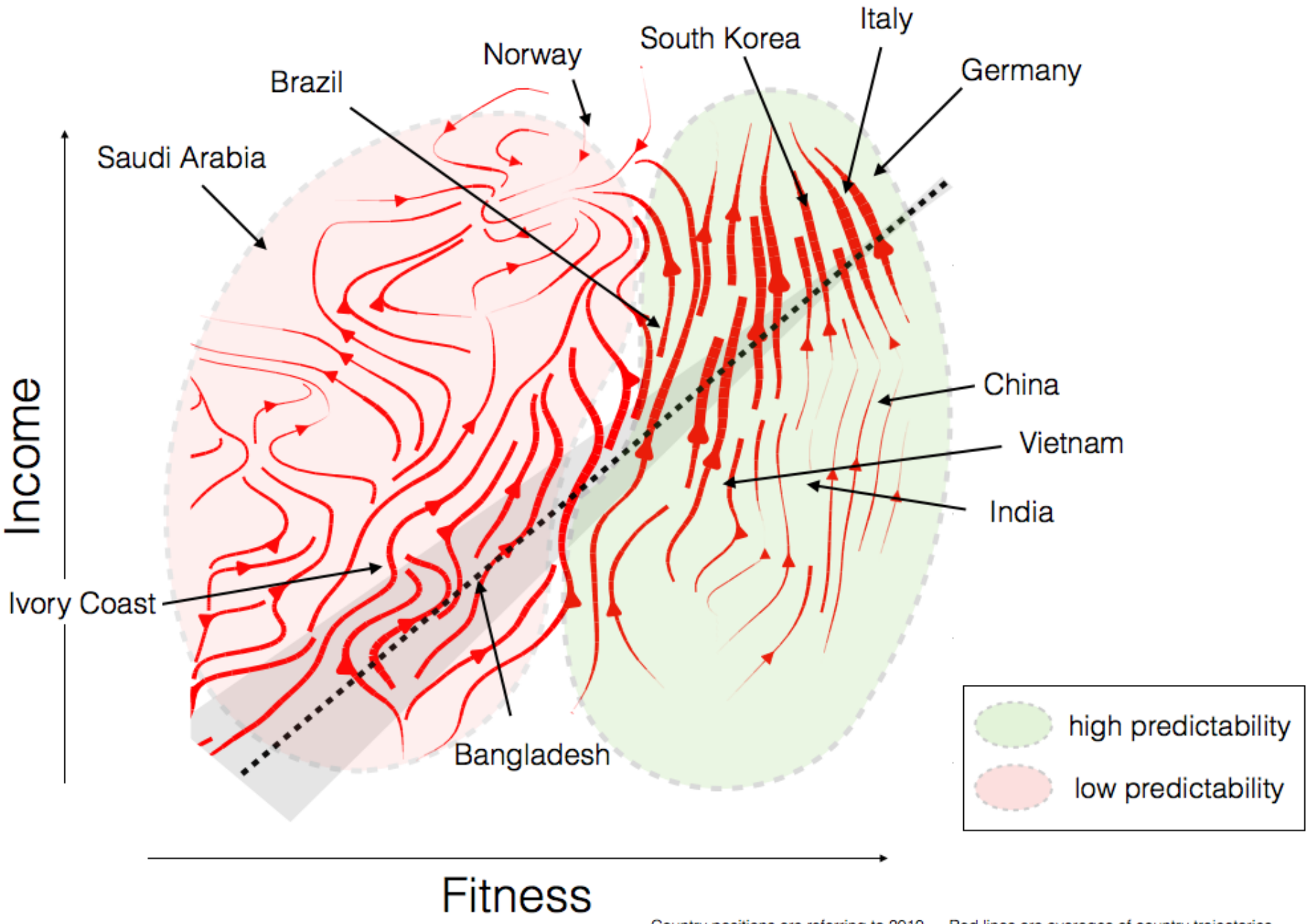
Fitness is the relevant and driving variable for the economic dynamics in this regime

