

IIASA System Analysis 2015:
Vienna 11 –13 November 2015

NEW METRICS FOR ECONOMIC COMPLEXITY:

Measuring the Intangible Fitness of Countries and Complexity of Products

Luciano Pietronero^{1,2,3}

Collaborators: G. Chiarotti^{1,2}, G. Cimini^{1,2}, M. Cristelli^{1,2}, R. Di Clemente^{1,2},
A. Gabrielli^{1,2,3}, E. Pugliese^{1,2}, F. Saracco^{1,2}, F. Sylos Labini^{1,4}, T. Squartini^{1,2},
A. Tacchella^{1,2}, A. Zaccaria^{1,2}

[1] Institute for Complex Systems, CNR, Rome, Italy; [2] "Sapienza" University of Rome, Italy

[3] London Institute for Mathematical Sciences, UK; [4] Centro Fermi, Rome

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



SAPIENZA
UNIVERSITÀ DI ROMA



2014 African Transformation Report

Growth with Depth

Amman conference, June 2014

Stiglitz's Task Force on Industrialization:

Yau Ansu:

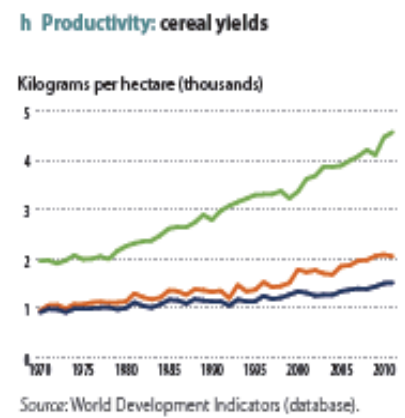
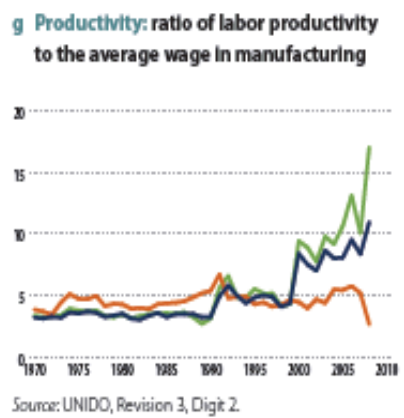
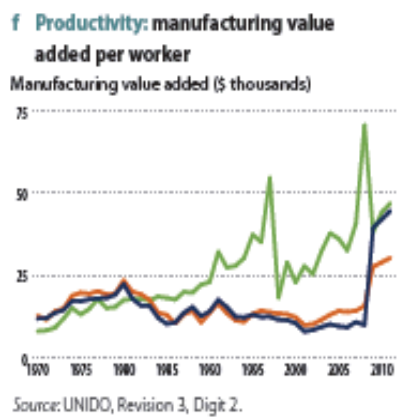
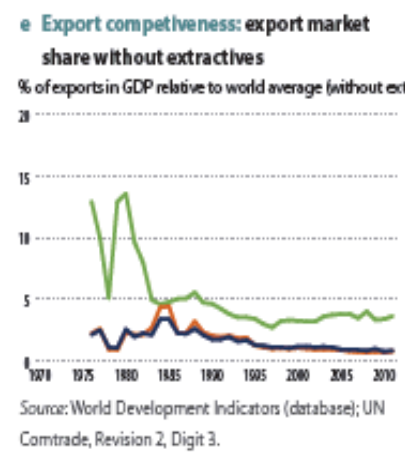
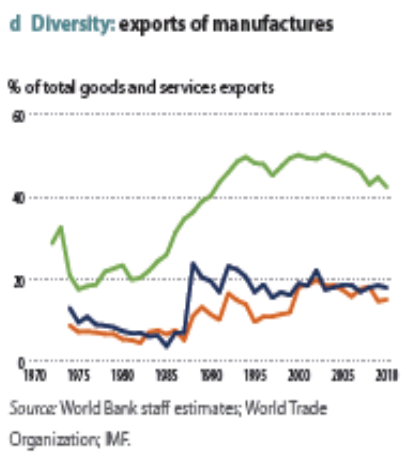
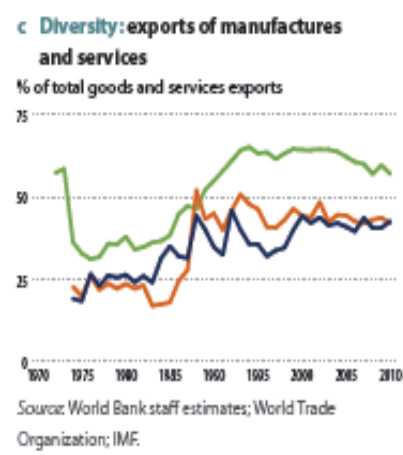
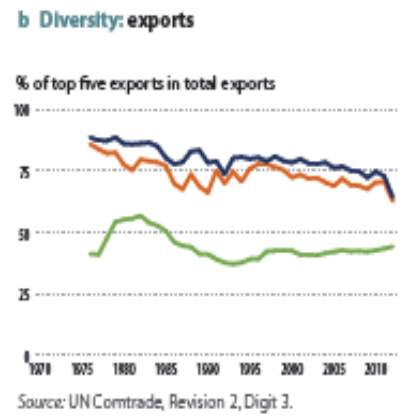
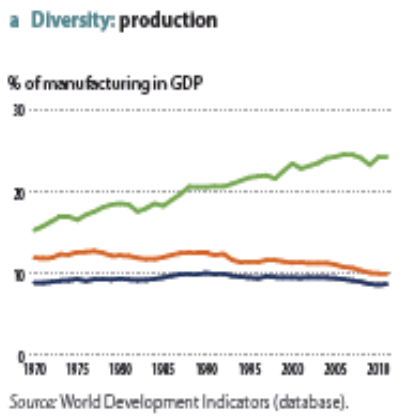
ACET Report (221pages)

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

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



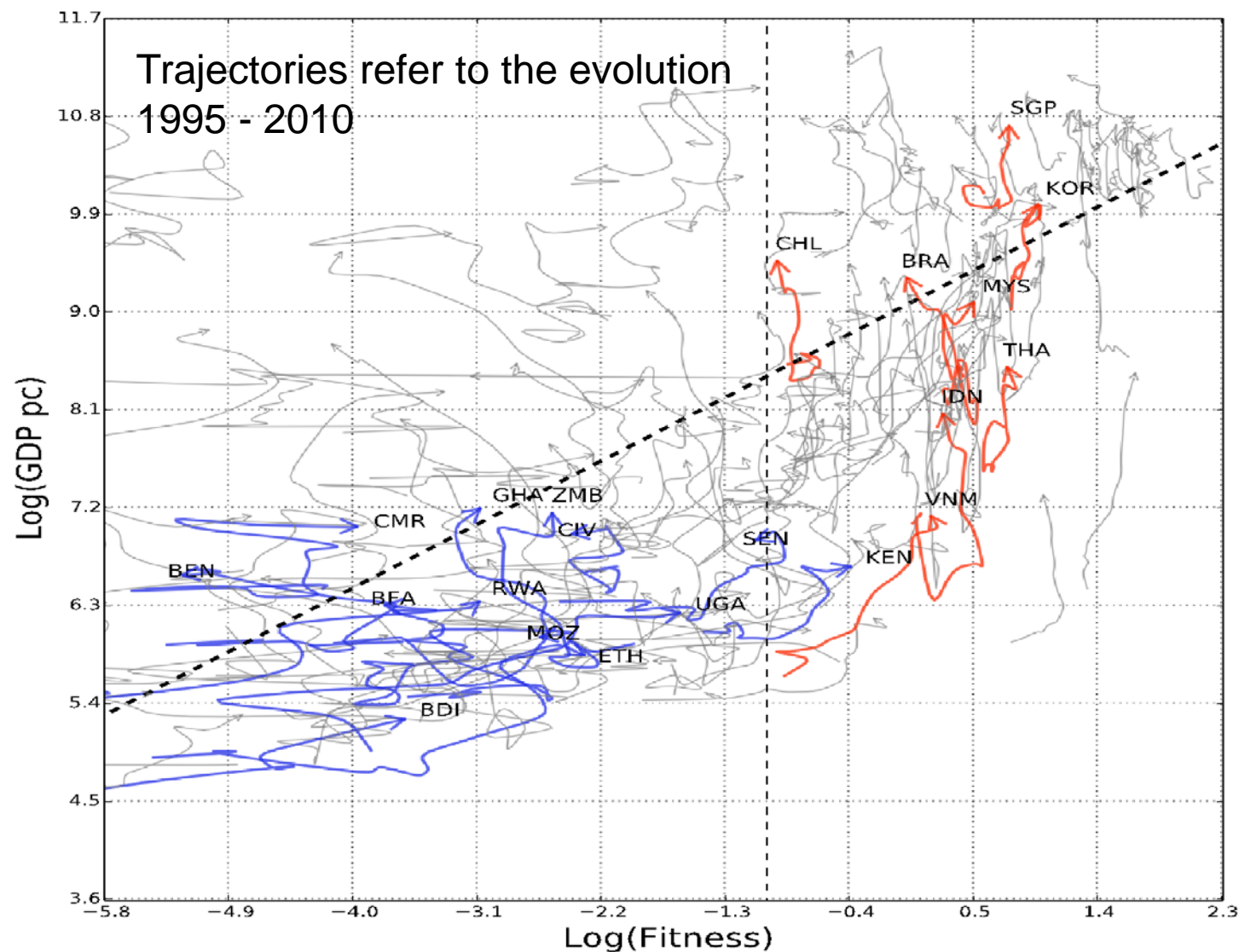
More and more data but difficult to draw a clear conclusion ???

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

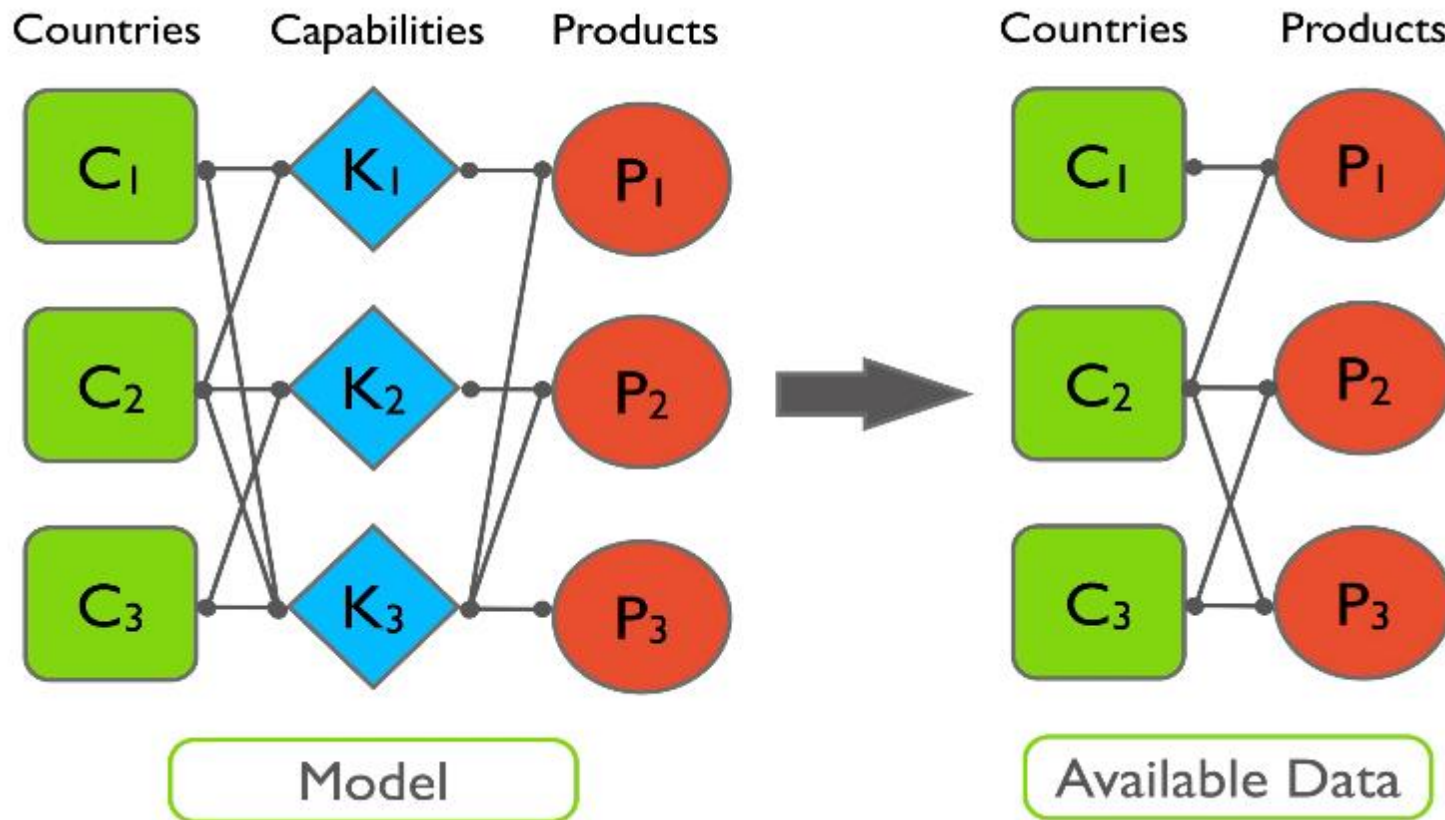
Clear interpretation - Complete information - Visual impact



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?

COMTRADE database:
Which country exports
which product

Bipartite Network:

New algorithm to

extract information for

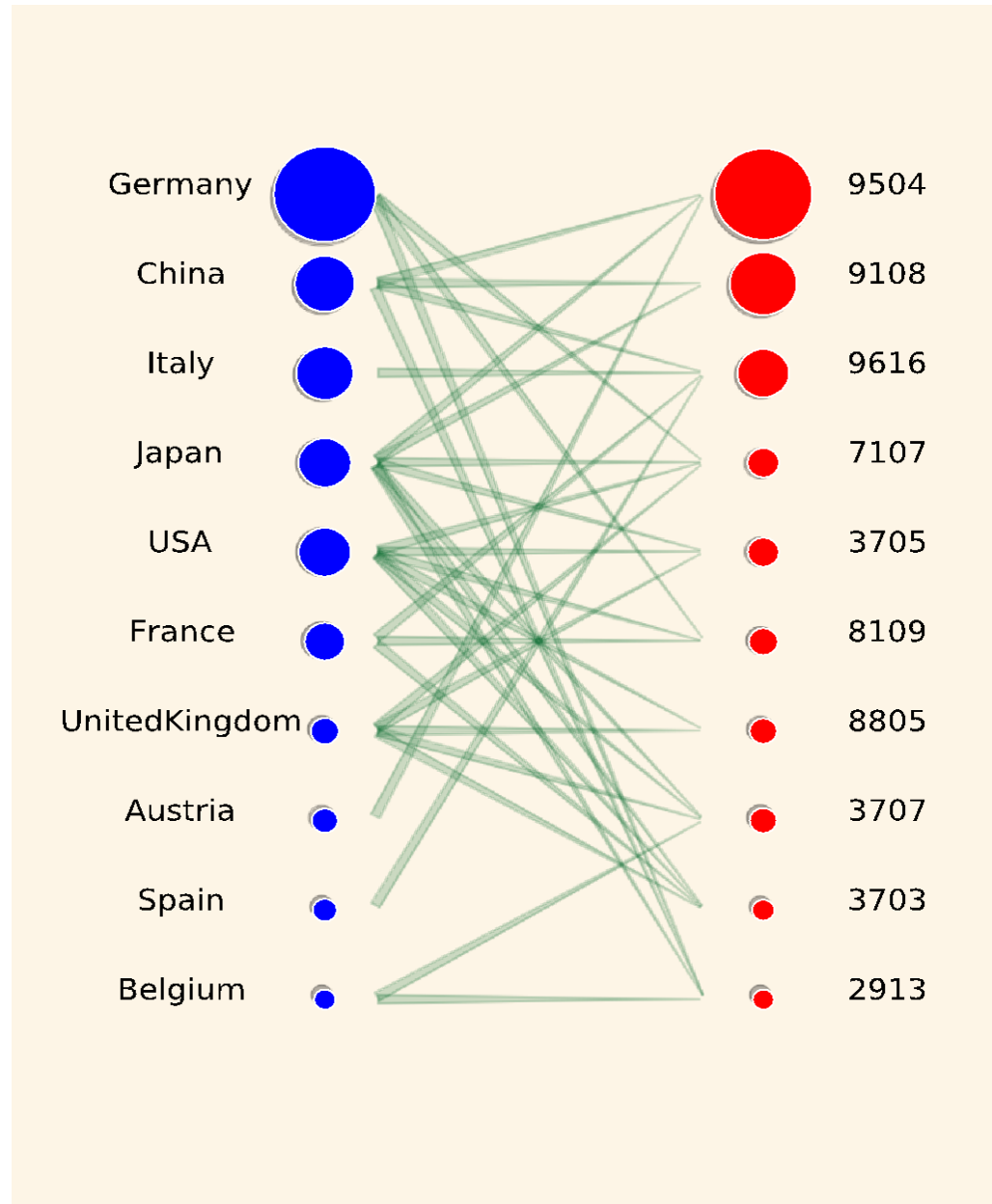
- Fitness of Countries
- Complexity of Products

NB: this is not an analysis
of the export volumes.

The information is derived
from the nature of products

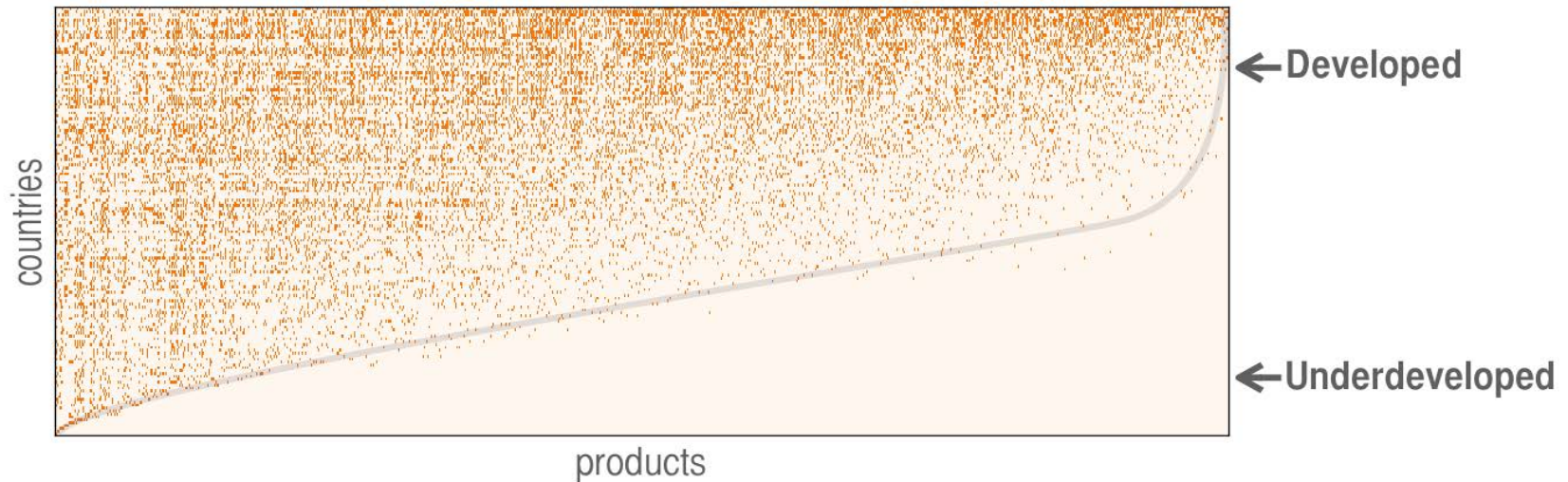
Countries

Products



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

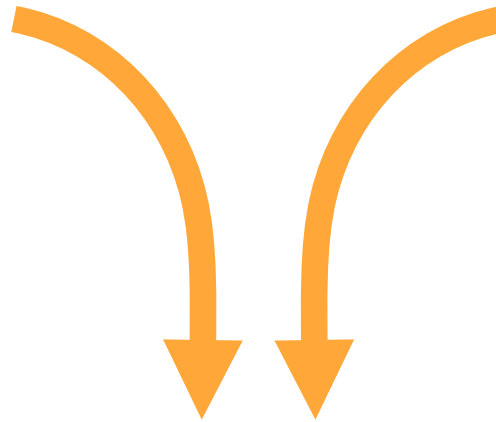
- Math. Problem: minimal elements to have a triangular matrix
Complex Hierarchical structure, nestedness etc.
- For sectors and companies the situation evolves towards specialization

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

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

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

F_c : diversification weighted by complexity

Complexity

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

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

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

F_c : diversification weighted by complexity



Platinum
0.0032



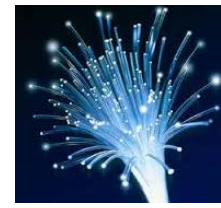
Nails
0.0099



Wheat
0.12



Chips
1.81



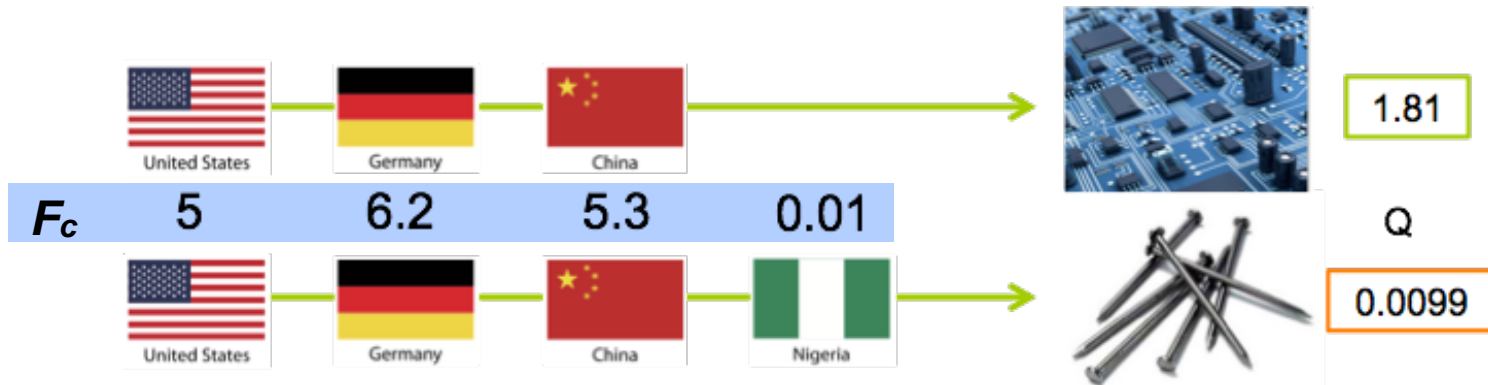
Optic Fibers
4.39



United States

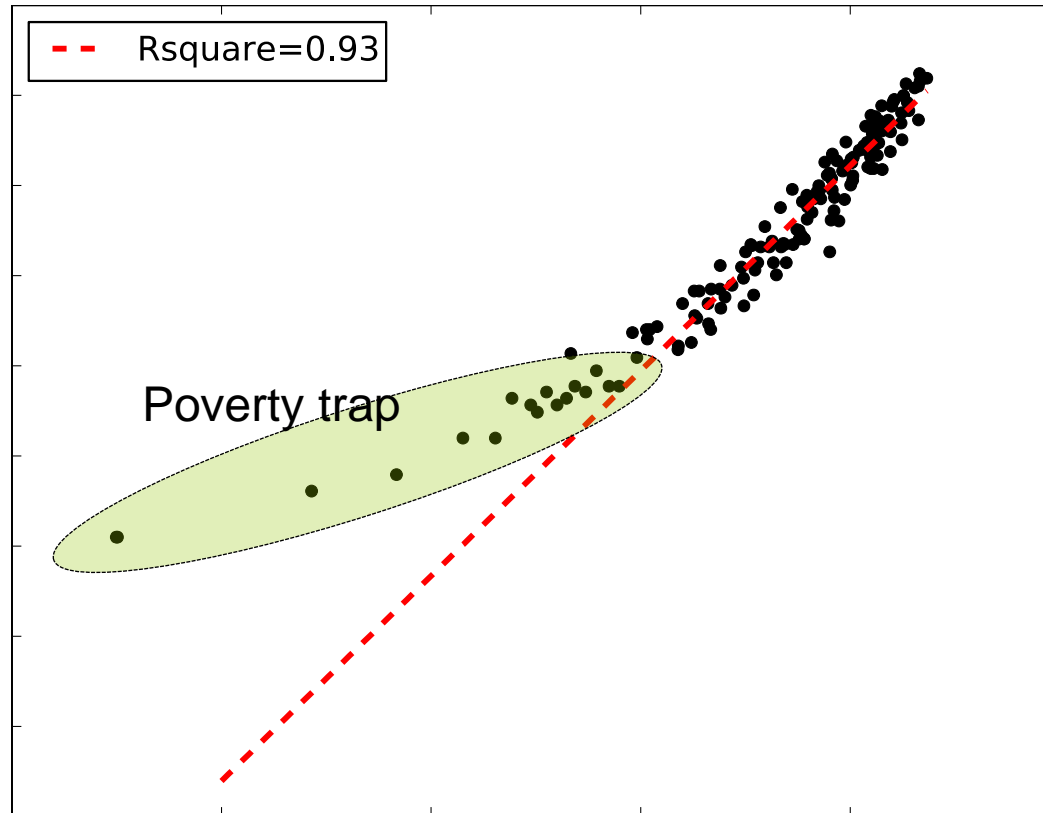
F_c
6.3331

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

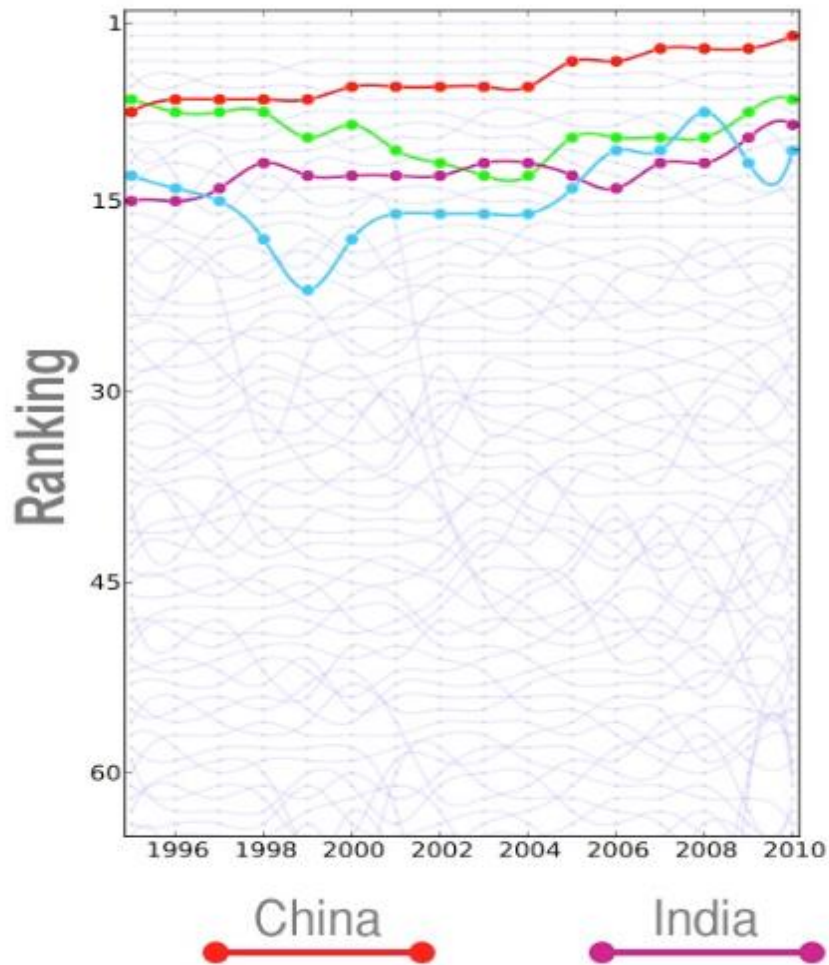


MICRO ORIGIN OF POVERTY TRAP?