high predictability

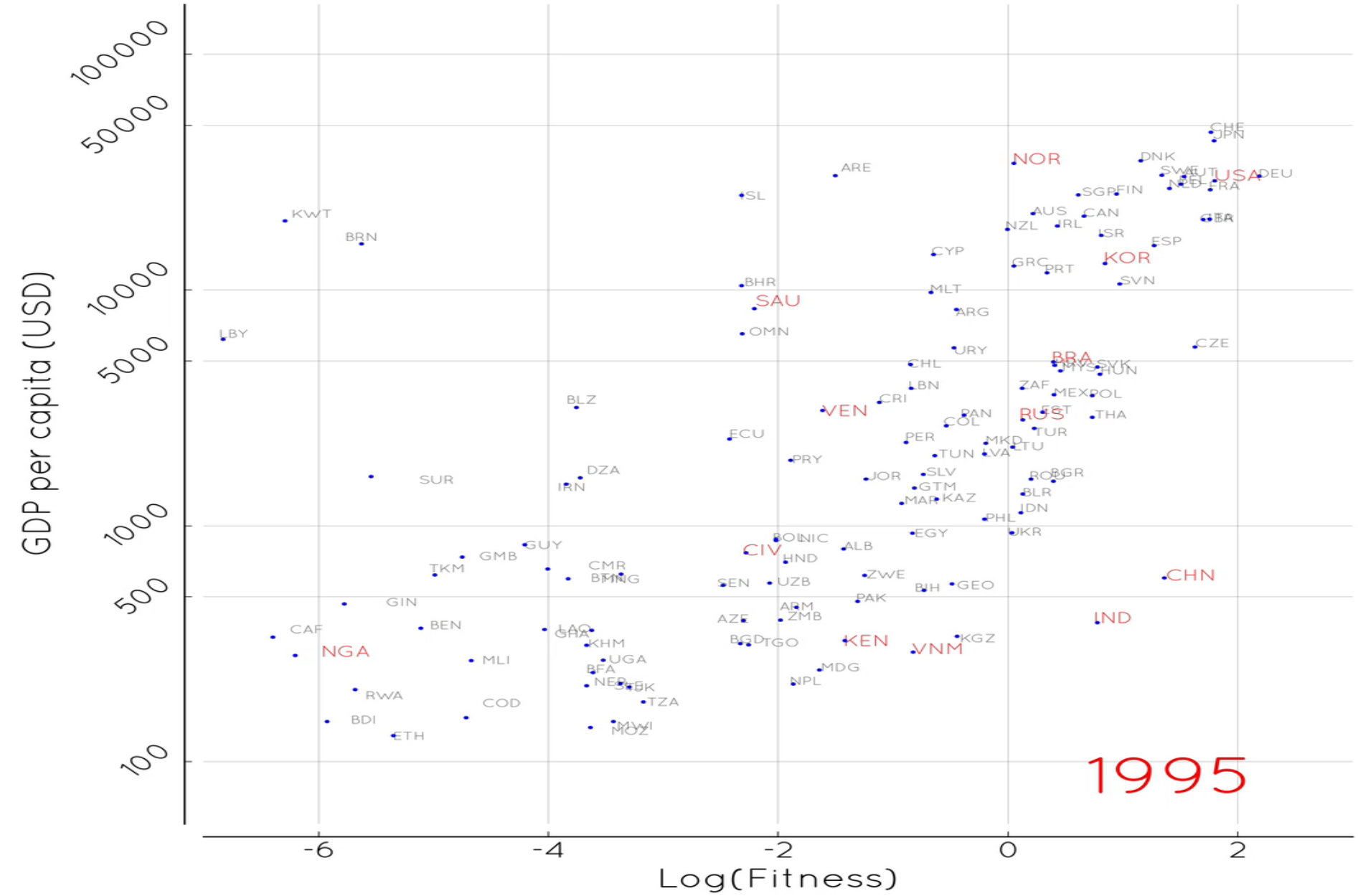
Chaotic regime

Dynamics is ruled by several other exogenous factors competing with Fitness

low predictability

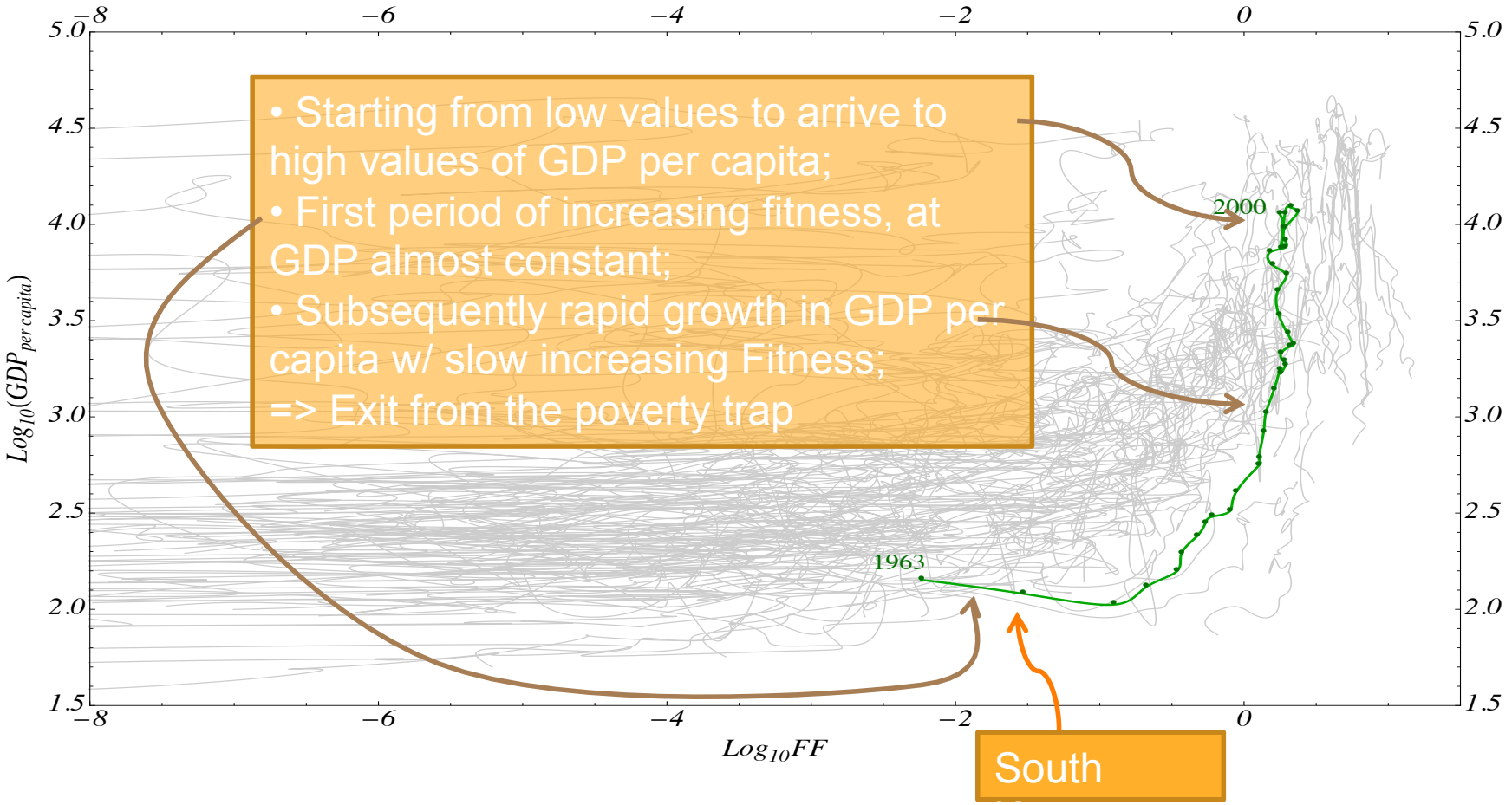


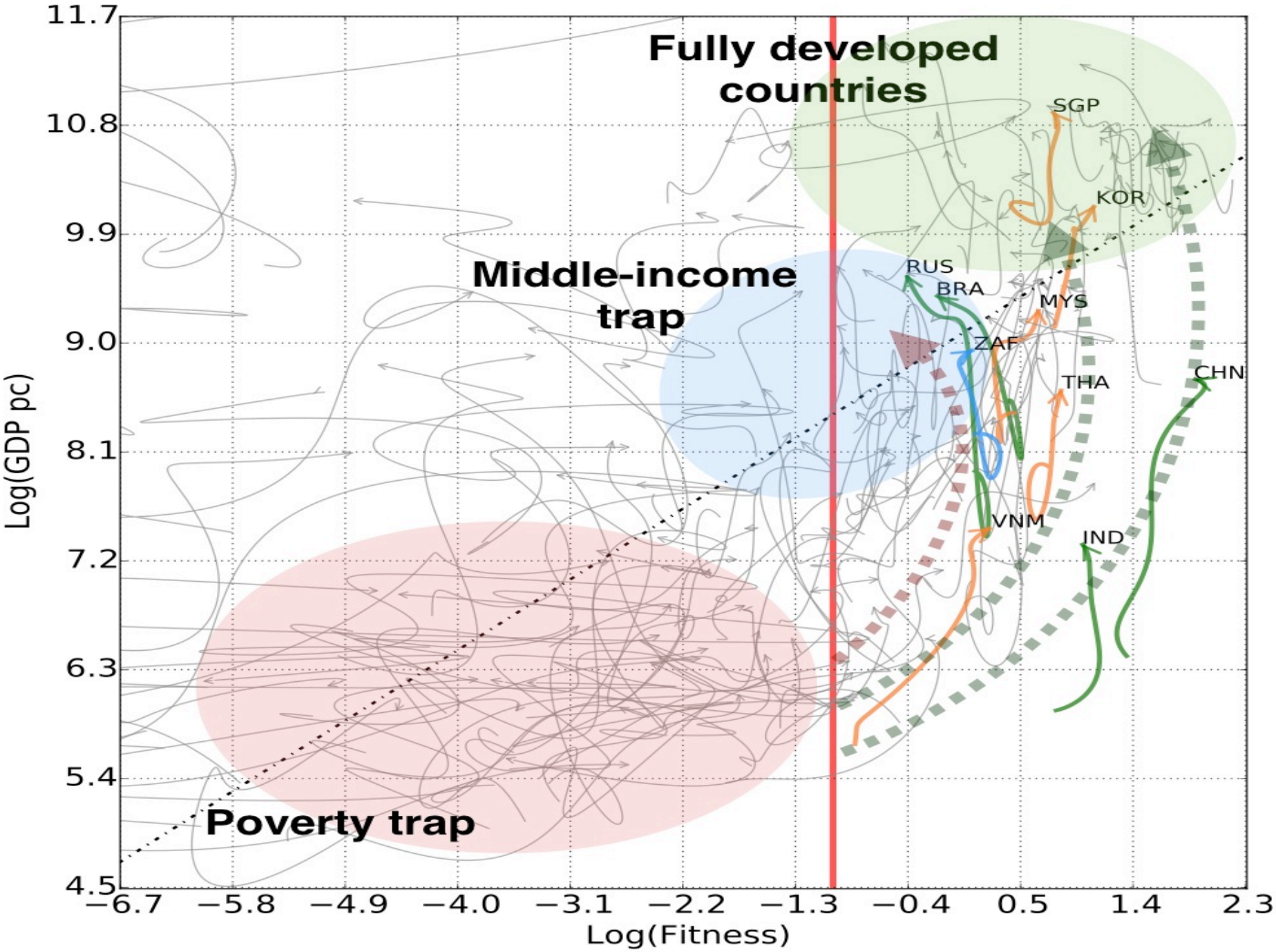
Country positions are referring to 2010 — Red lines are averages of country trajectories
Income is measured by Gross Domestic Product *per capita*, PPP (current international $)


GDP per capita (USD)
100000
50000
10000
5000
1000
500
100
-6
-4
-2
0
2
Log(Fitness)
1995
NOR
USA
KOR
SAU
BRA
VEN
RUS
CIV
CHN
IND
KEN
VNM
NGA
CHE
JPN
DNK
DEU
FIN
SGP
AUS
CAN
NZL
IRL
ESP
GRC
PRT
SVN
CZE
ARE
SL
KWT
BRN
CYP
BHR
MLT
ARG
OMN
LBY
URY
CHL
LBN
ZAF
MEX
POL
CRI
PAN
COL
THA
TUR
ECU
PER
MKD
LTU
TUN
PRY
SLV
GTM
BLR
IDN
PHL
EGY
UKR
ALB
HND
ZWE
GEO
PAK
ZMB
AZE
KGZ
UZB
SEN
TGO
BGD
MDG
NPL
UGA
KHM
LAO
BEN
GIN
CAF
MLI
RWA
COD
BDI
ETH
TZA
MOZ
GMB
GUY
TKM
CMR
DZA
IRN
SUR
BLZ

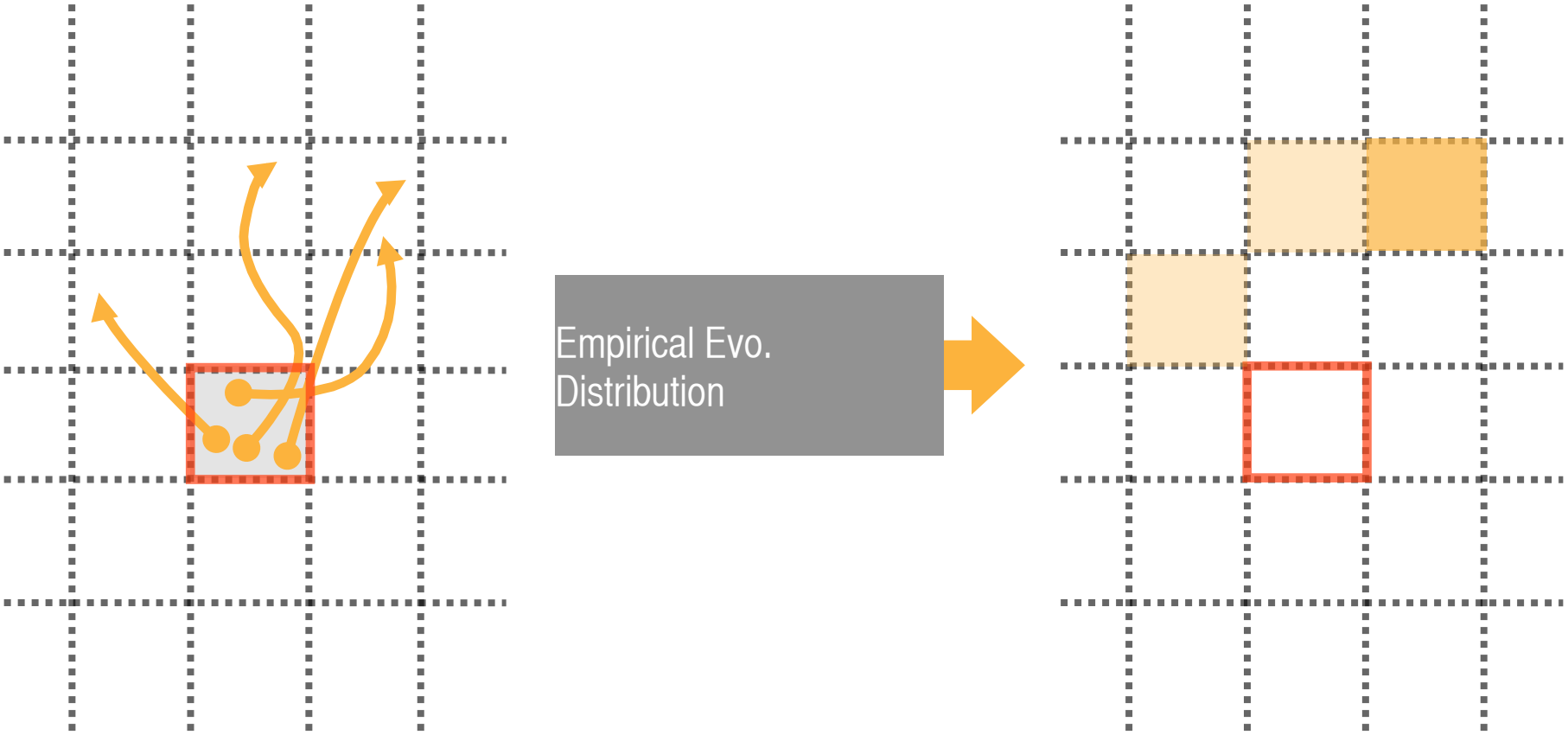
South Korea Evolution

Some examples of different regimes… 1963 - 2000

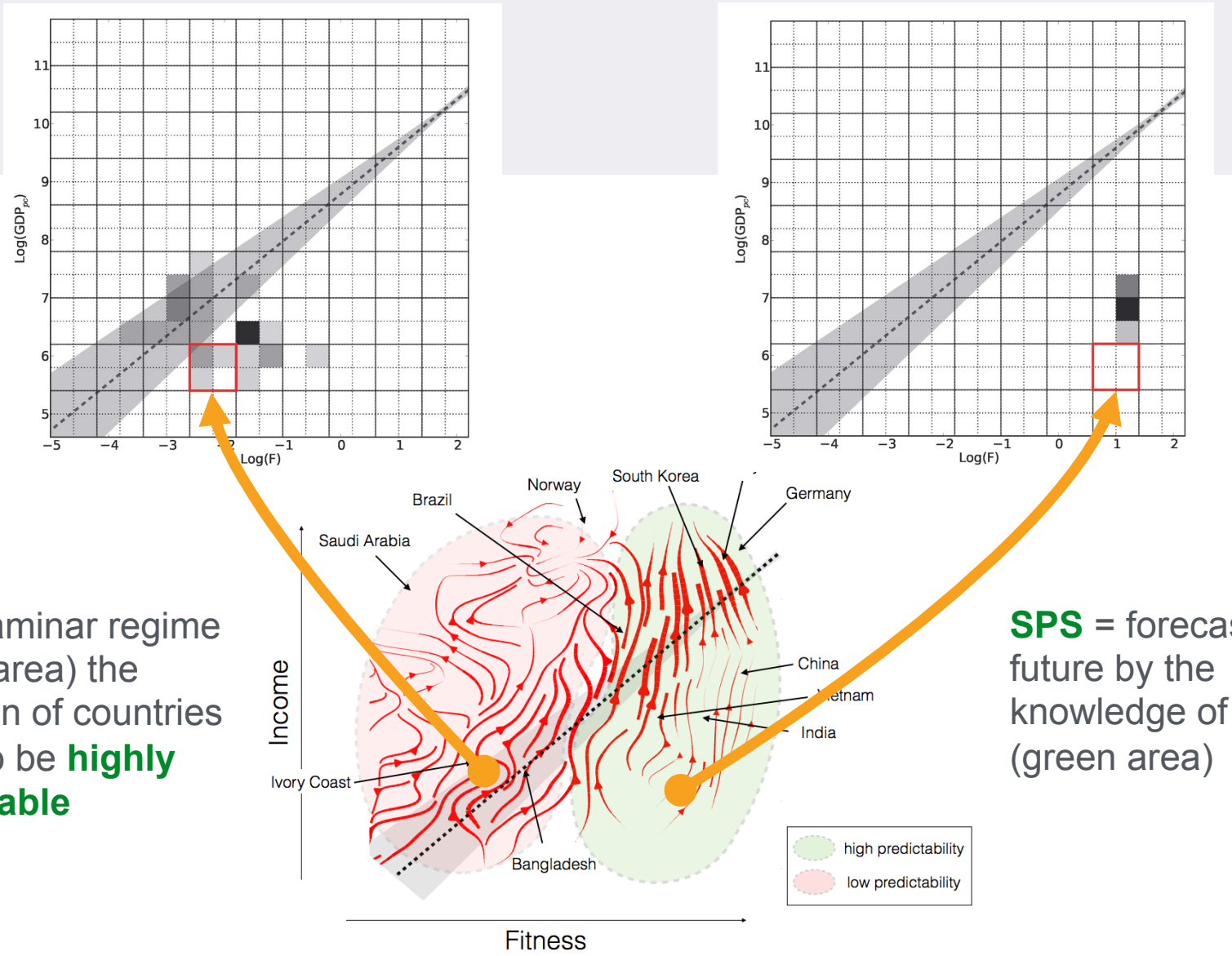



Fully developed countries
Middle-income trap
Poverty trap
SGP
KOR
RUS
BRA
MYS
ZAF
THA
CHN
VNM
IND
11.7
10.8
9.9
9.0
8.1
7.2
6.3
5.4
4.5
Log(GDP pc)
−6.7
−5.8
−4.9
−4.0
−3.1
−2.2
−1.3
−0.4
0.5
1.4
2.3
Log(Fitness)

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**

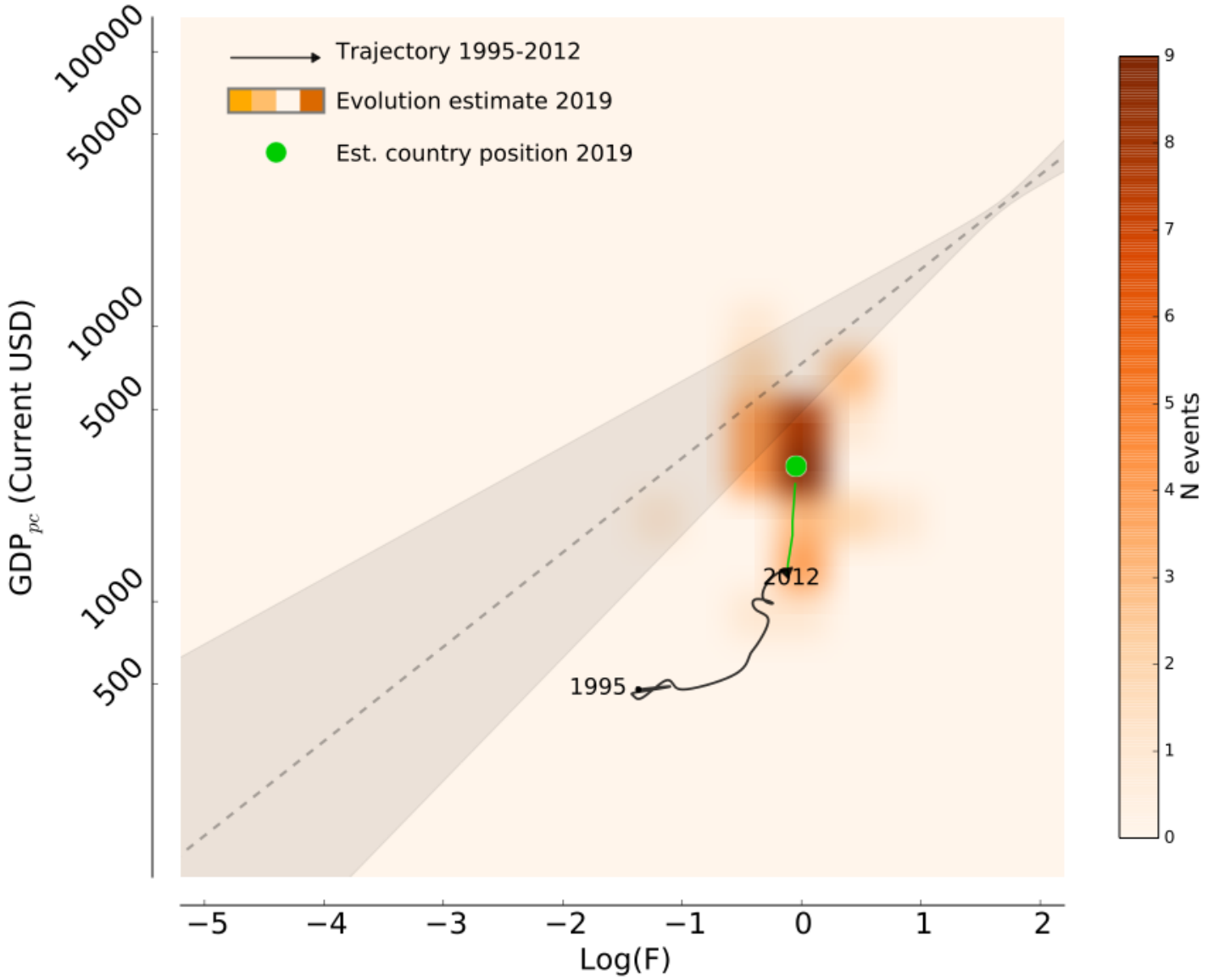
SPS = forecasting the future by the knowledge of the past (green area)

Country 1

Predictability 0.659

Fitness 0.887 (2012)

GDP $_{pc}$ 1255 Current USD (2012)

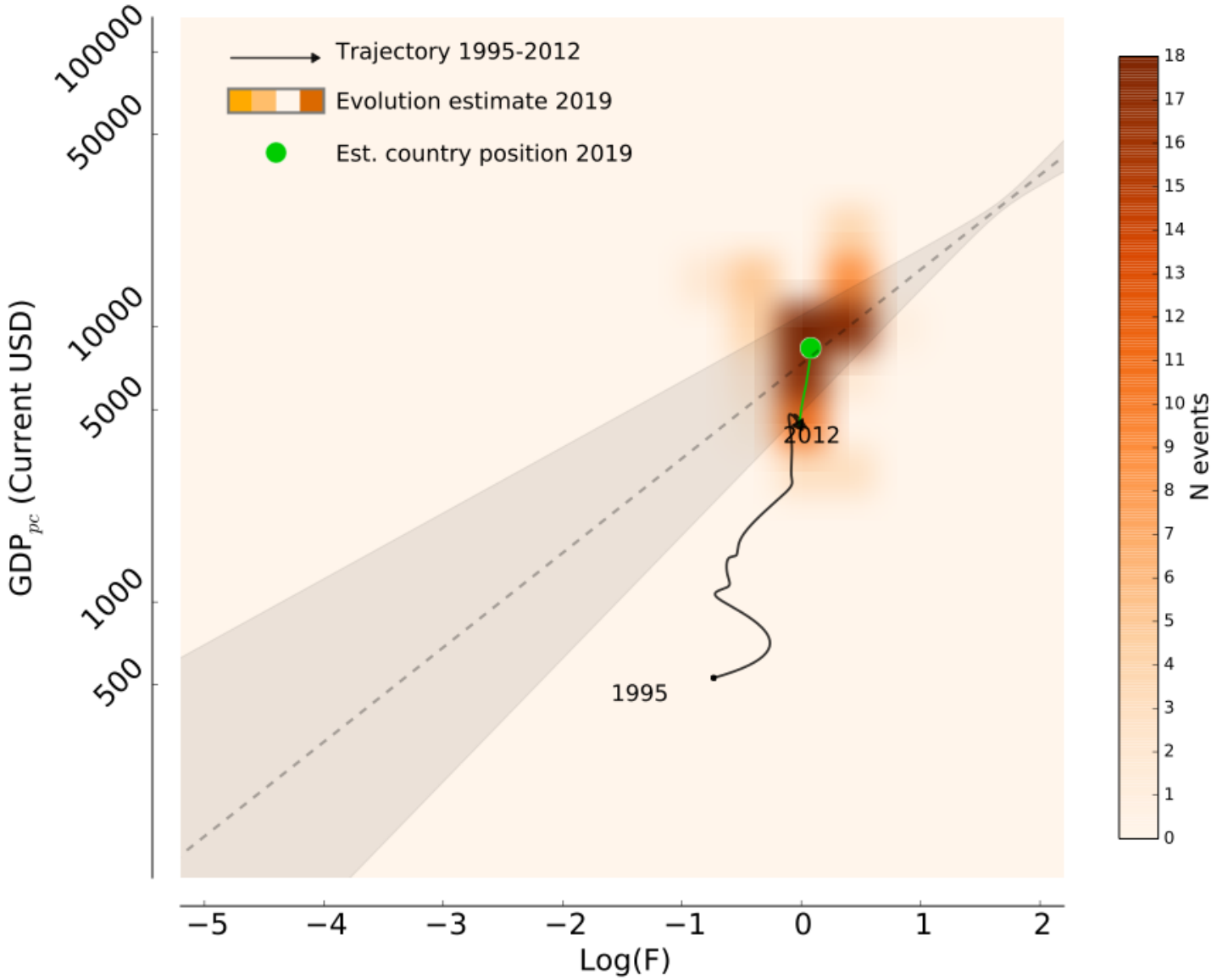


Country 6

Predictability 0.827

Fitness 0.982 (2012)

GDP $_{pc}$ 4396 Current USD (2012)

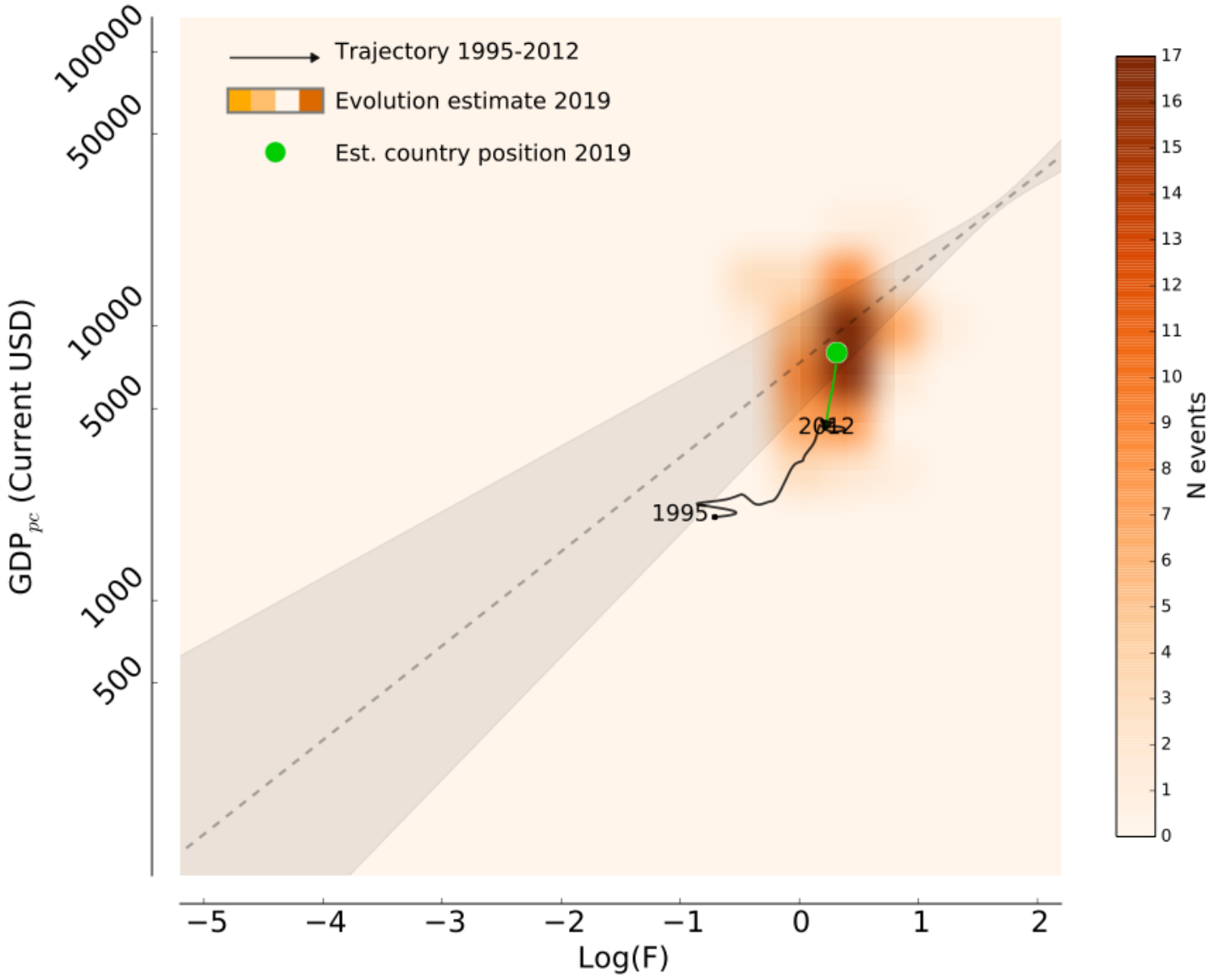


Country 9

Predictability 0.827

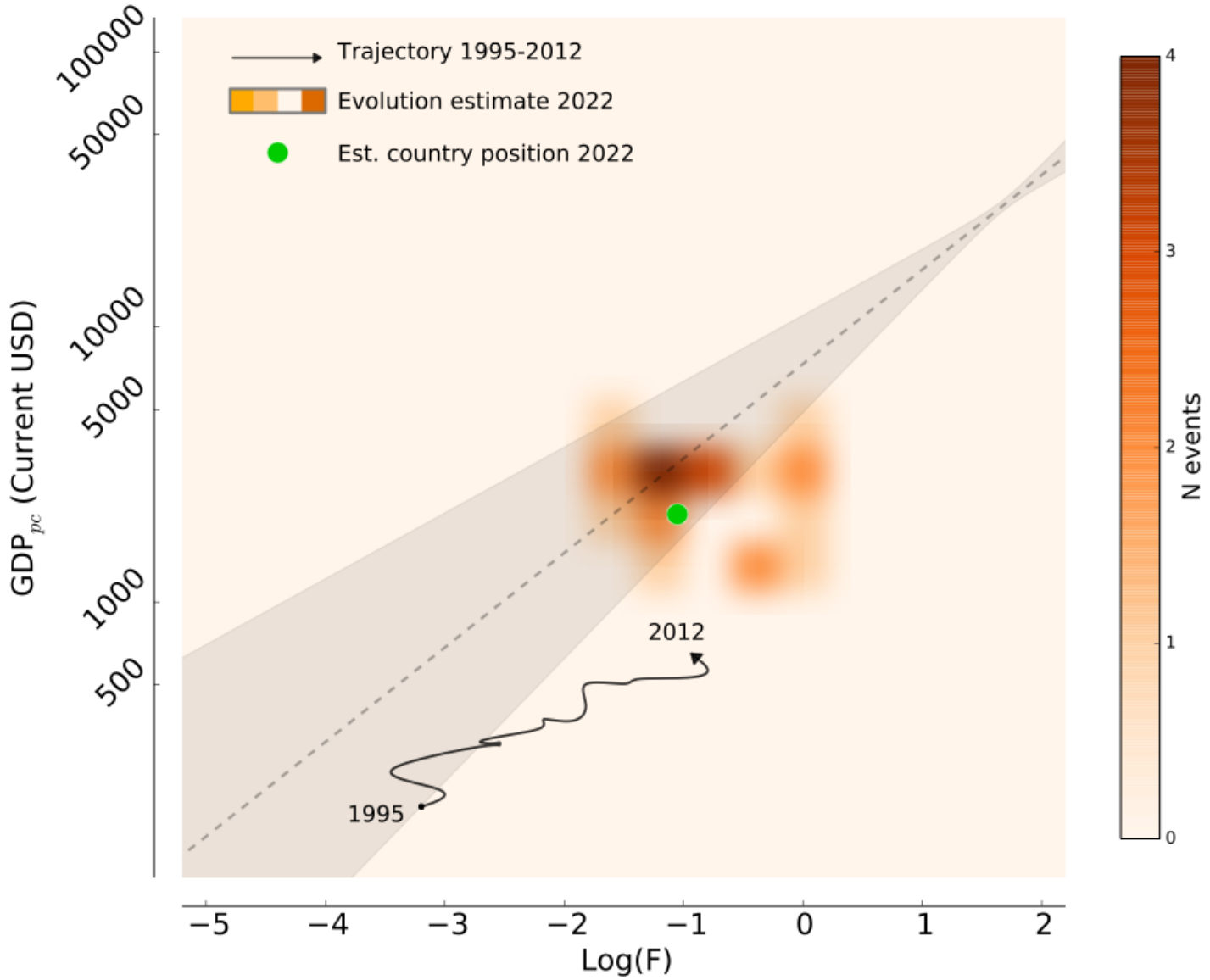
Fitness 1.245 (2012)