No longer exponential relationship btw
diversification and *complexity* (i.e. $\text{Log}(\text{Fitness})$)

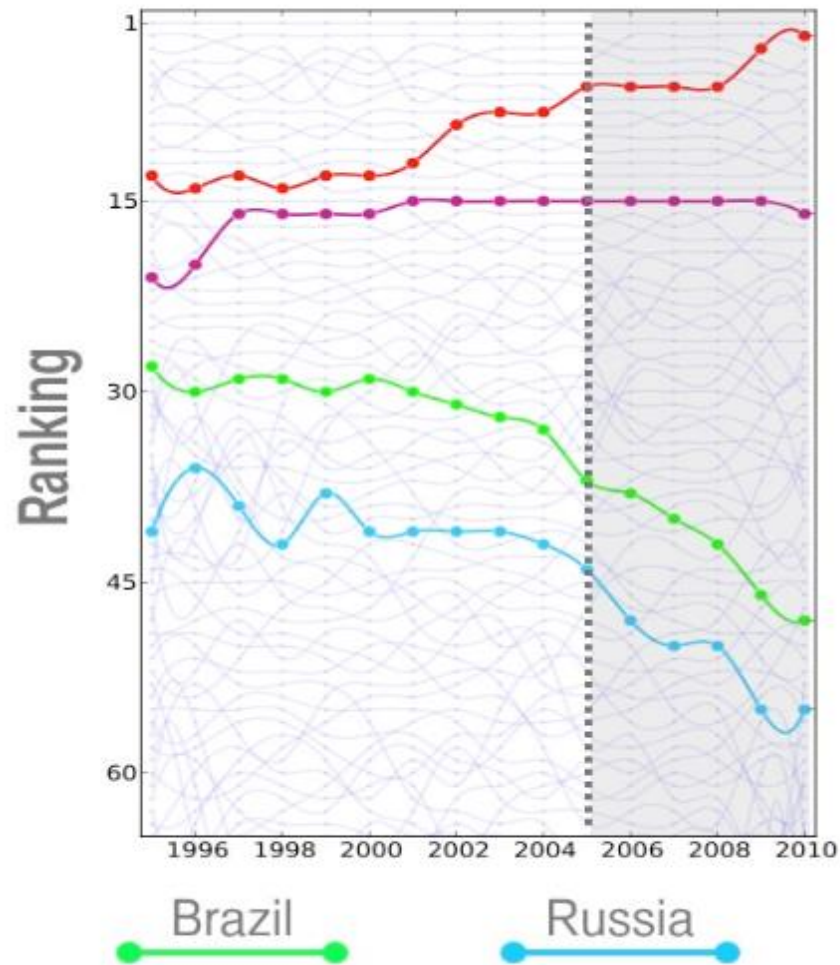


GDP



Goldman Sachs 2001
BRIC countries will dominate the
World economy for the next 50 years

Fitness



Bloomberg News November 2015
Goldman's BRIC Era Ends as
Fund Folds After Years of Losses

The Economic Dynamical Ecosystem:

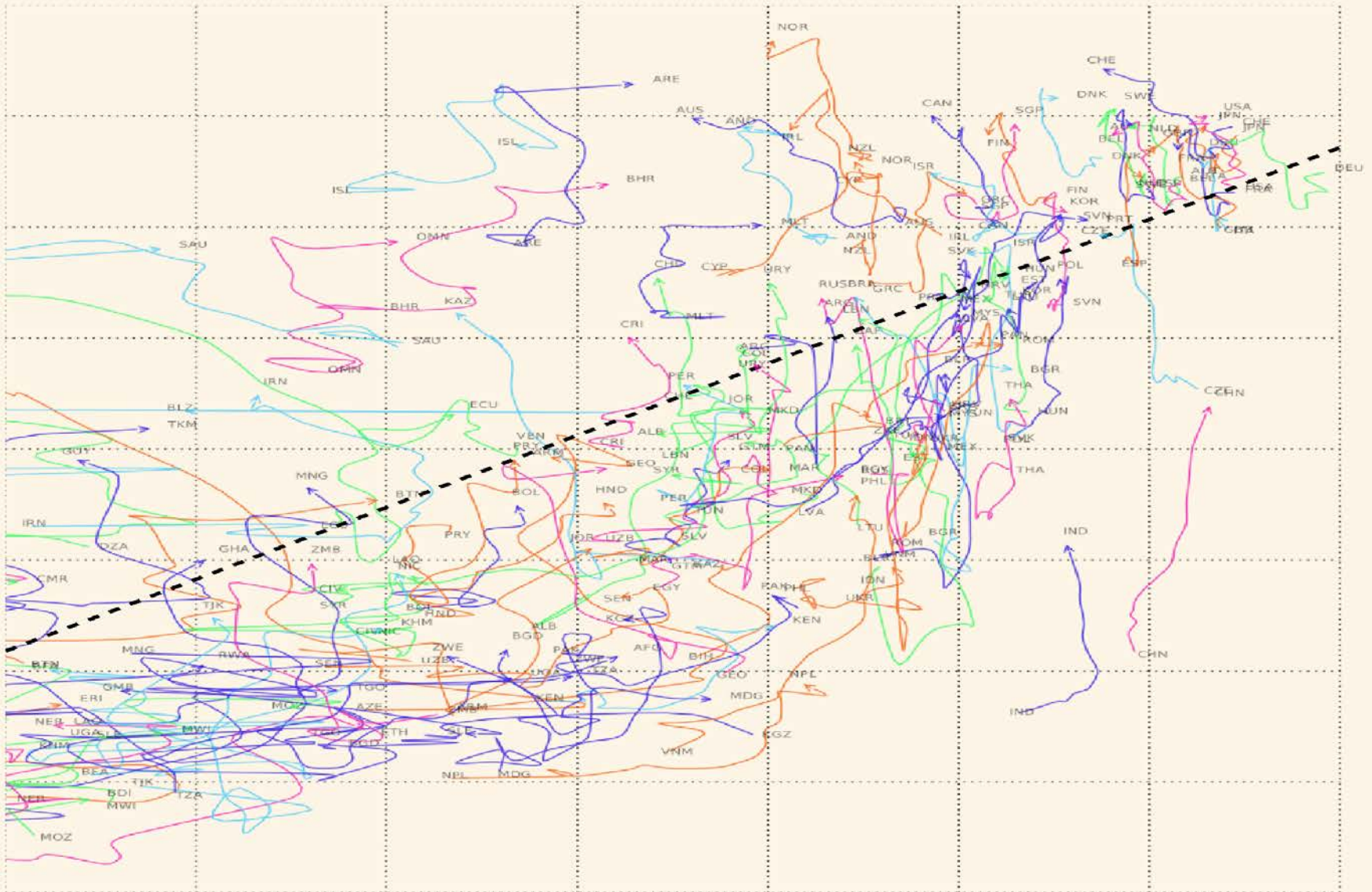
- Countries: diversified in products
Countries and Products: Google like approach – Big Data
Countries: Fitness index
Products: Complexity index
Dynamics: Monetary vs Intangible metrics – Hidden potential
- Subsystems: Regions, Districts, Cities (London, Shanghai)

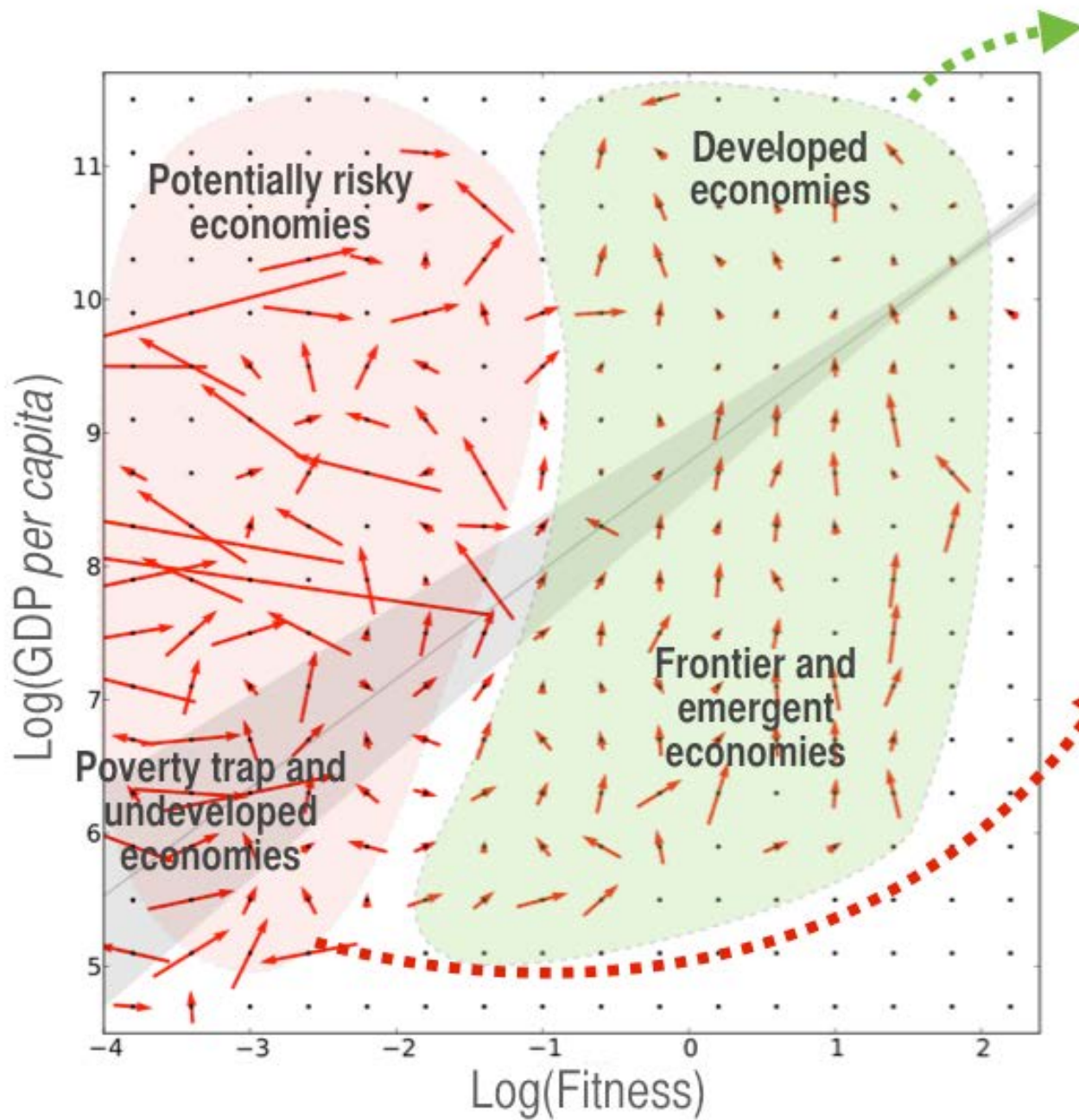
NEW: Regional Analysis of China

NEW: Fitness analysis of small, beautiful shops

-
- Companies: specialized in products (Strategic evolution of EC)
But diversified in terms of Technologies in their control
(ie patents), Trade Network etc.