GDP $_{pc}$ 4197 Current USD (2012)



Country Tanzania Predictability 0.457

Fitness 0.424 (2012) GDP $_{pc}$ 609 Current USD (2012)

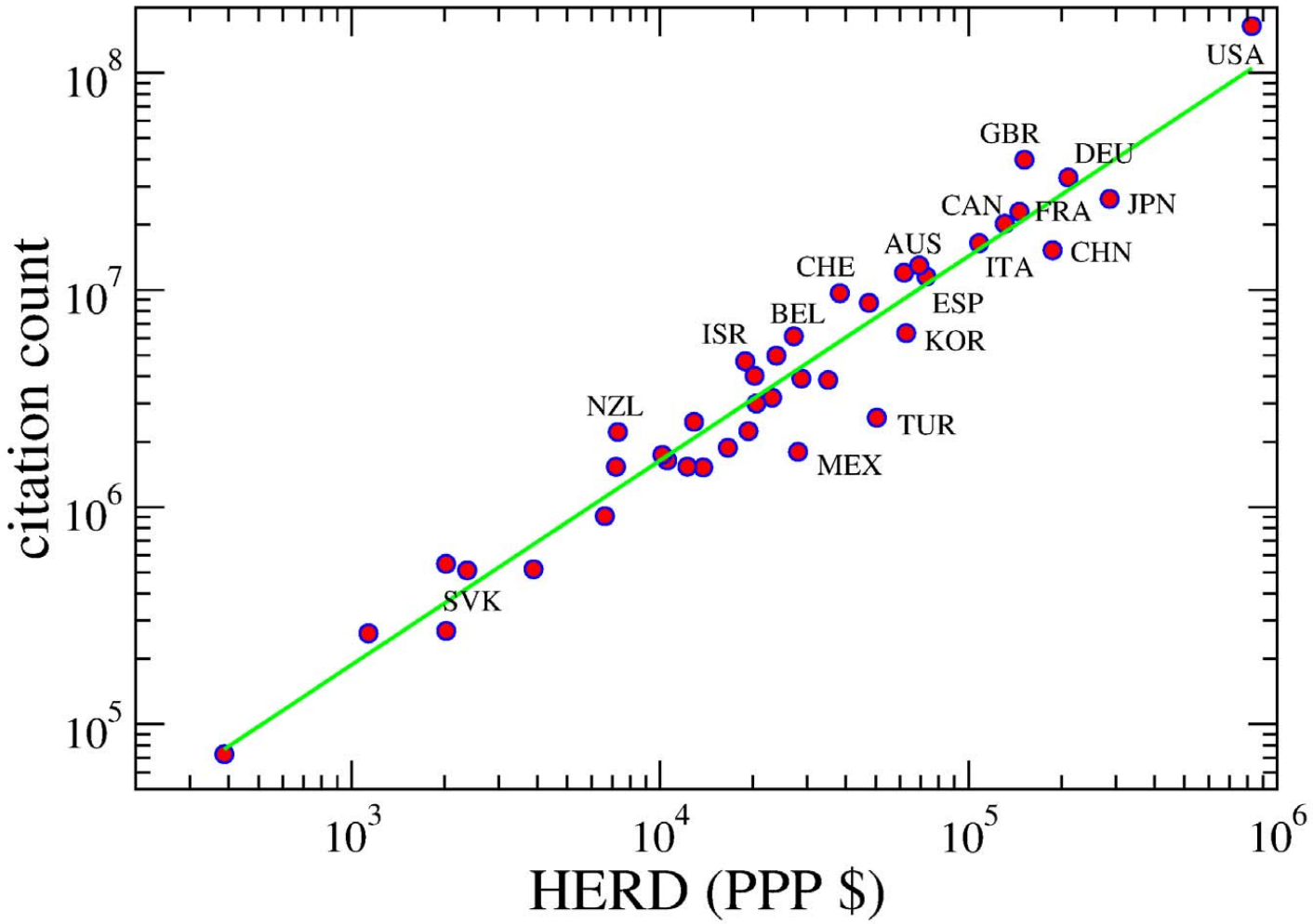


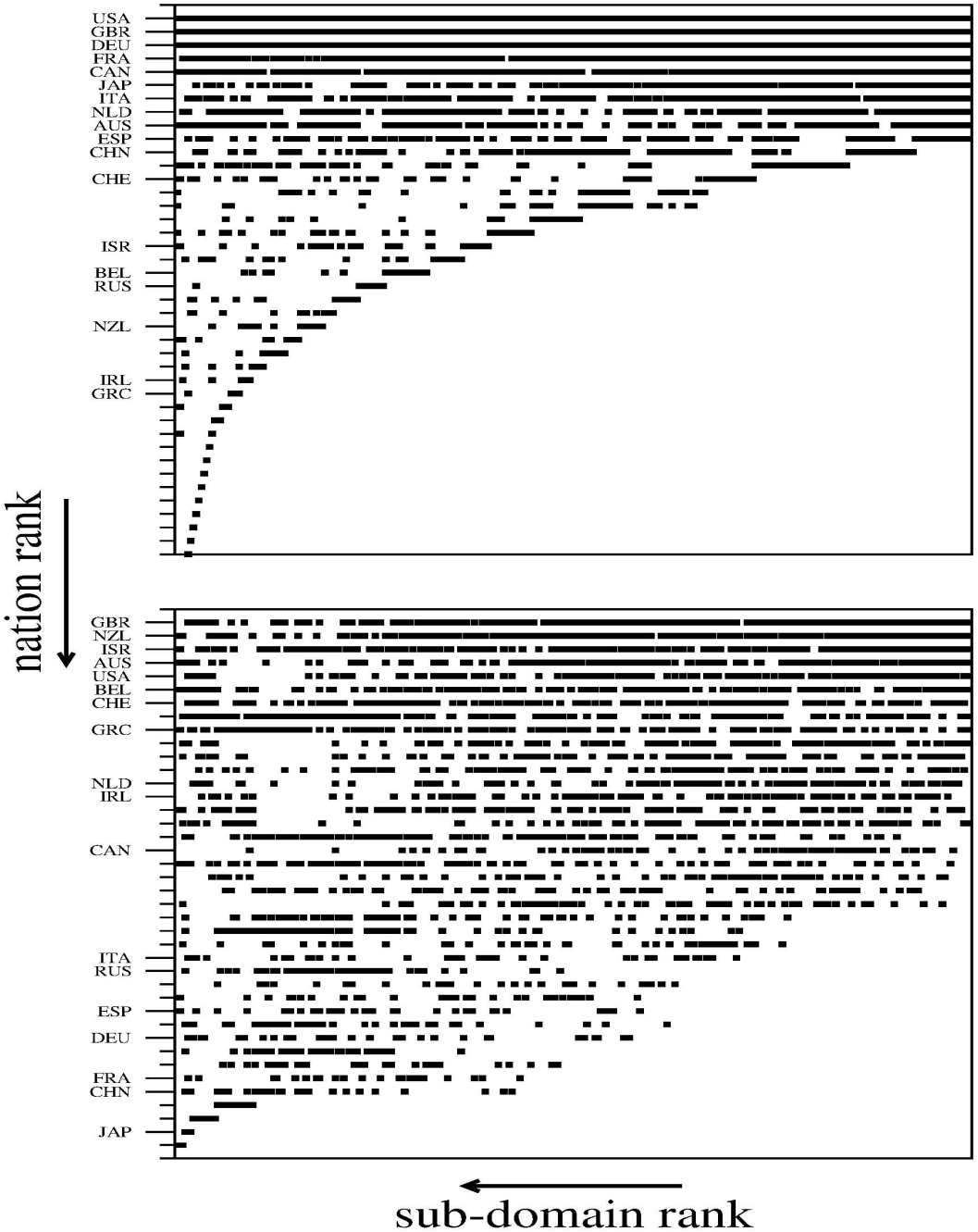
NEW:

SCIENTIFIC COMPETITIVENESS OF COUNTRIES

Do countries specialize or diversify their research Activity?

Is it economically worth spending in research?

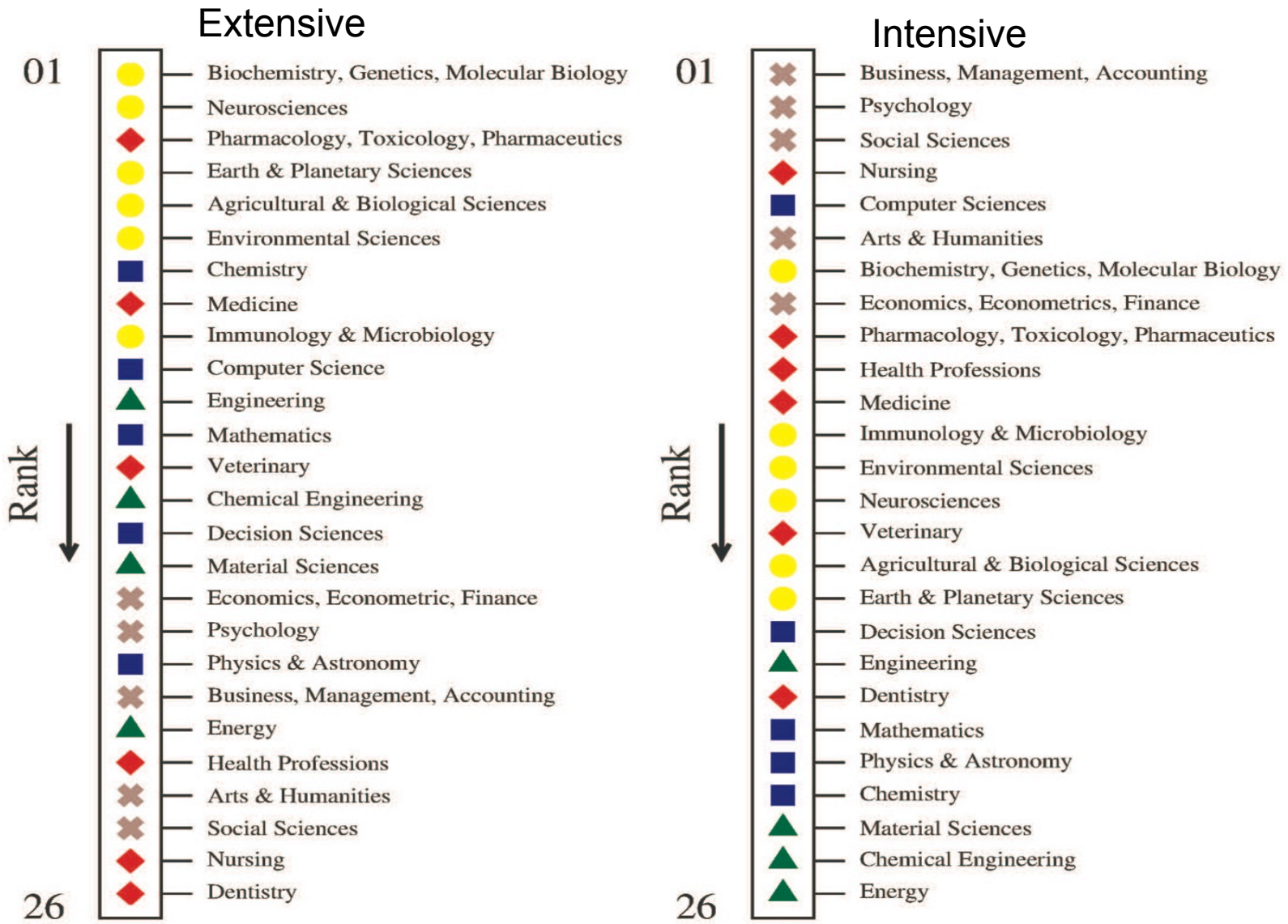




Extensive adiacency matrix

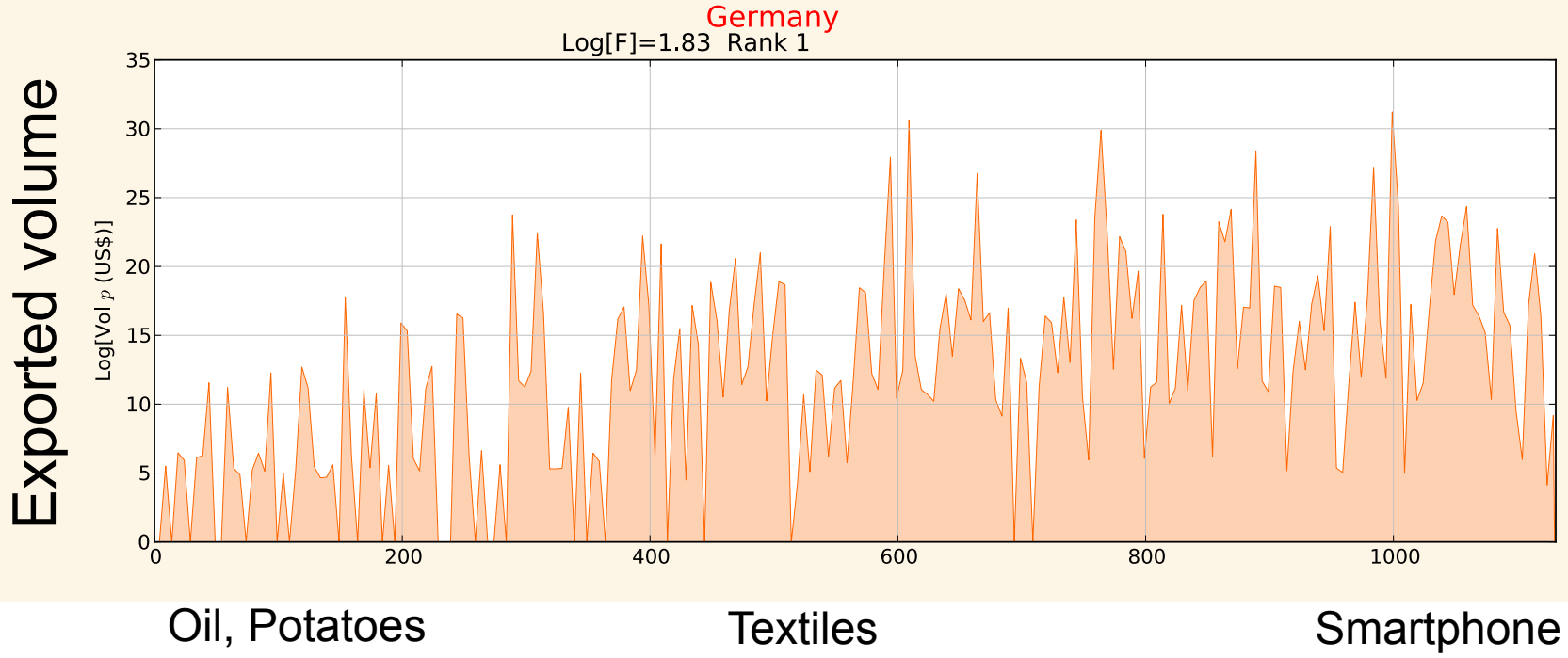
Intensive adiacency matrix

Ranking of scientific domains

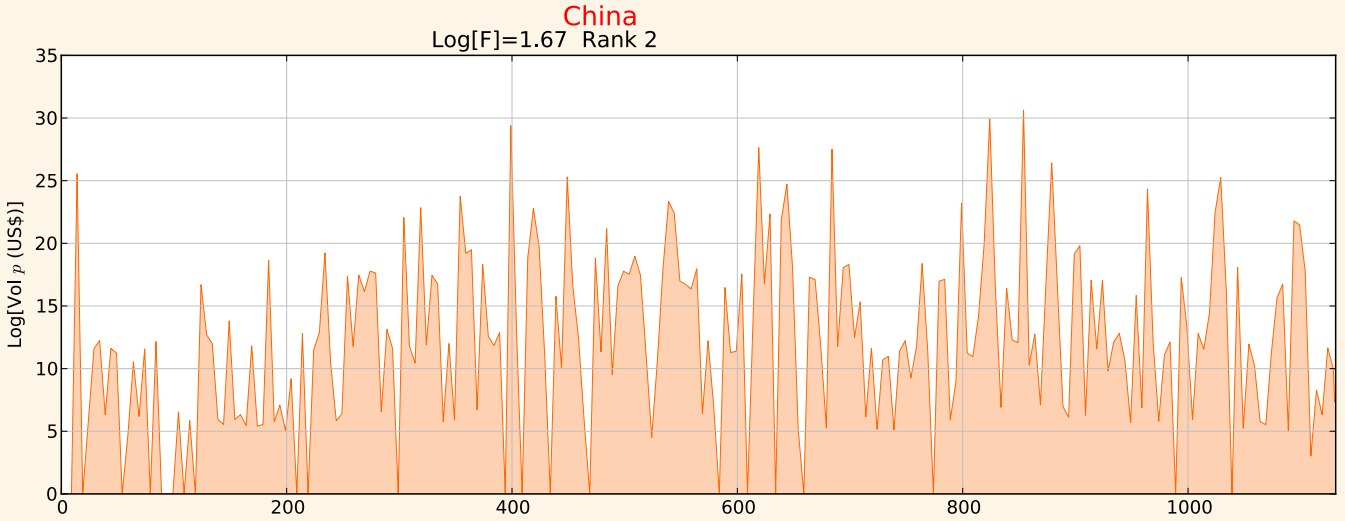


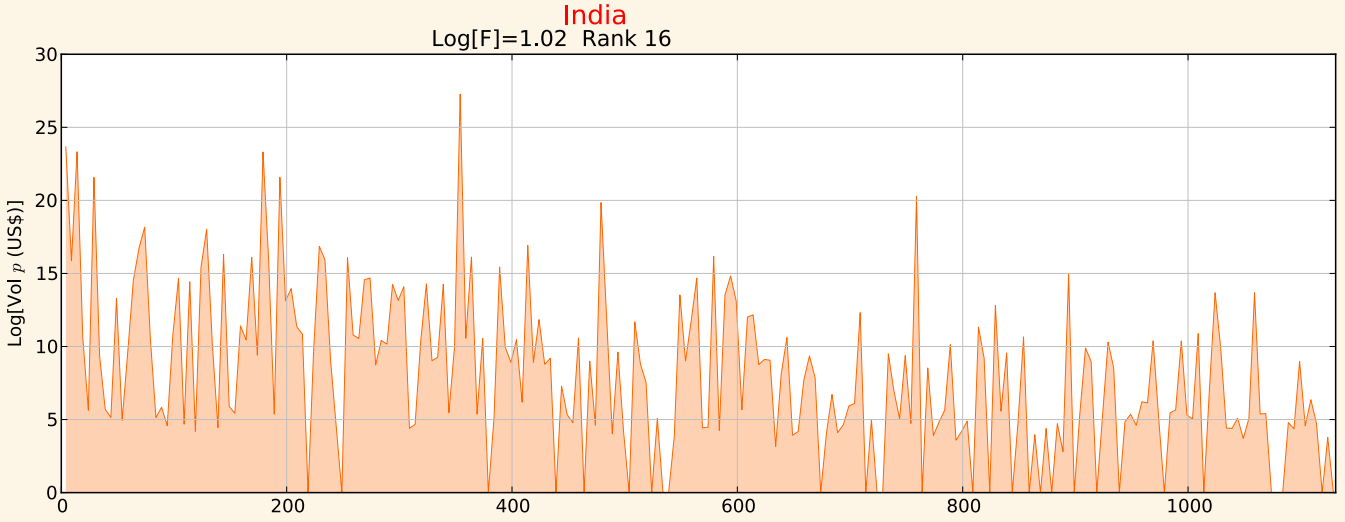
COUNTRY SPECTROSCOPY

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

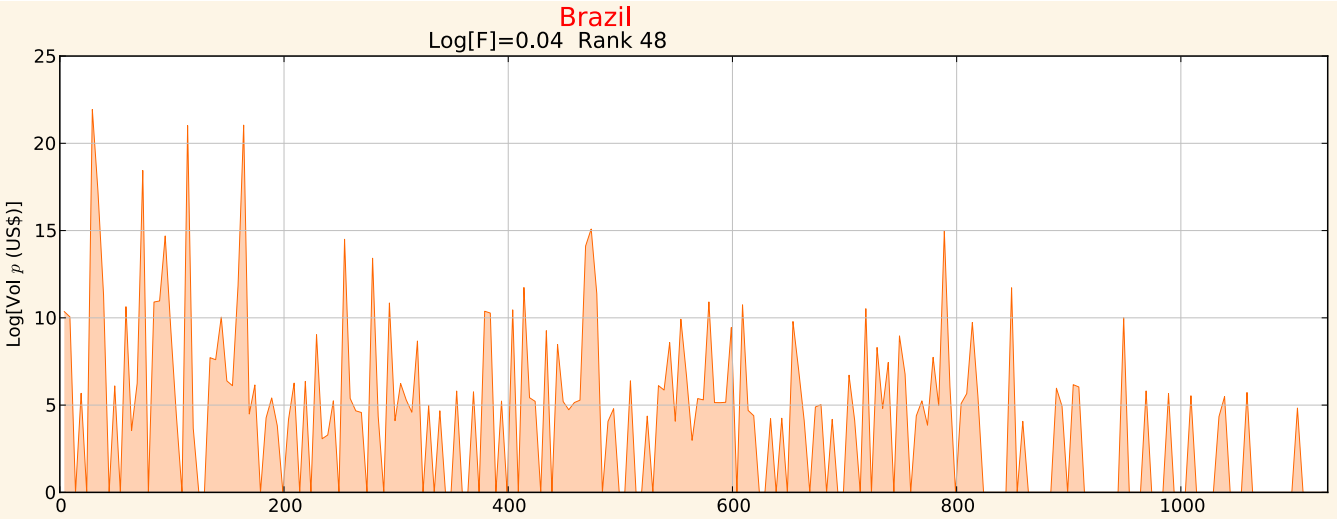


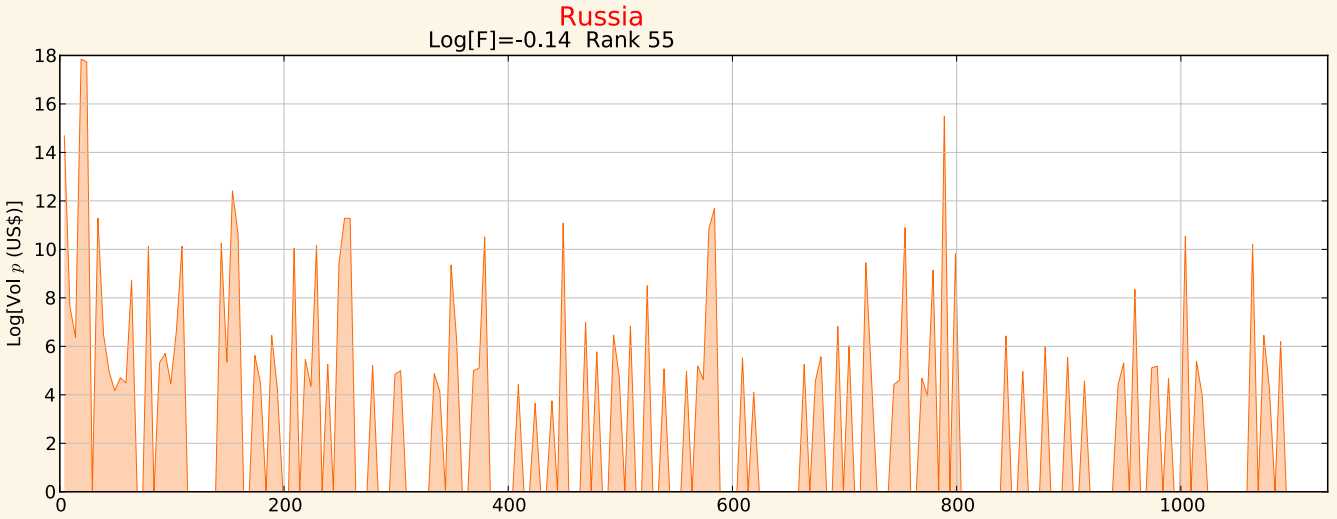
COUNTRY SPECTROSCOPY



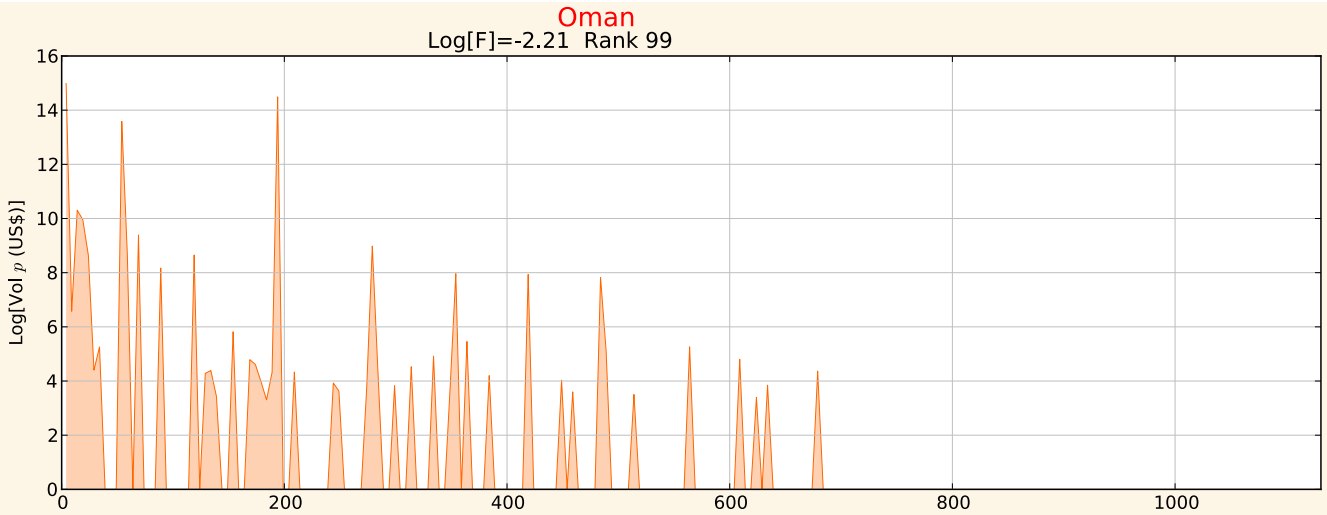


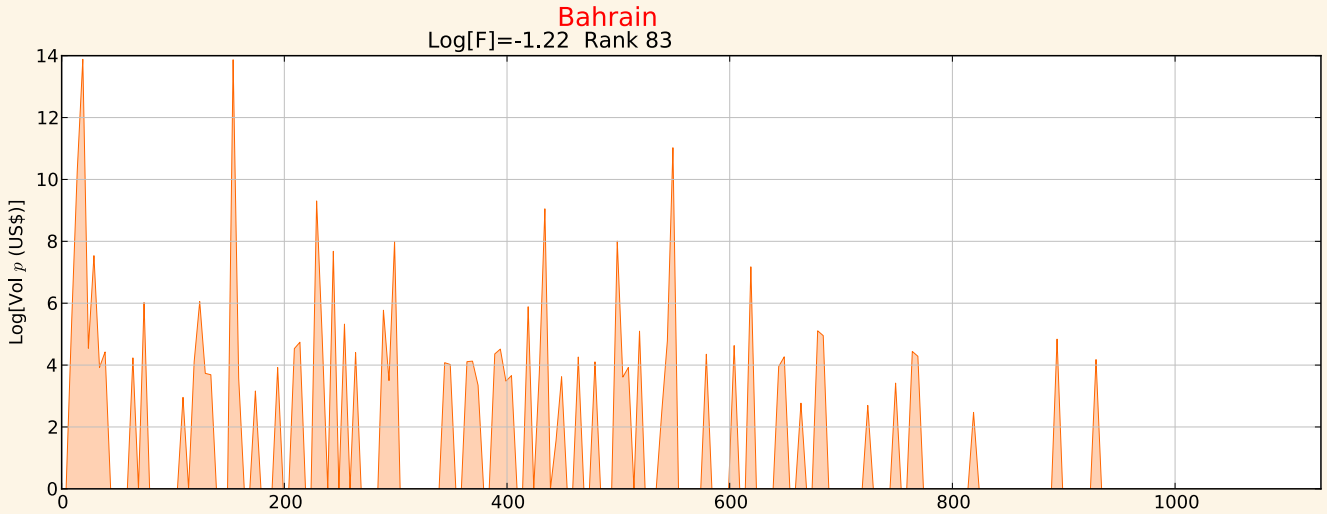
COUNTRY SPECTROSCOPY



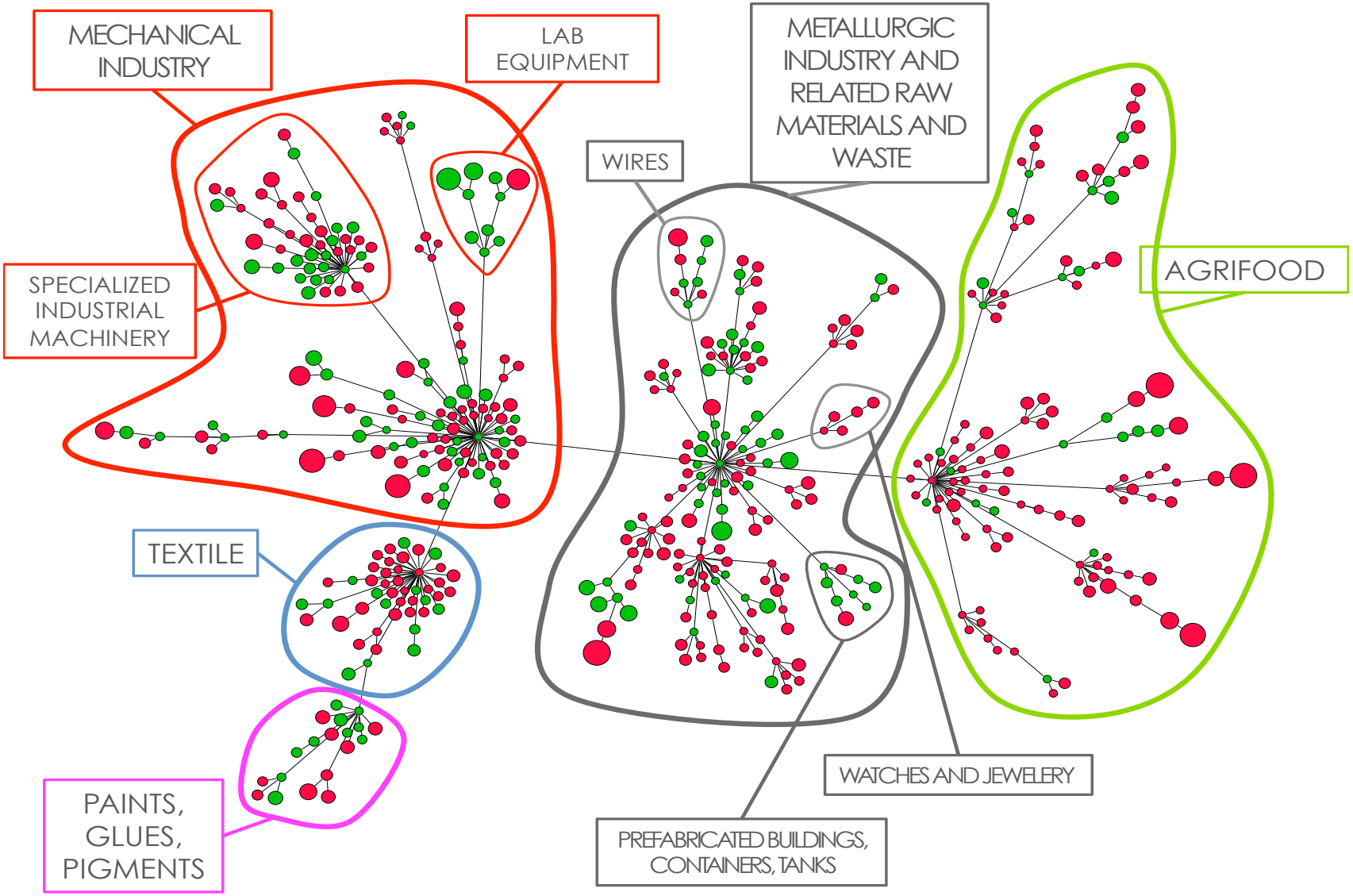


COUNTRY SPECTROSCOPY

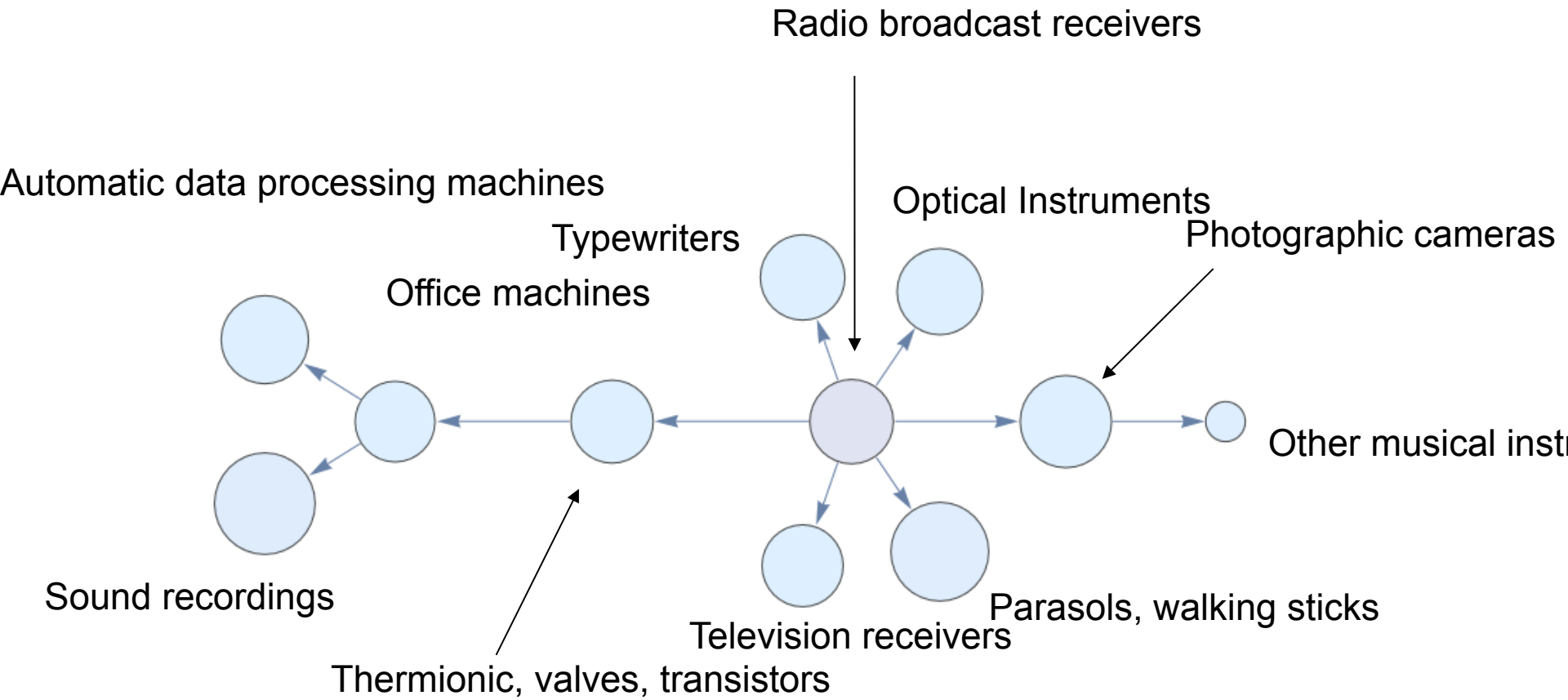




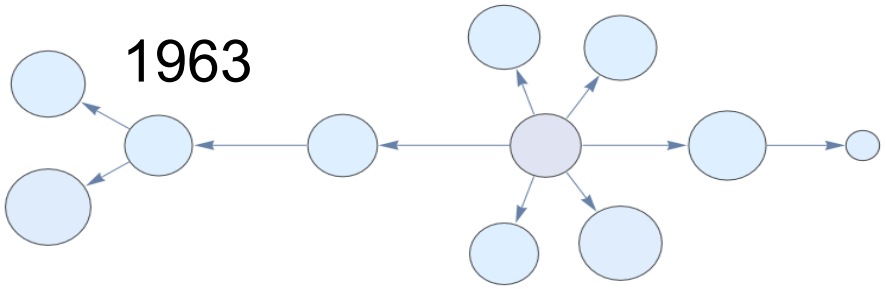
SWEDEN: PORTION OF THE PRODUCT SPACE