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

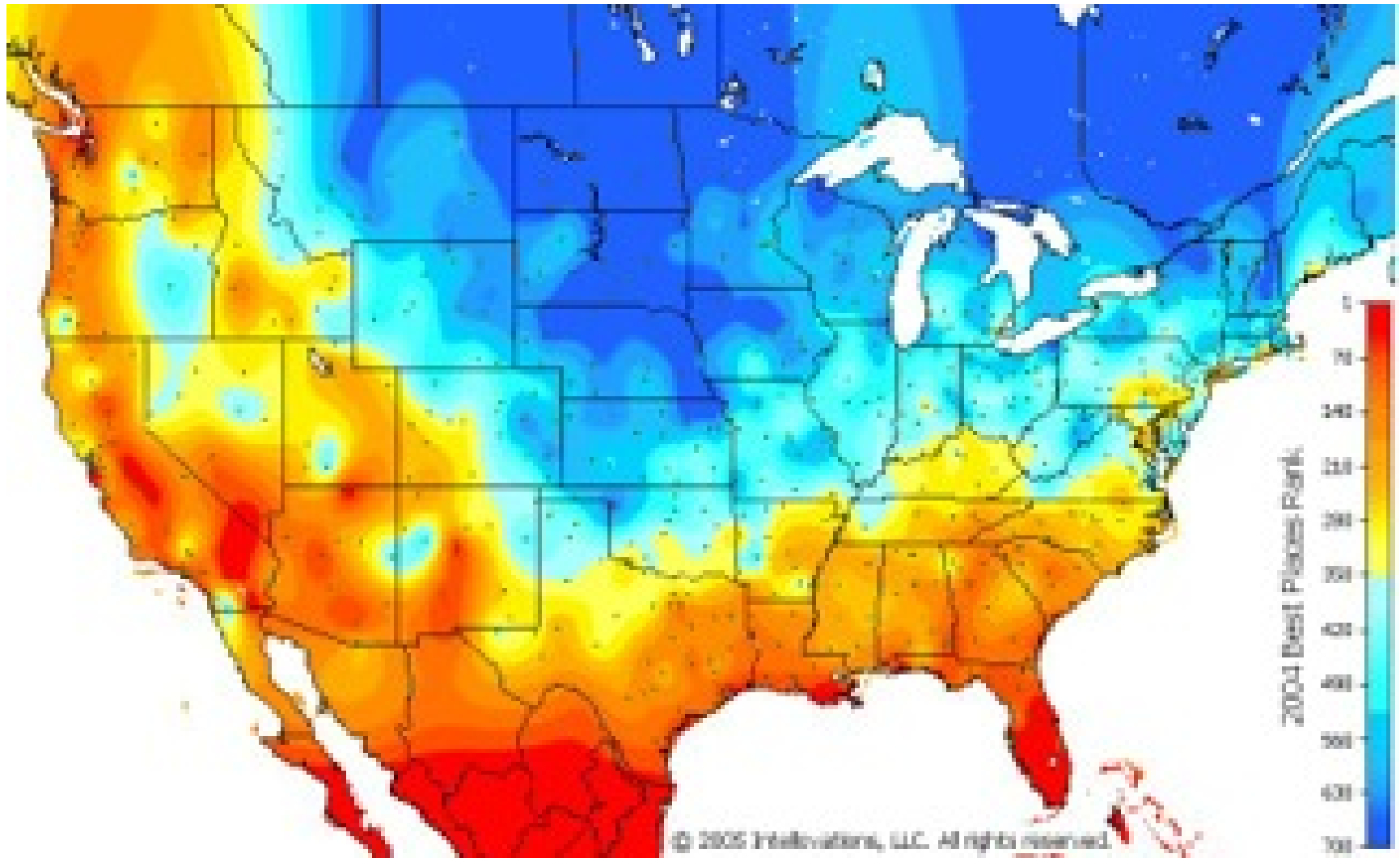


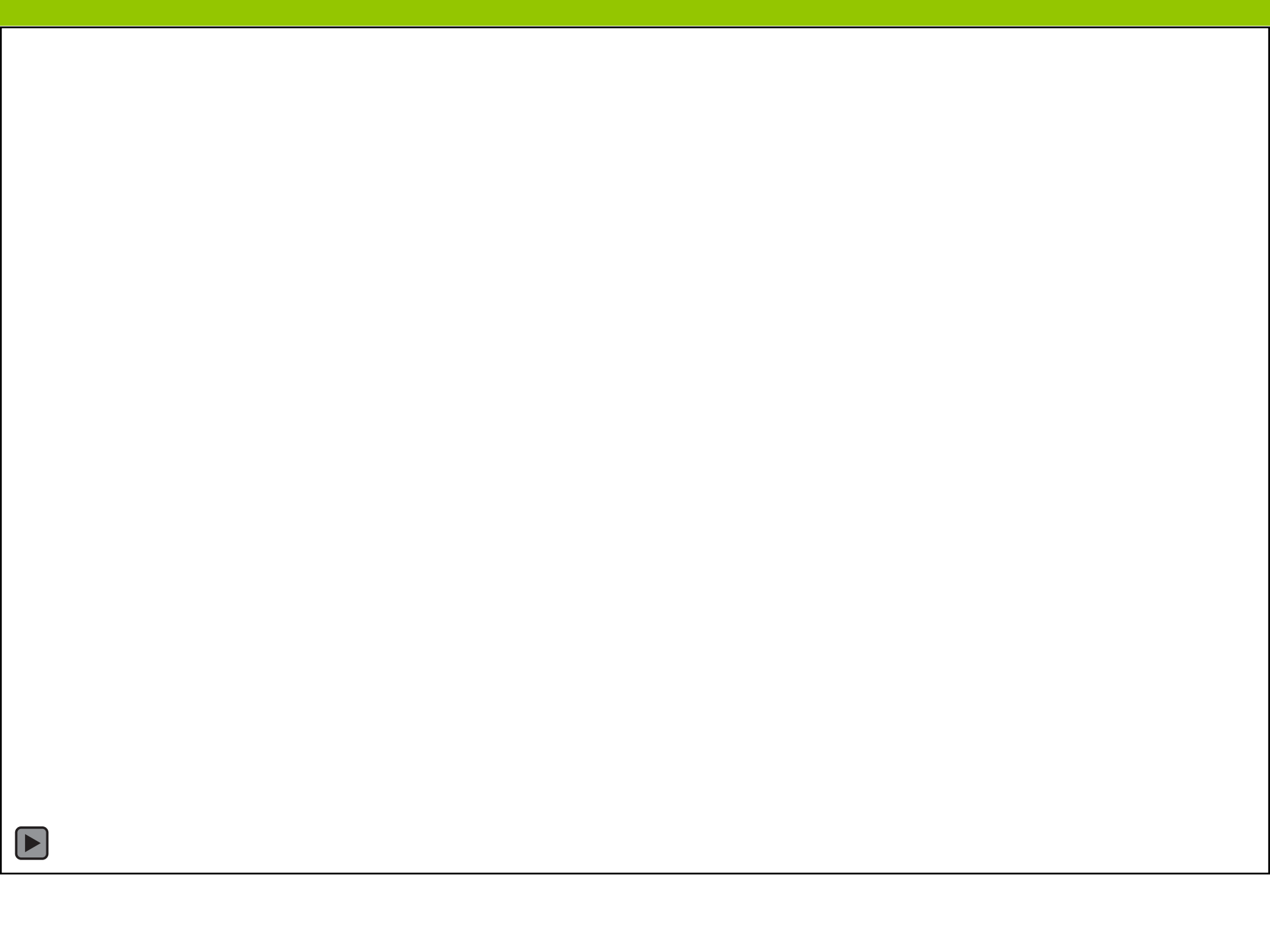
low predictability

Heterogeneous Weather Forecasting:

RED: High predictability

BLUE: Low predictability







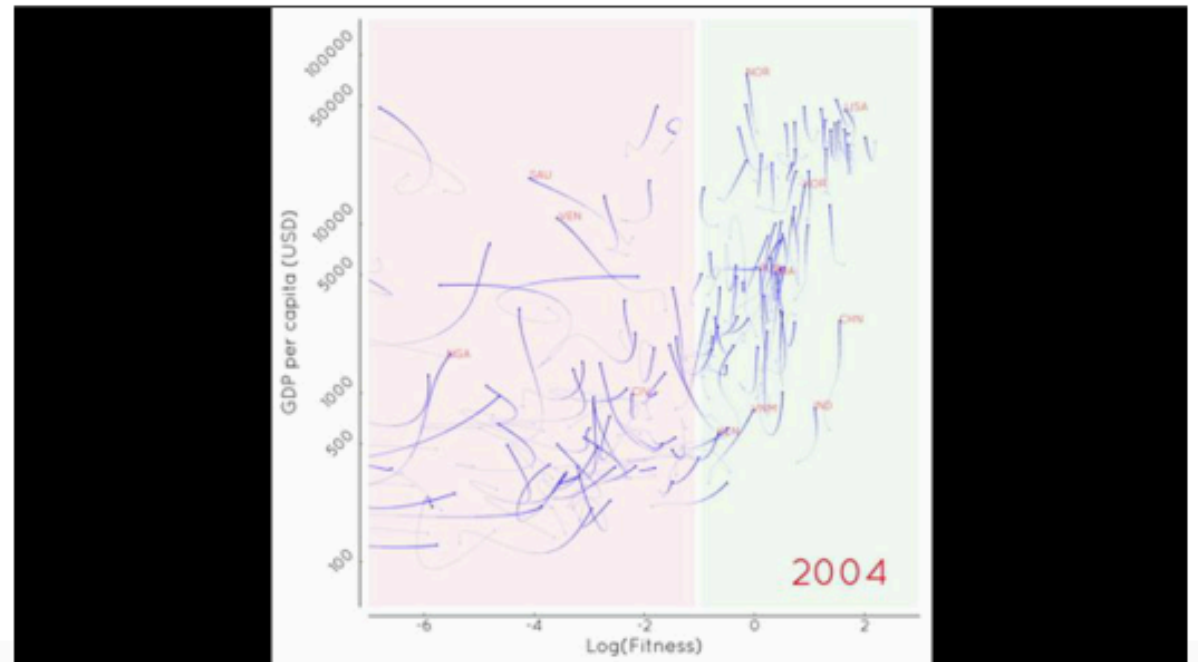
Physicists make 'weather forecasts' for economies

The development of some countries is as predictable as steady winds, but for others it is more chaotic, physicists find.

Richard Van Noorden

23 February 2015

Rights & Permissions



NEW:

M. Cristelli, A. Tacchella, L. Pietronero

*THE HETEROGENEOUS
DYNAMICS OF ECONOMIC
COMPLEXITY*

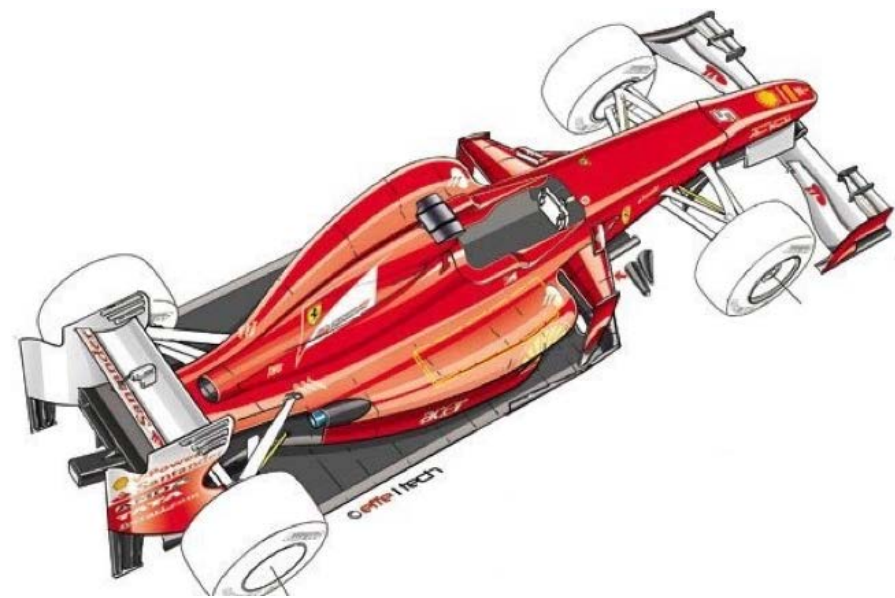
PLoS ONE 10(2): e0117174.
doi:10.1371/journal.pone.0117174
(2015)

ECONOMIC PREDICTIONS!!!

**IL DEBITO PUBBLICO...
SCENDERA' ... lo scrive l'Unione Europea**

www.ilnord.it - quello che gli altri non scrivono

Fitness of a country



PERFORMANCE



**FITNESS
of a
COUNTRY**

Engine Power (HP)
Scientific measure
Of th productive potential

MANAGING

- Driver
- Gasoline
- Oil
- Tyres
- ...



- Politics
- Finance
- Monetary policy
- Investments
- ...

The Fitness is a scientific measure, quantitative and systematic of the intrinsic power of an industrial economy. The political and financial variables are exogenous to this measure.

David Pilling Financial Times Nov. 19 2014

“What goes up must eventually come down – even China”

Regression to mean could spell trouble for Asian powerhouses.

What would China look like if it were growing at just 2 per cent a year?

(NB: China has been growing up to 10% a year and now it is 7-8%).

According to an influential paper by US economists Lant Pritchett and Lawrence Summers. For them, “the single most robust and striking fact” about growth is “**regression to the mean**” of about 2 per cent.

Only rarely in modern history, they say, have countries grown at “super-rapid” rates above 6 per cent for much more than a decade. China has managed to buck the trend since 1977 by harnessing market forces, engineering possibly the longest spell “in the history of mankind”. But what goes up, the authors tell us, Must eventually come down.

Mark Buchannan Bloomberg's View March 1, 2015

“China Might Still be Booming”

Where will China and India be in a decade, economically speaking? Judging from the abnormal speed at which they have grown in recent decades, most forecasters think they are due for a slowdown -- and, **in the case of China, possibly even a crash.**

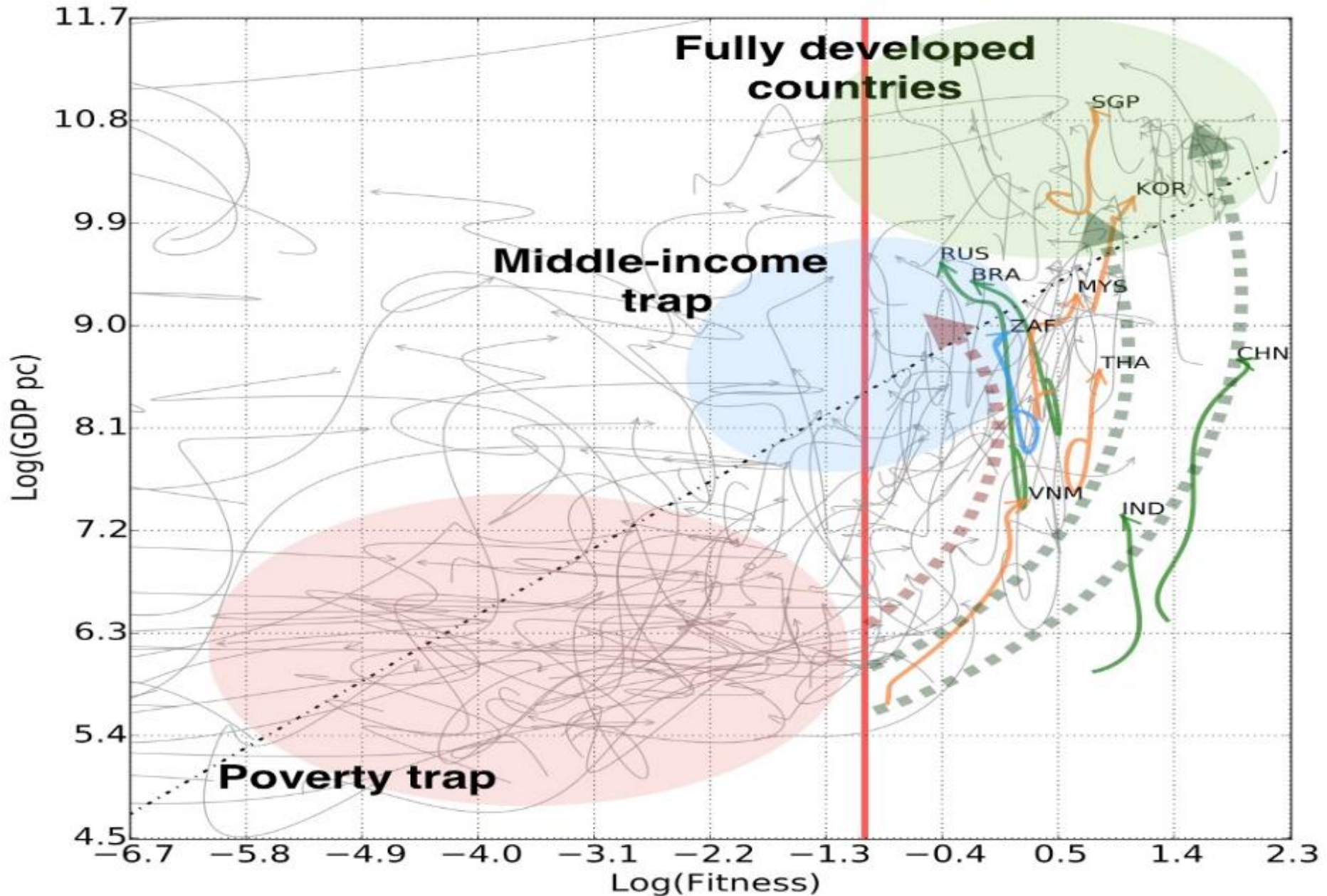
As Lant Pritchett and Lawrence Summers have **demonstrated**, ... history shows that periods of fast growth generally portend reversals back to the world average.

Recently, however, researchers have been developing new ways to forecast economic performance. A group of researchers at Rome Sapienza, using methods drawn from the analysis of dynamical systems and adding the new concept of Fitness, reach different conclusions. **The physicists' insight could have big implications for China and India.**

To be sure, the new research is highly unconventional, and provides only a taste of what we might be able to learn by tapping big data and going beyond the simple statistical analysis techniques that economists commonly use.

That said, by wading into the messy details of actual economic activity, it does offer a promising way to forecast growth -- **and grounds for much more optimism** about the future of the developing world.

NEW: DEBATE ABOUT CHINA PERSPECTIVES



South Korea Evolution

Some examples of different regimes...

1963 - 2000

- Starting from low values to arrive to high values of GDP per capita;
 - First period of increasing fitness, at GDP almost constant;
 - Subsequently rapid growth in GDP per capita w/ slow increasing Fitness;
- => Exit from the poverty trap

South

RELATION TO PICKETTY ANALYSIS

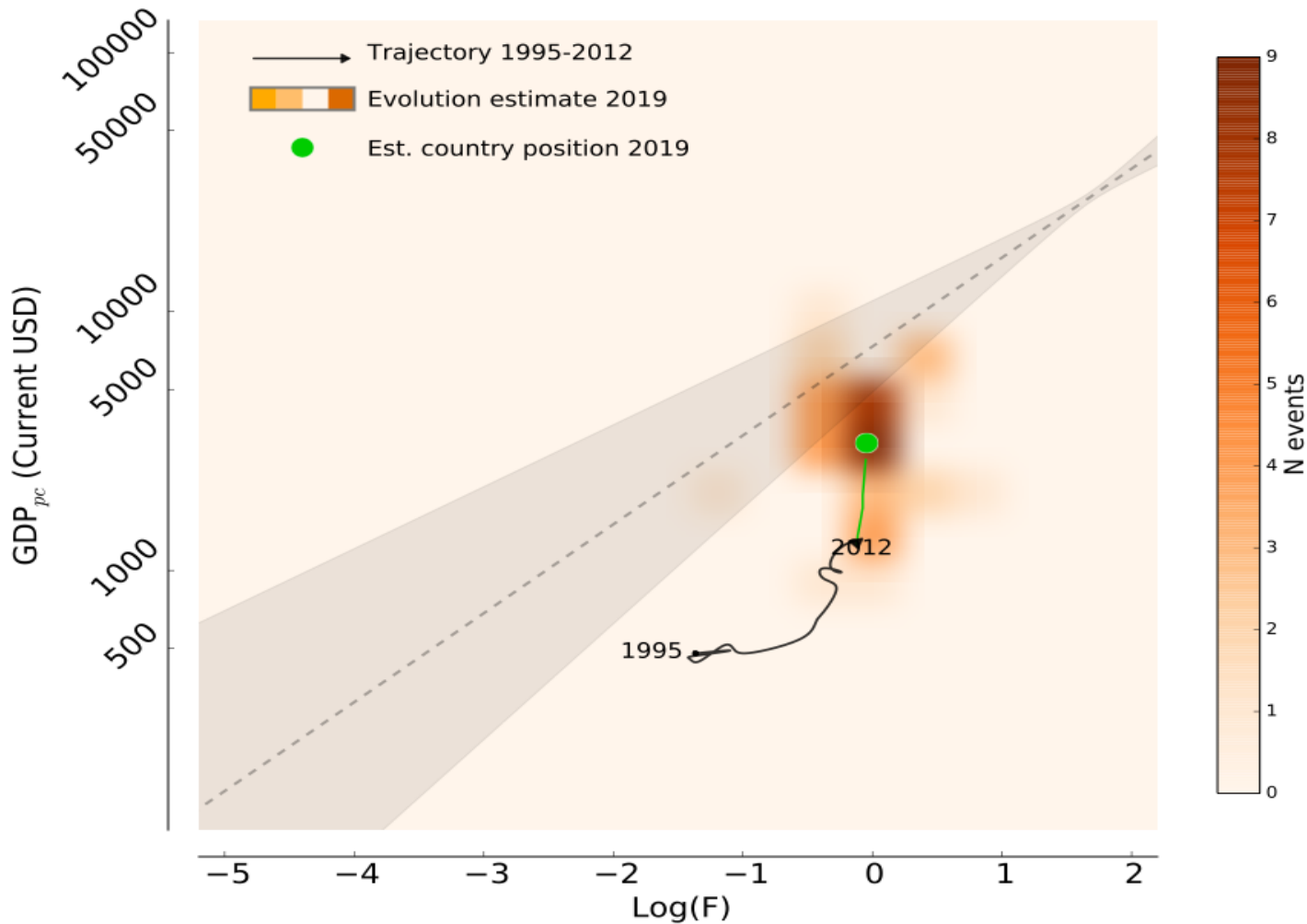
NEW: AZIMUT INVESTMENT FUND

Country 1

Fitness 0.887 (2012)

Predictability 0.659

GDP_{pc} 1255 Current USD (2012)

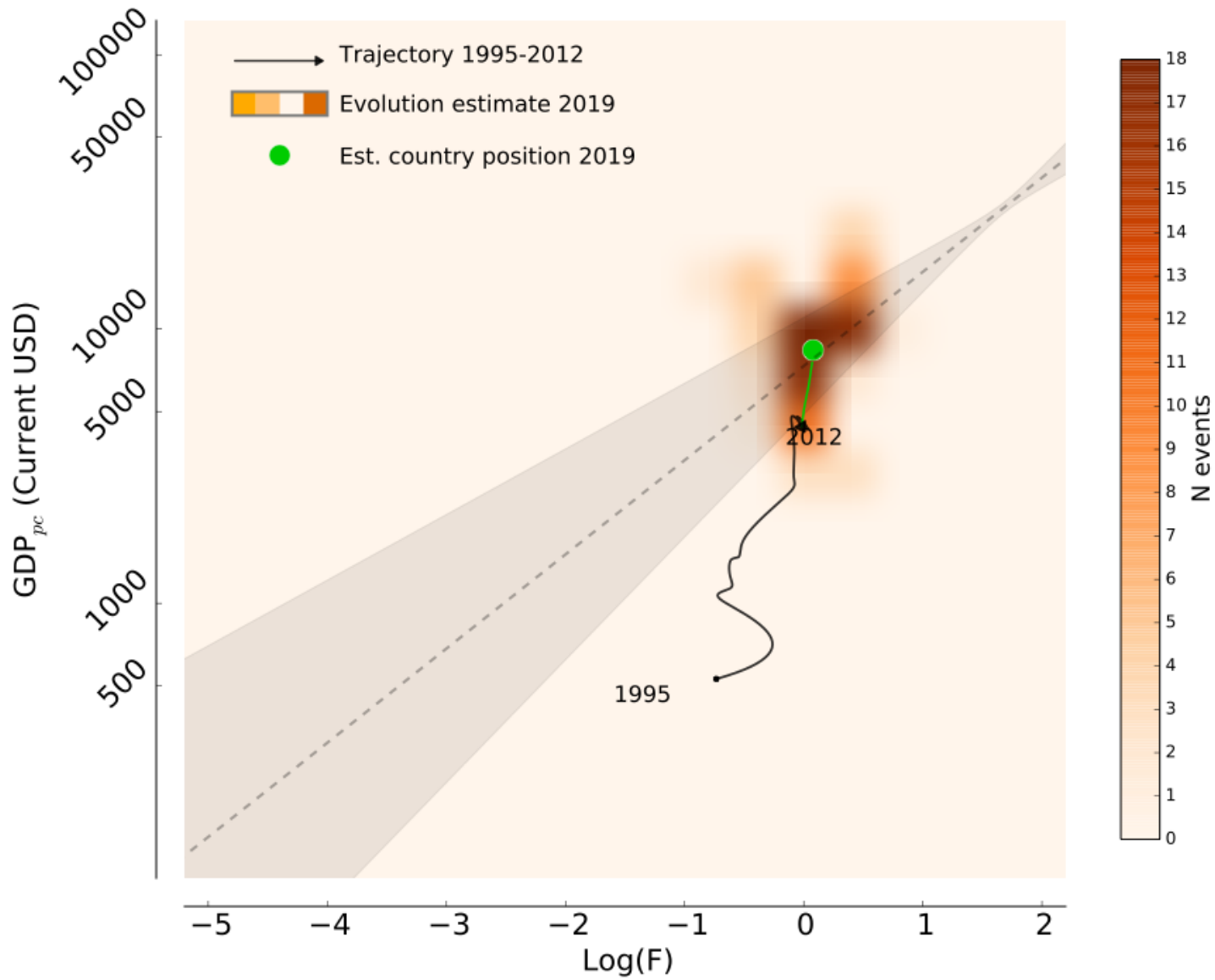


Country 6

Fitness 0.982 (2012)

Predictability 0.827

GDP_{pc} 4396 Current USD (2012)

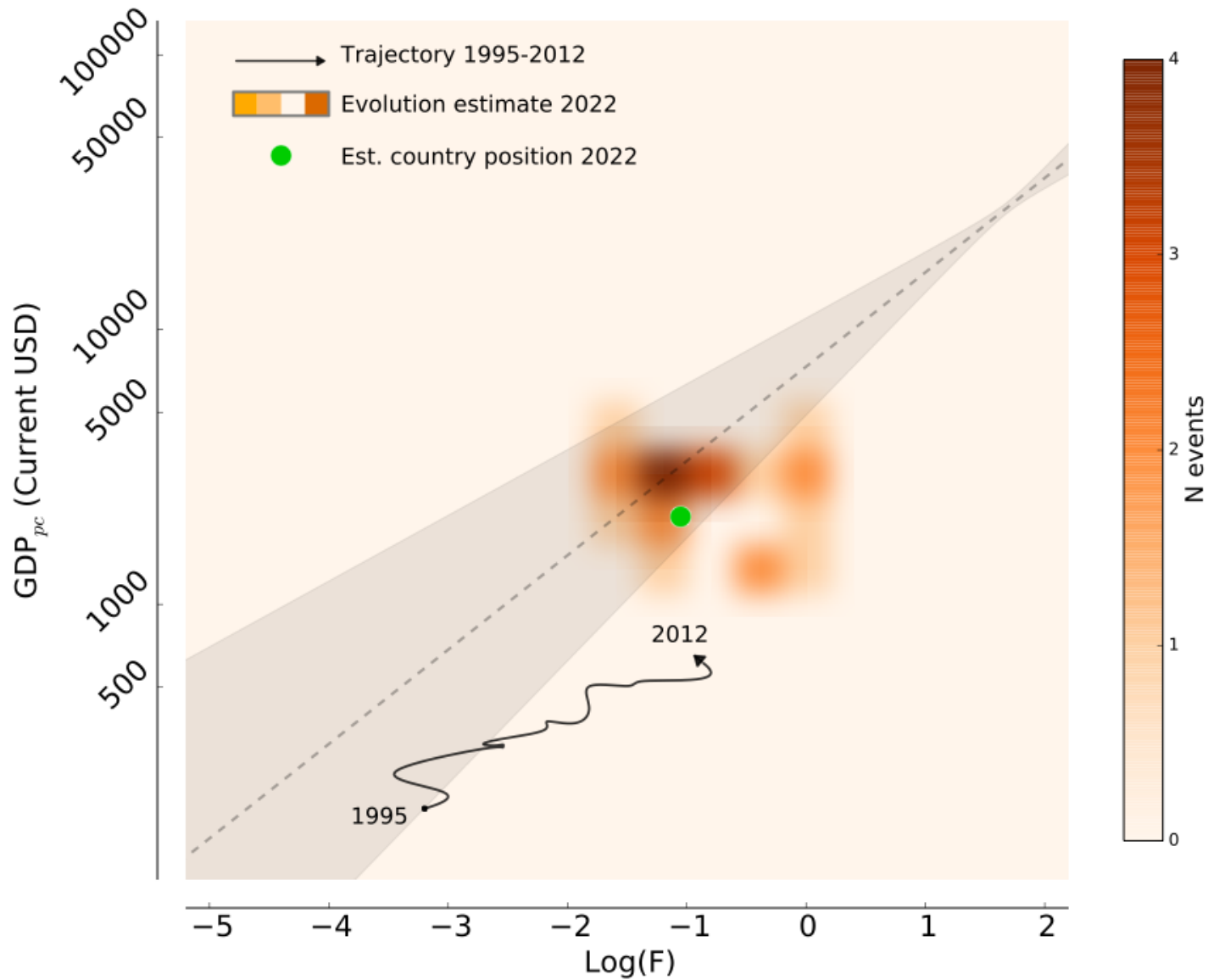


Country Tanzania

Predictability 0.457

Fitness 0.424 (2012)