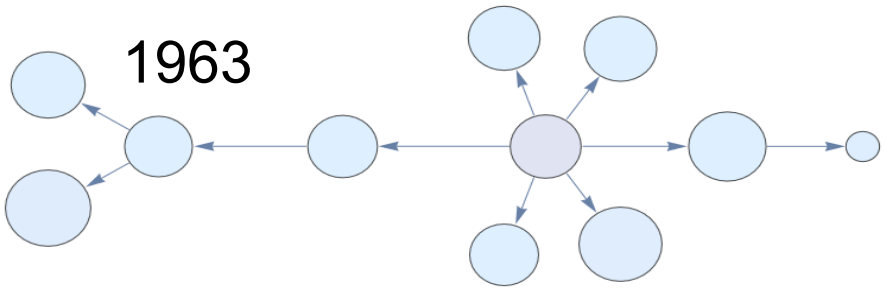
Example: SK 81 detailed products

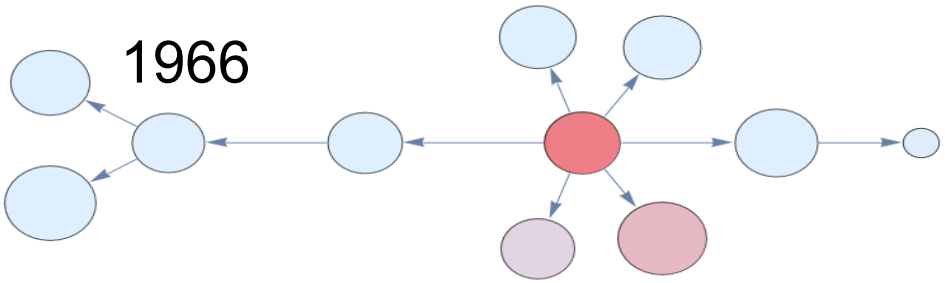


Diffusion of South Korea 1963-2000

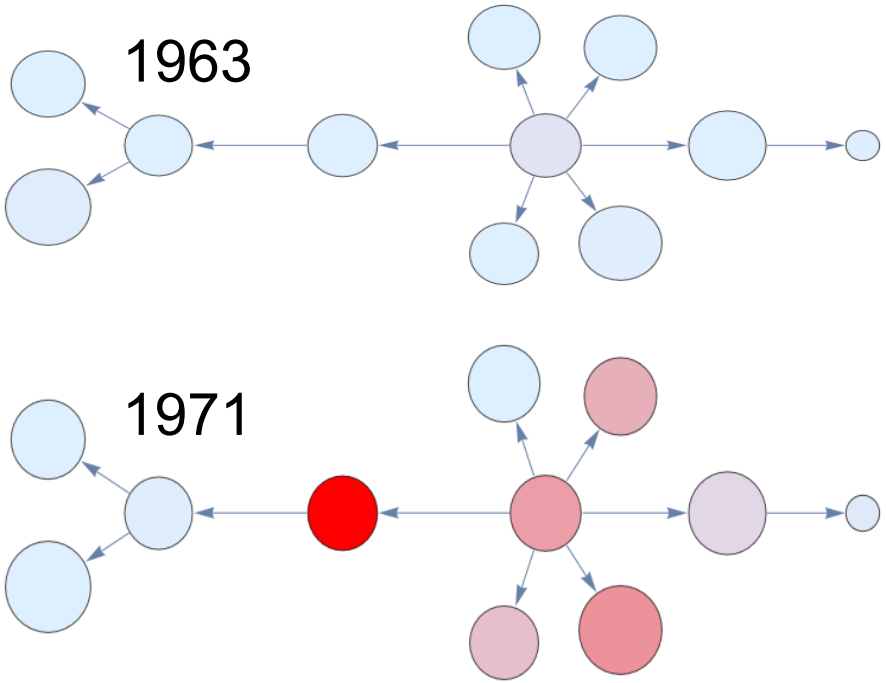


Example: Diffusion of SK 1963-2000

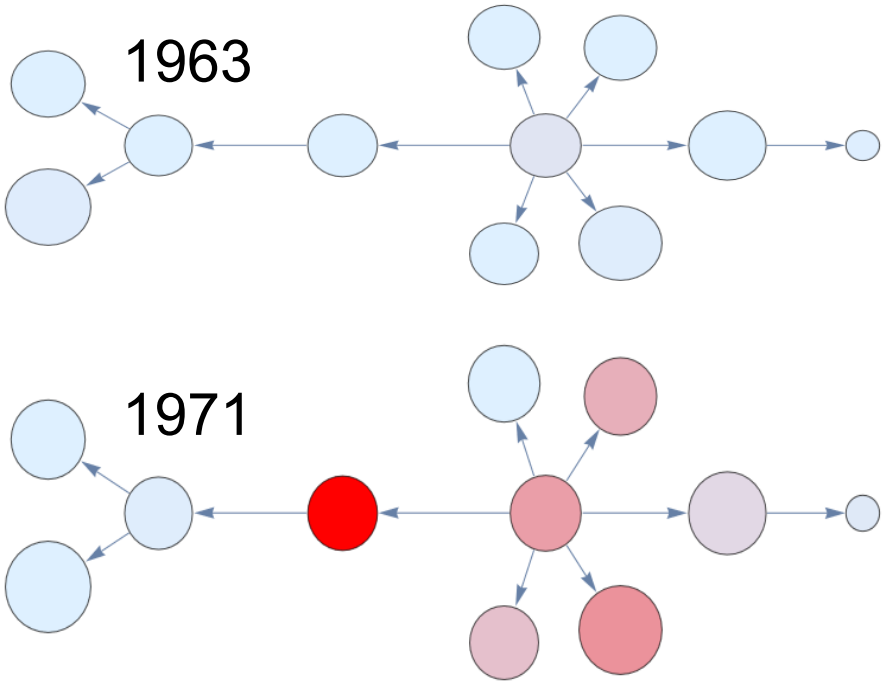




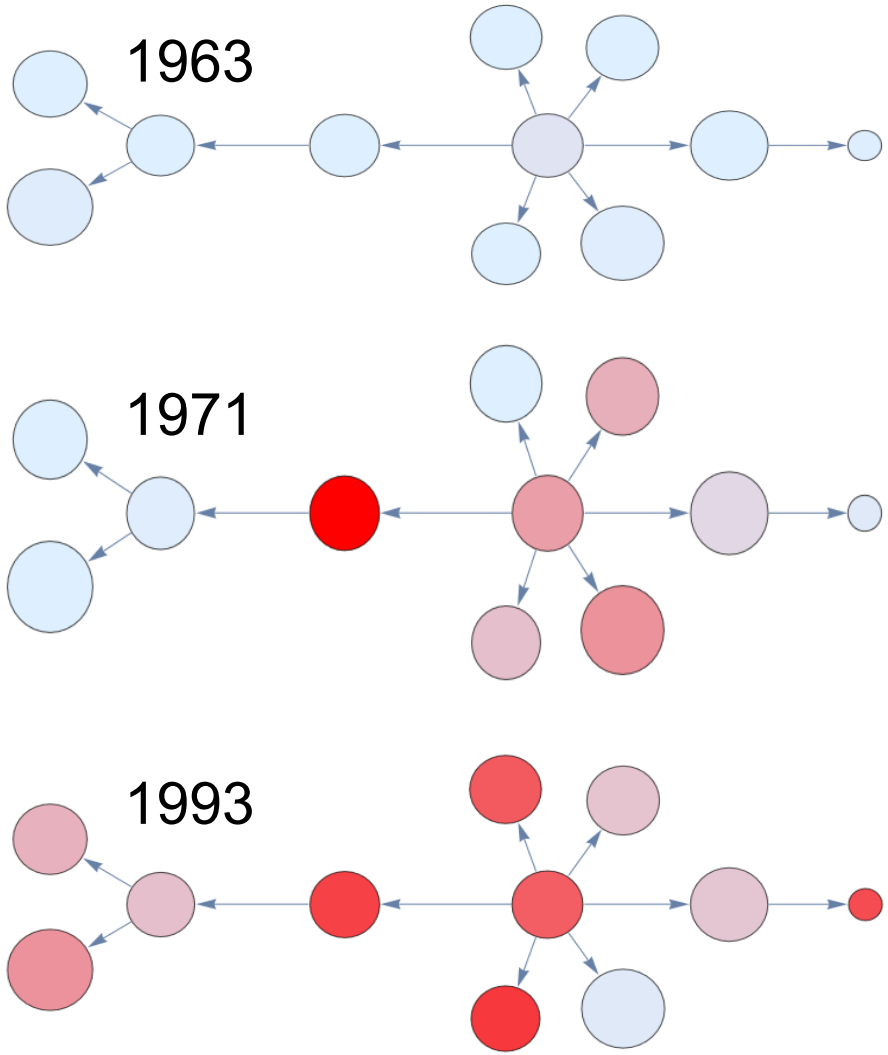
Example: Diffusion of SK 1963-2000



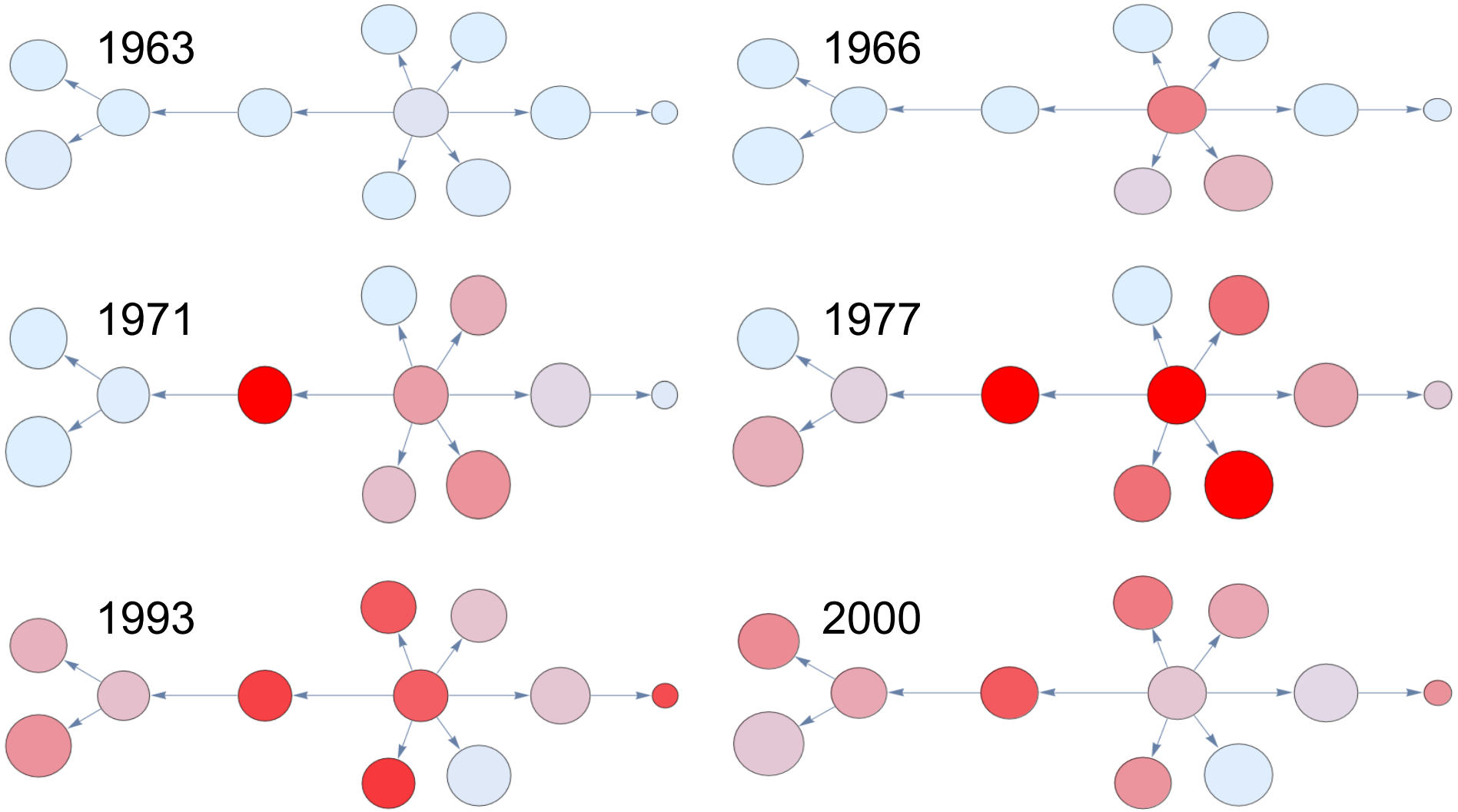
Example: Diffusion of SK 1963-2000



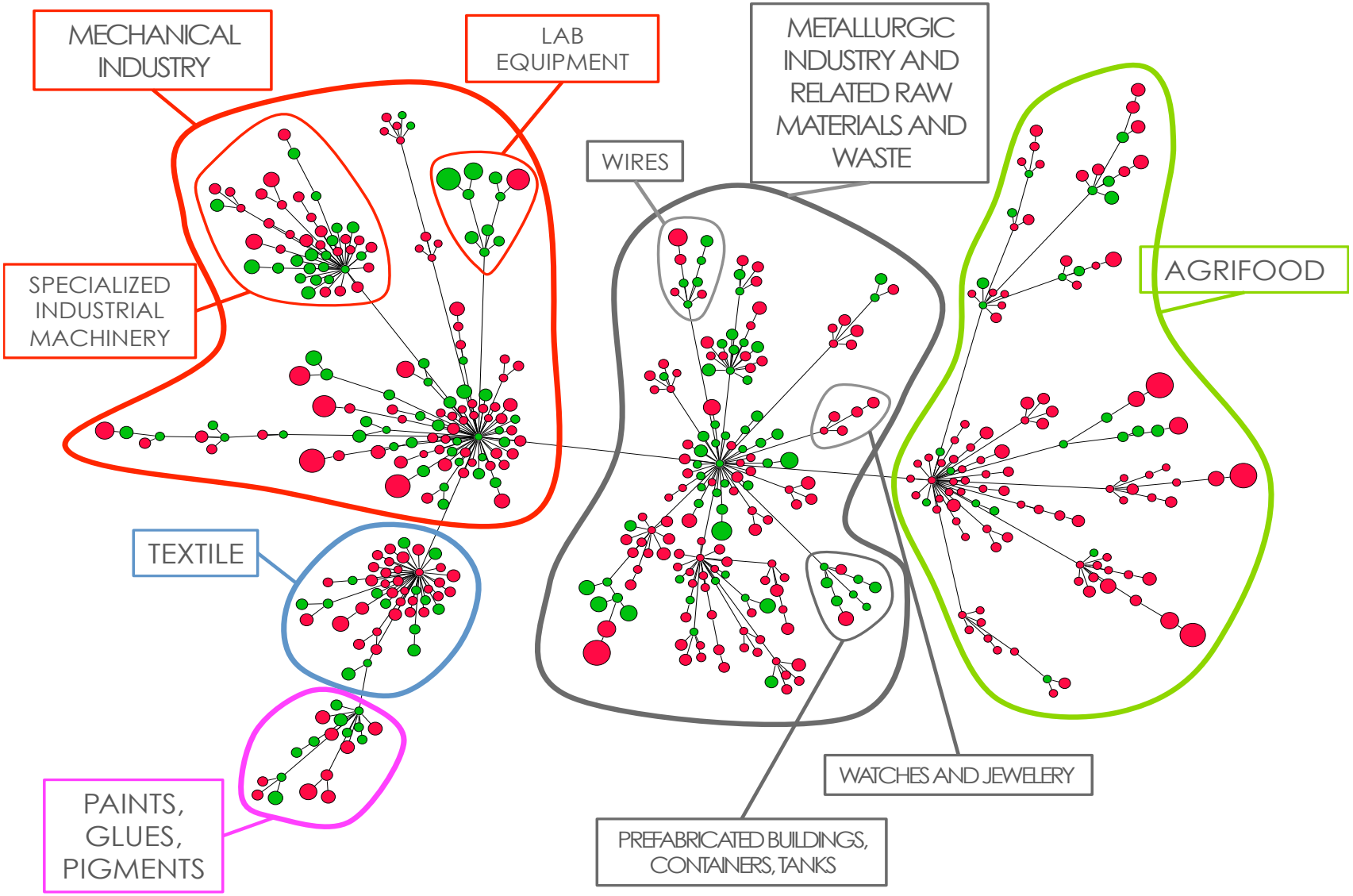
Example: Diffusion of SK 1963-2000



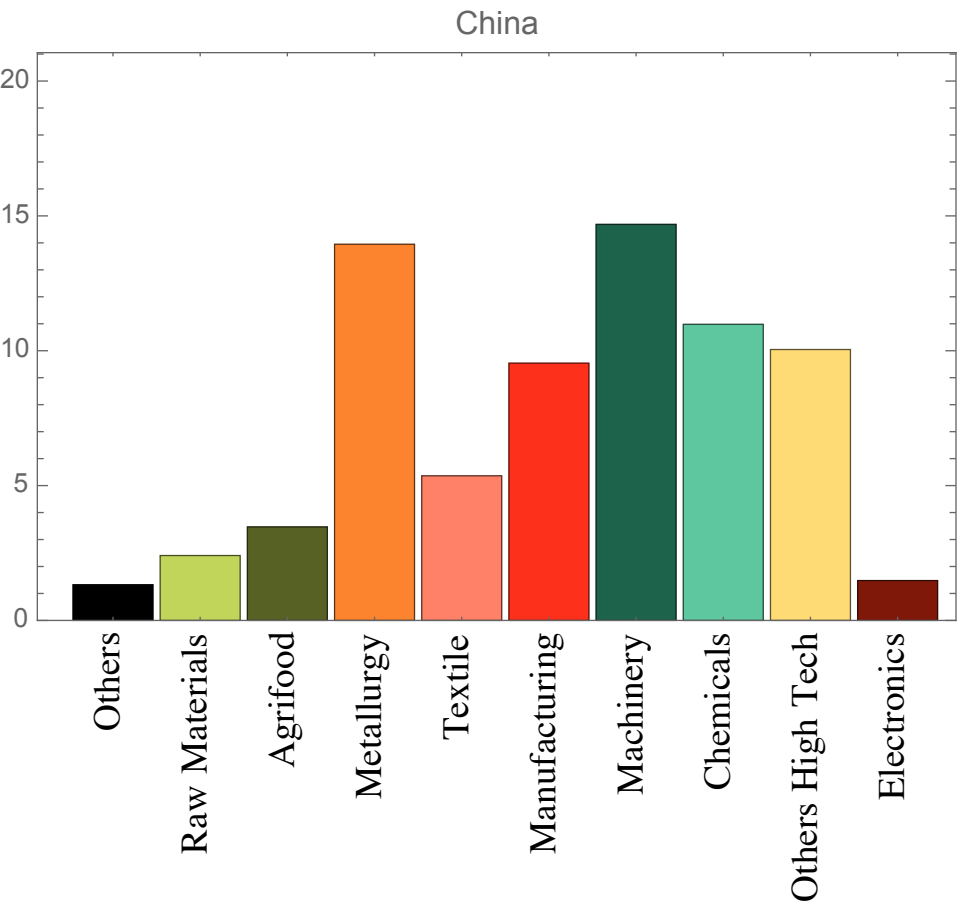
Example: Diffusion of SK 1963-2000

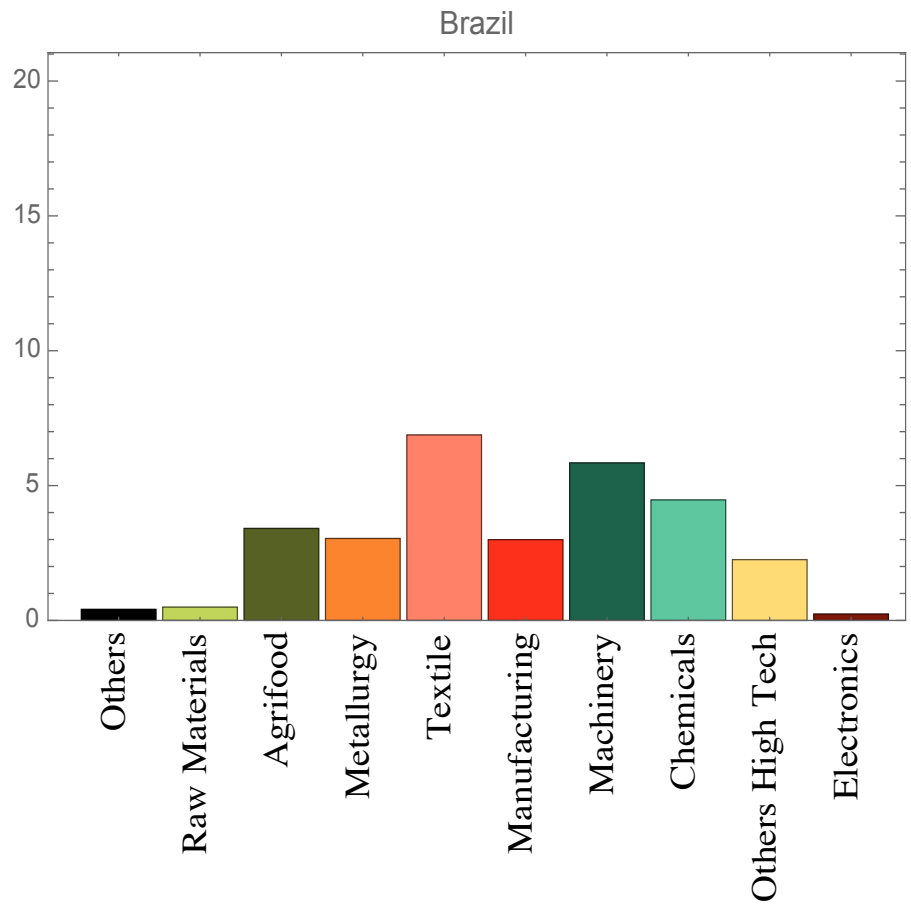


SWEDEN: PORTION OF THE PRODUCT SPACE



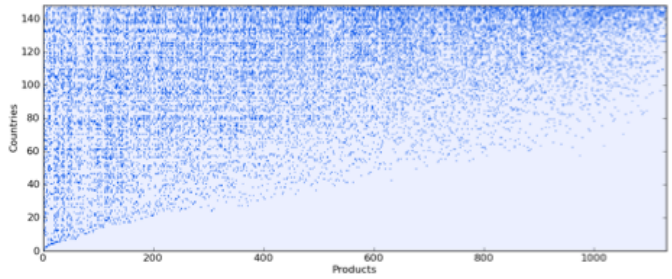
NEW: Forecasting of the new products (sectors) which have
a high probability to appear in the near future



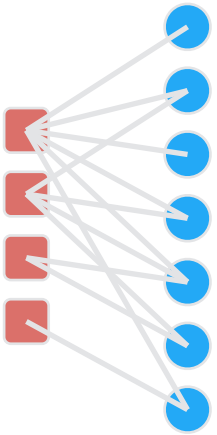


NEW:

Economics

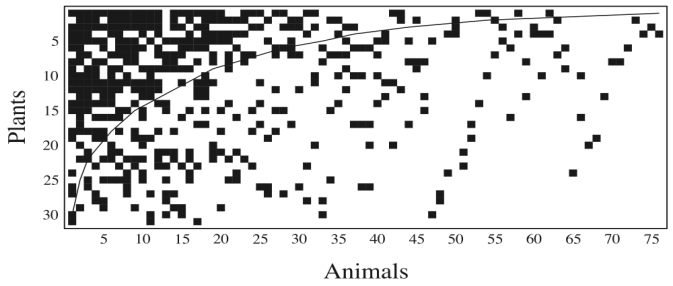


Countries Products

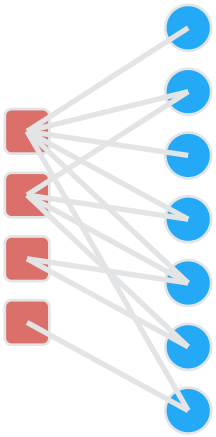


M. Munoz et al, preprint 2014

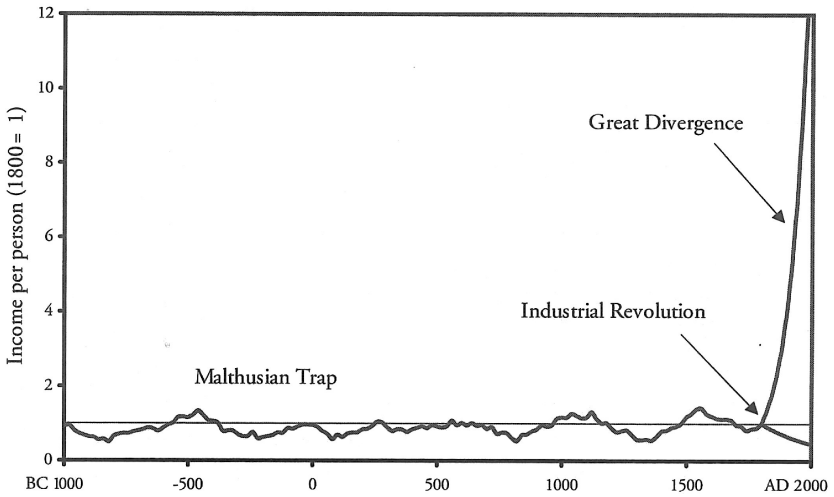
Ecology



Plants Pollinators



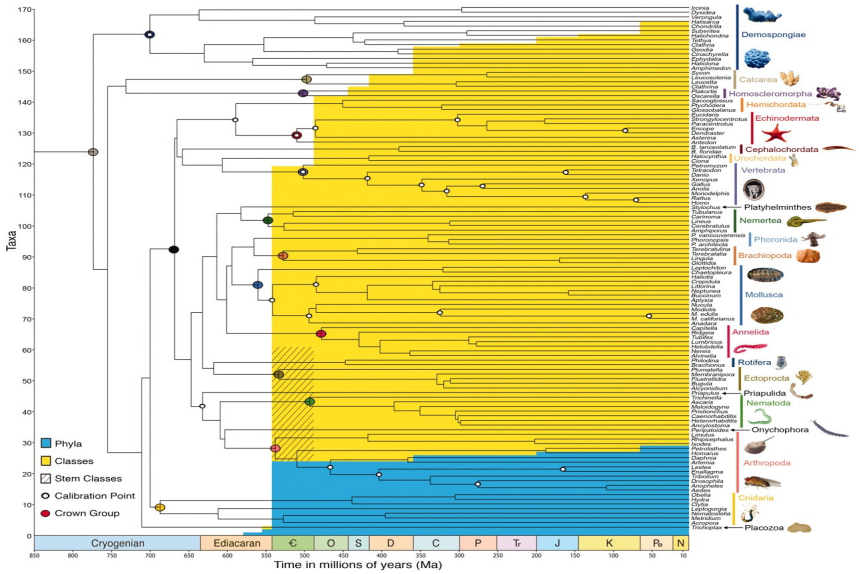
Economics



Great divergence

DIVERSITY

Ecology



Cambrian Explosion

DIVERSITY

Future developments of Economic Complexity

- COUNTRIES have a long time horizon and they have to diversify for their long range stability. Meaning and implications of product complexity Q yet to be fully explored

- COMPANIES have a short time horizon (3 months) and have to specialize and compete on few products. A company which diversifies its products looses 14% of the stock value (BCG report). Also for companies diversification helps long range stability

- New database on trading between companies – Supply Chain:
  - Bloomberg: 38,000 quoted companies including volumes
  - Standard&Poor: 4 millions companies without volumes

  Fantastic information on the infrastructure and dynamics of economics. New ideas and algorithms are needed.
  - Possibly Alibaba data on trade between chinese companies

Policy making and consulting

- Institute for New Economic Thinking (2013)
- 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)
- Azimut private bank, Asset allocation Fund (2015)
- Alibaba Complexity Research Center (Hangzhou, China)