GDP_{pc} 609 Current USD (2012)

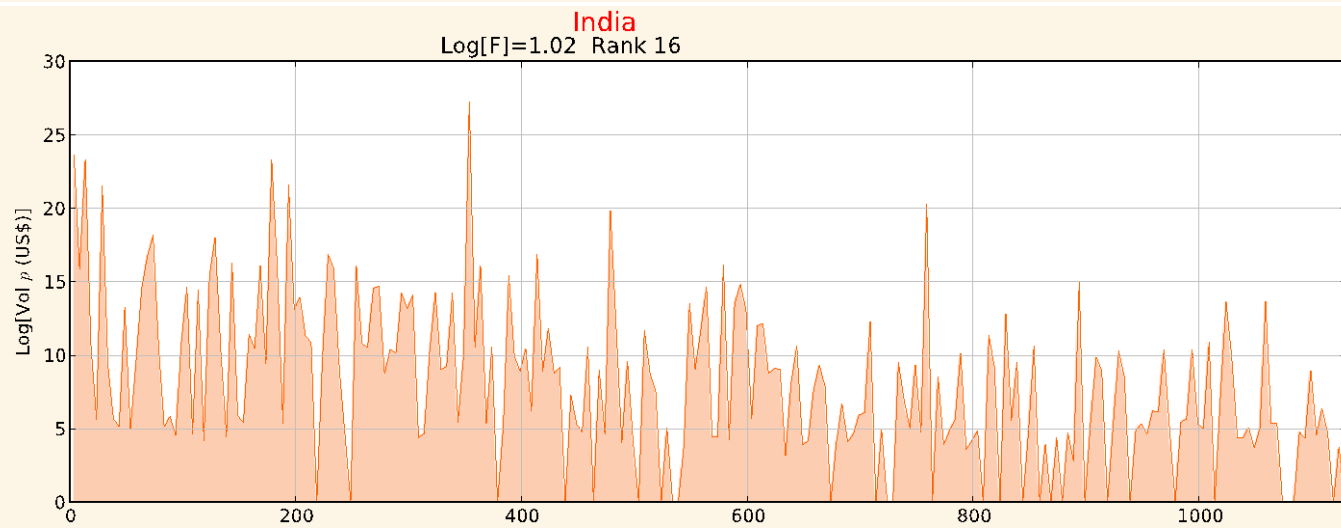
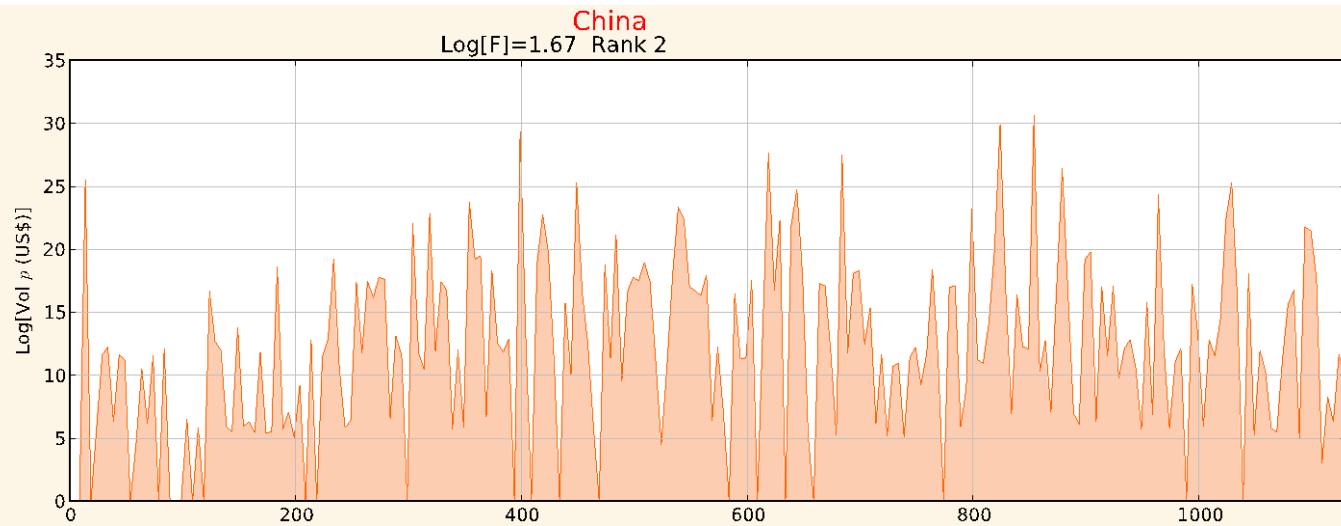


COUNTRY SPECTROSCOPY

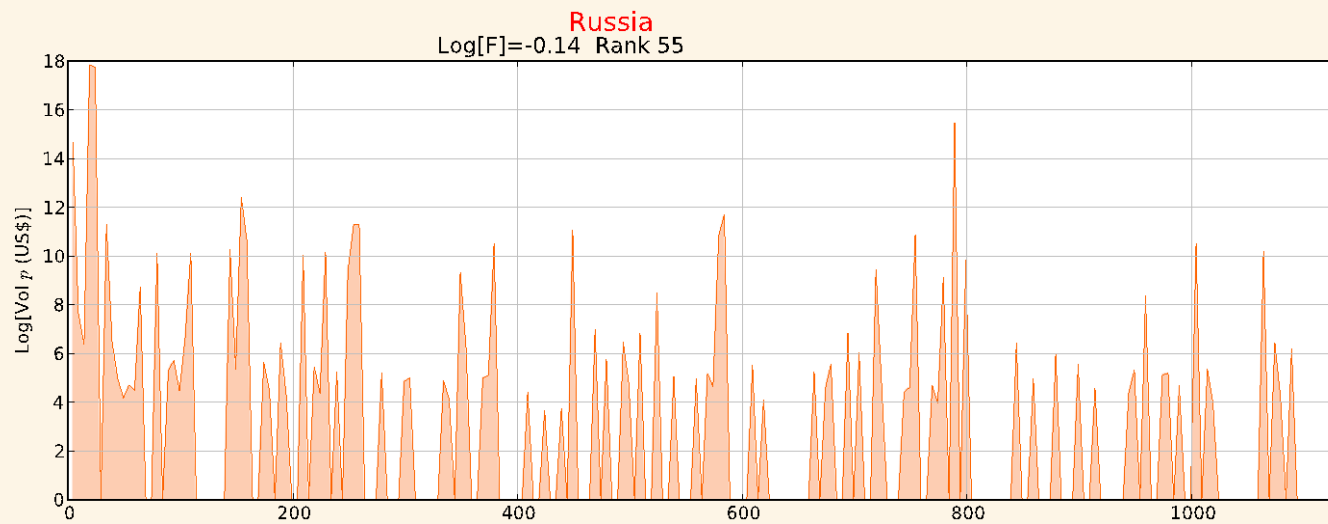
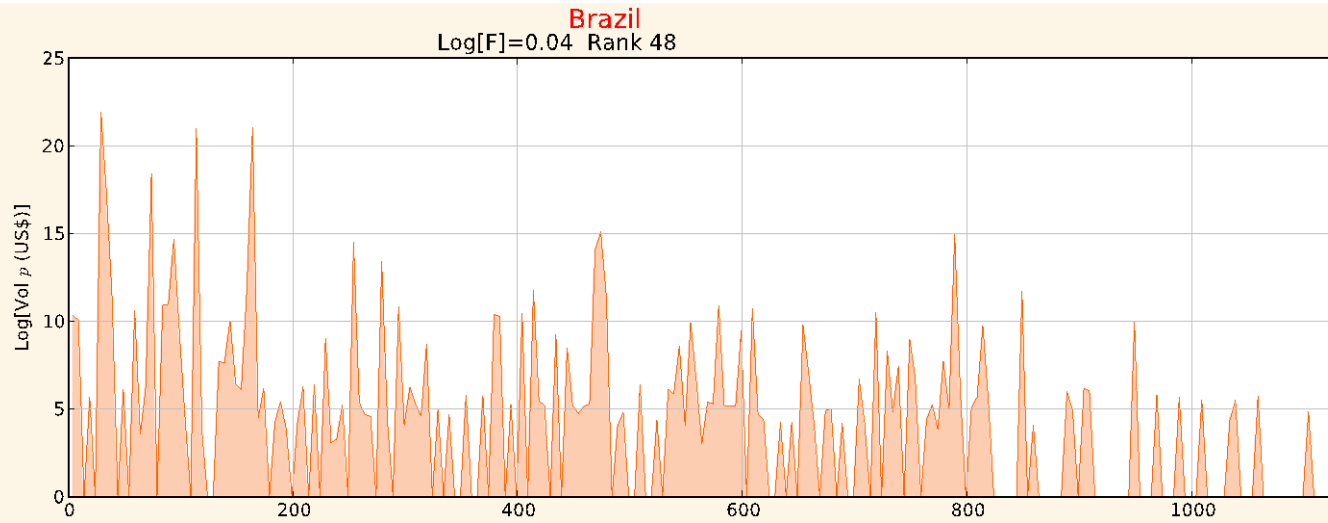
- Products appear clustered in Quality Space
- The revanche of specialization – Industrial sectors and individual companies tend to be reasonably specialized



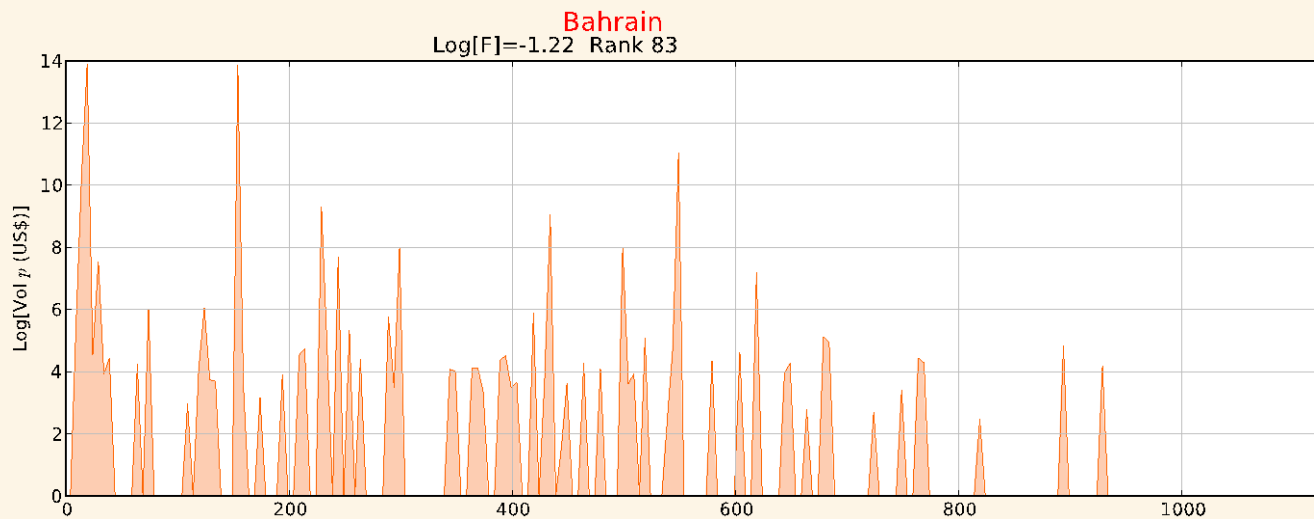
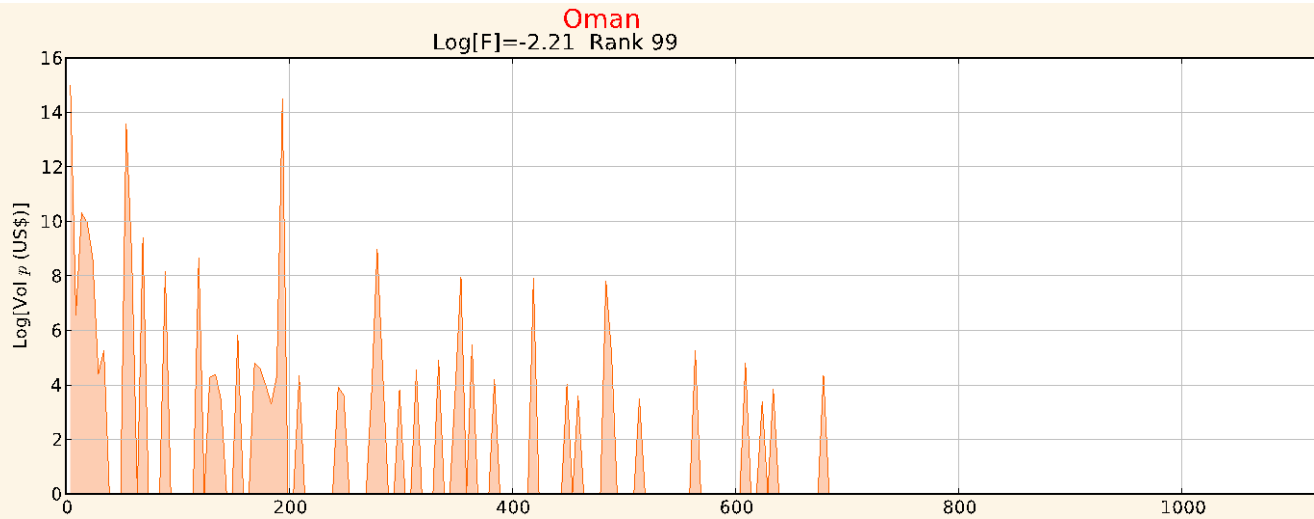
COUNTRY SPECTROSCOPY



COUNTRY SPECTROSCOPY



COUNTRY SPECTROSCOPY





Contraction: P-P network

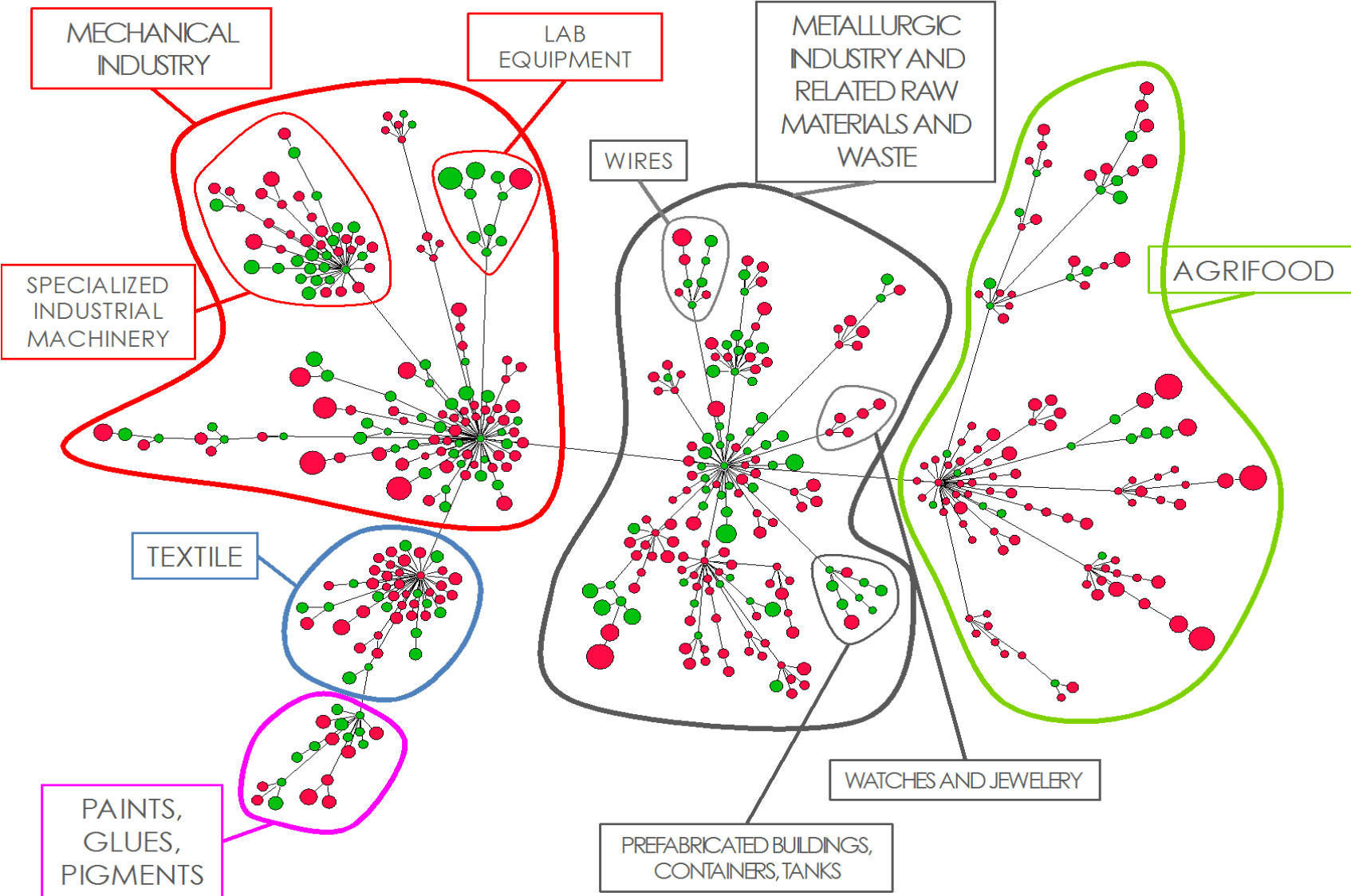


Filtering Procedure: selecting “dependency”
links



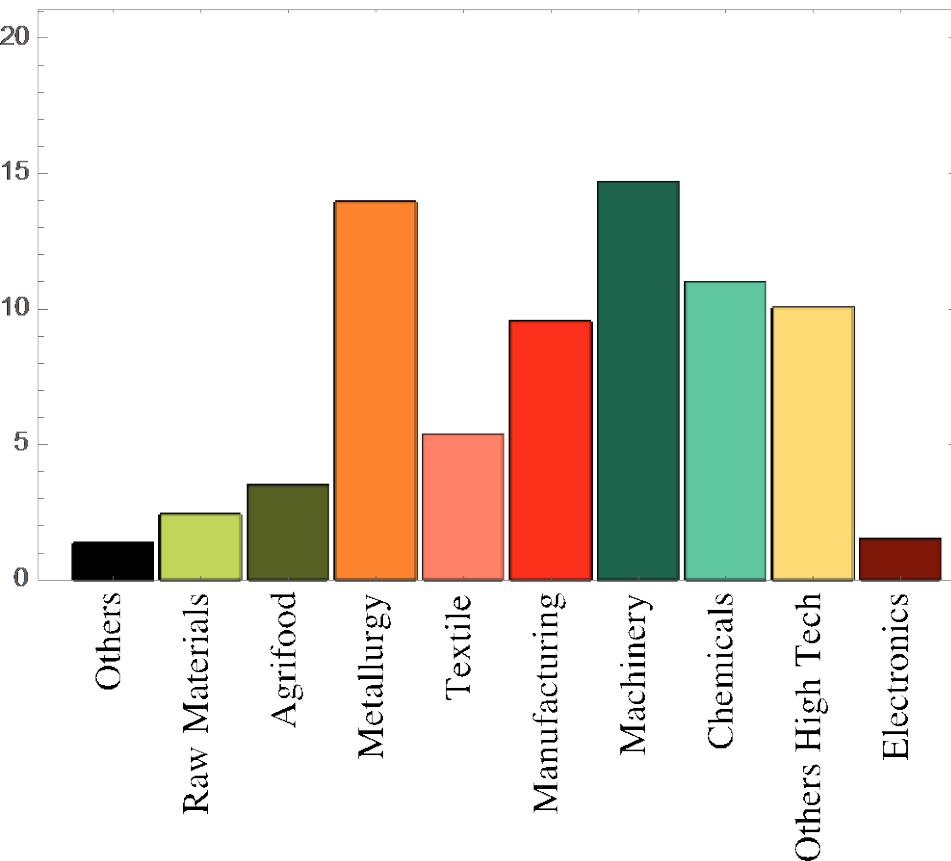
The “Product Space”

SWEDEN: PORTION OF THE PRODUCT SPACE

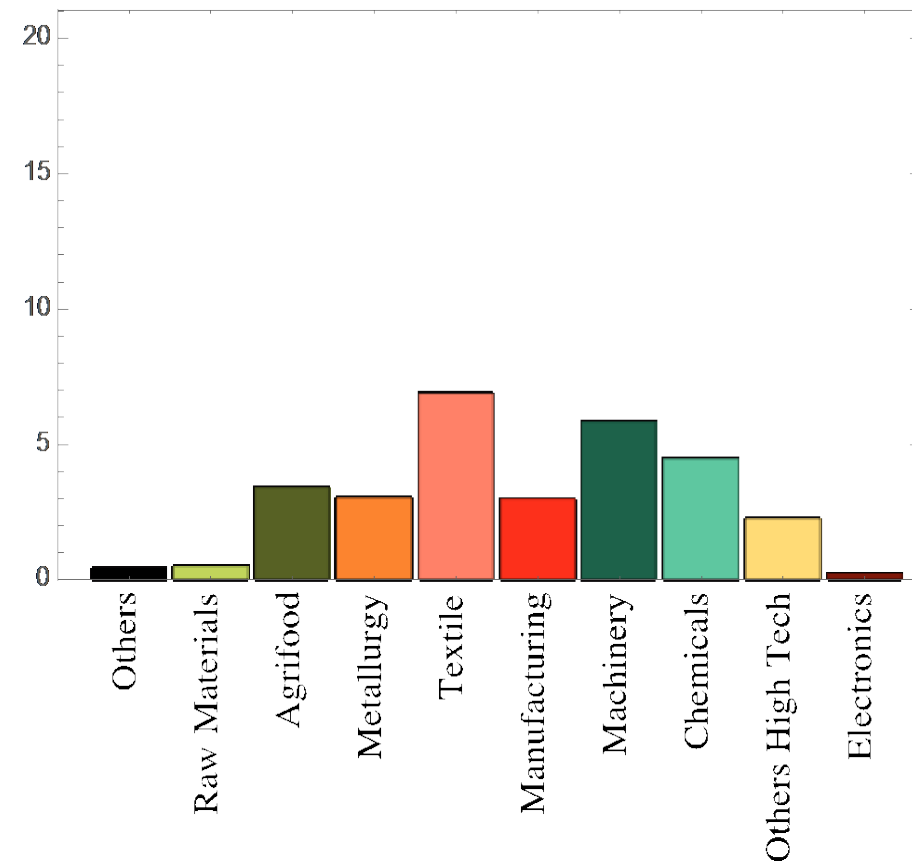


NEW: Forecasting of the new products (sectors) which have a high probability to appear in the near future

China



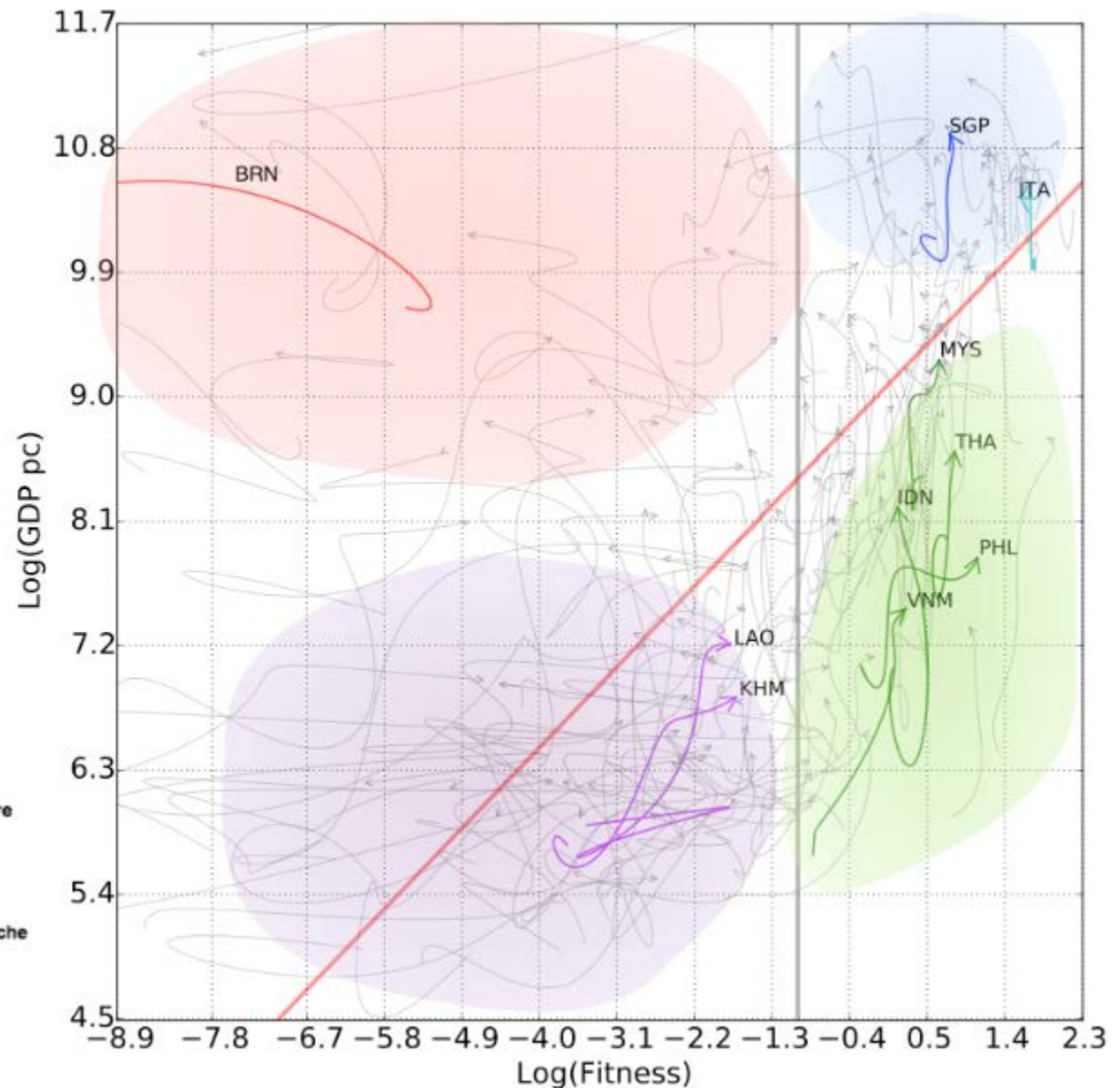
Brazil



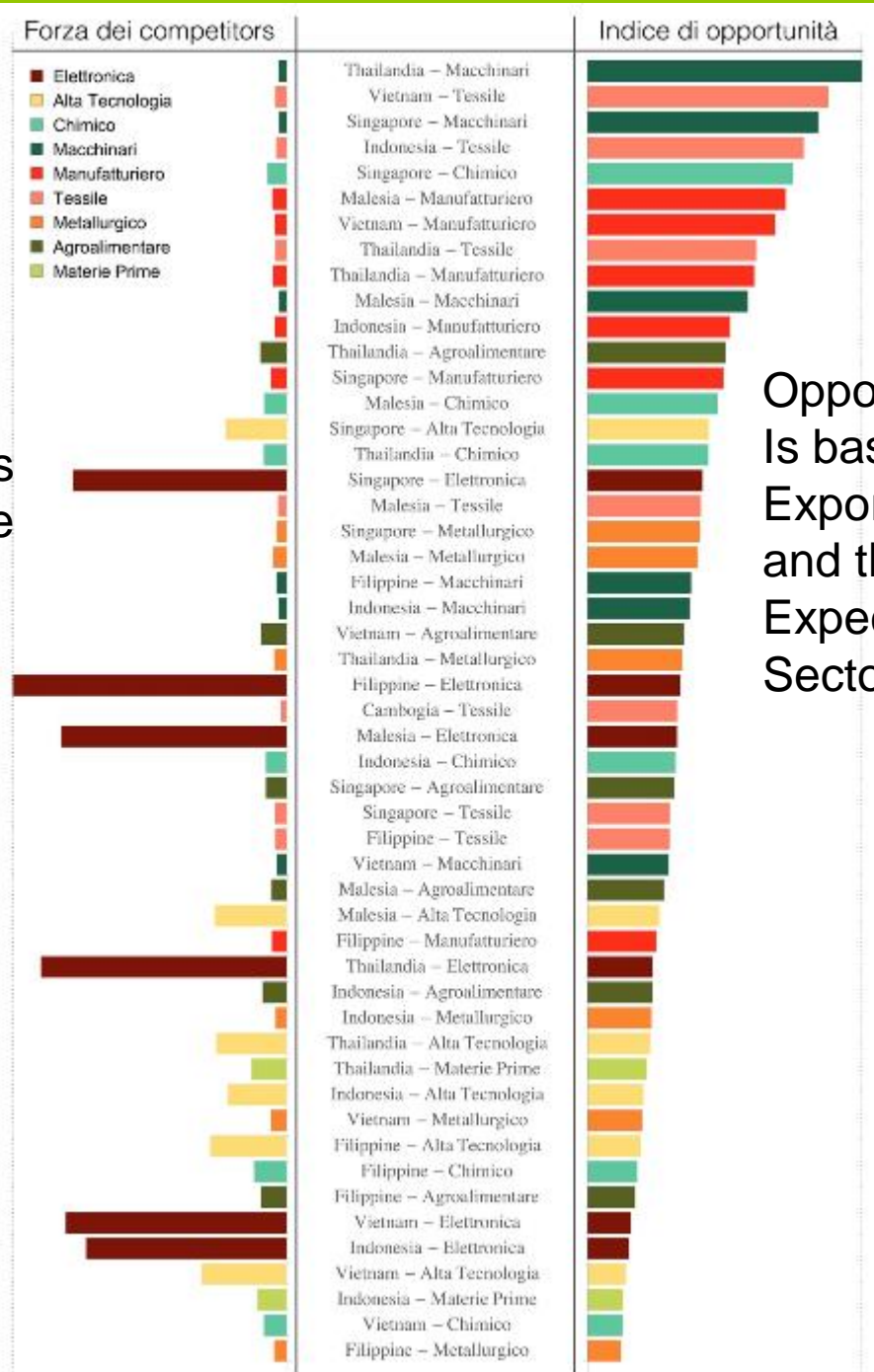
ASEAN Countries

SIGLA	PAESE
BRN	Brunei
LAO	Laos
KHM	Cambogia
VNM	Vietnam
PHL	Filippine
IDN	Indonesia
THA	Thailandia
MYS	Malesia
SGP	Singapore
ITA	Italia

- Petroliferi e paesi basati su settore primario
- Sviluppati
- Sottosviluppati / Economie caotiche
- Emergenti

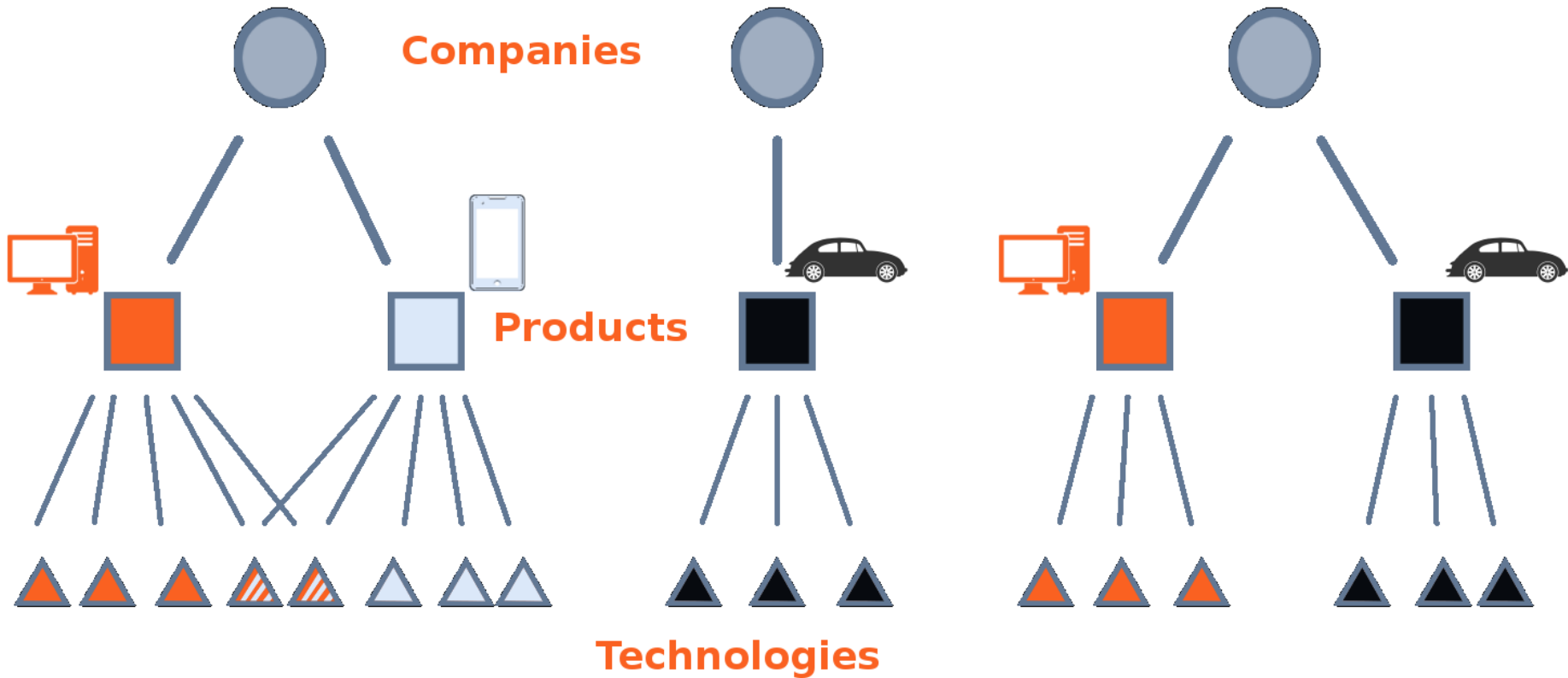


The strength of the competitors is based on their Sector Fitness and their market share



Opportunity Index for Italy is based on the share of Export That can be acquired and the Expected evolution of these Sectors

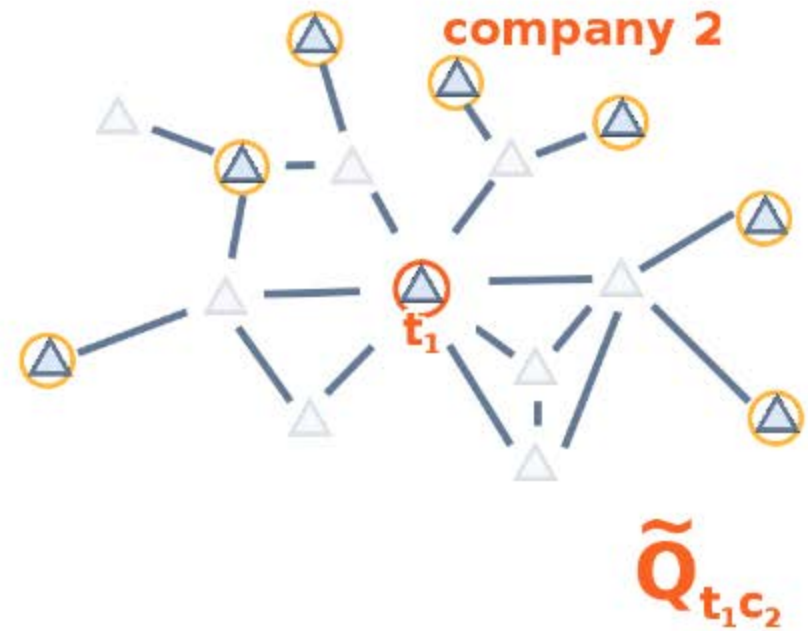
Companies, products and technologies



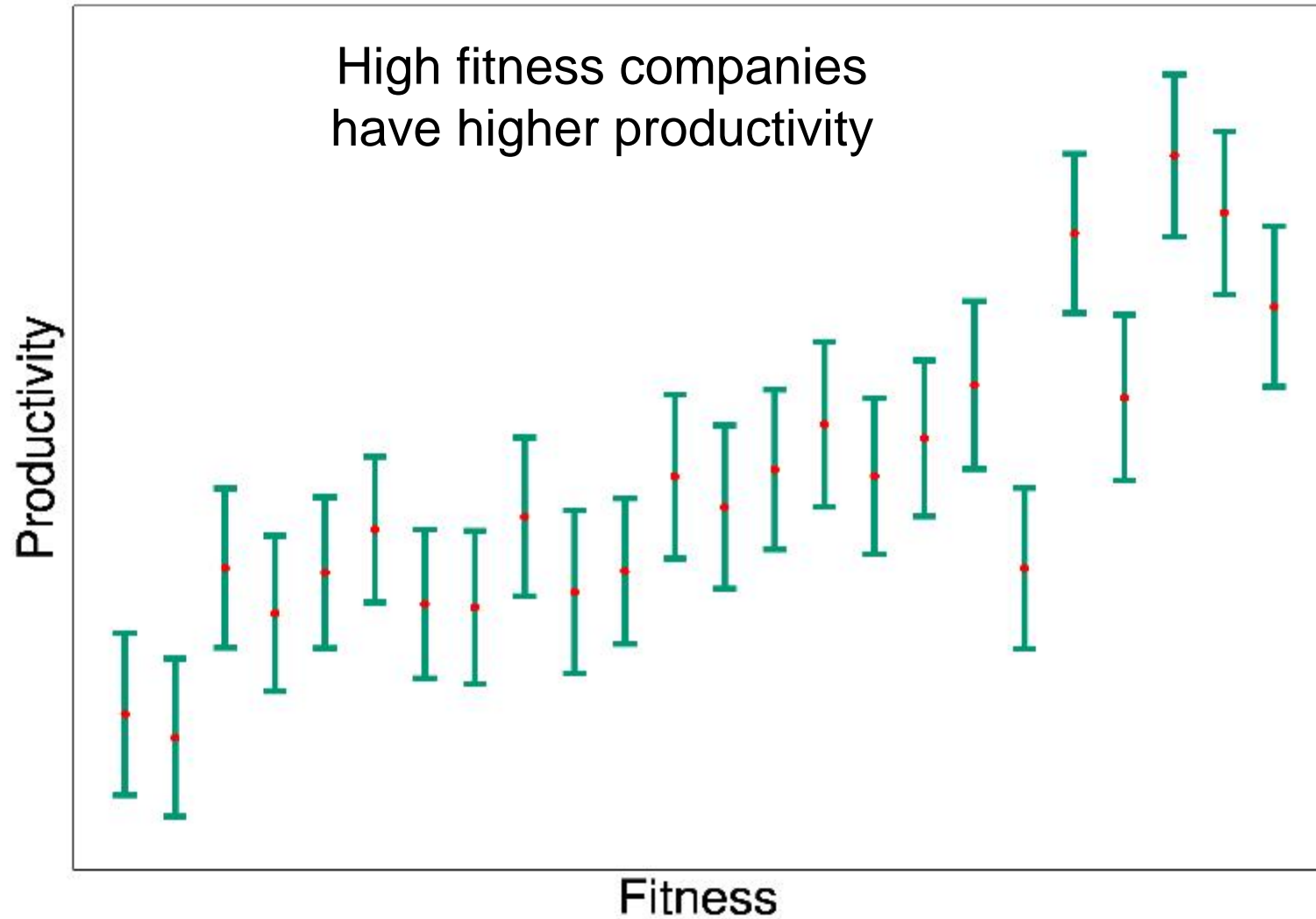
Companies owe patents to make products

The real underlying network is tripartite

Basic concept: a **technology** has more value if it is part of a **cluster of technologies** owned by the company that can participate to the **quality of a product**



Relationship with economic features



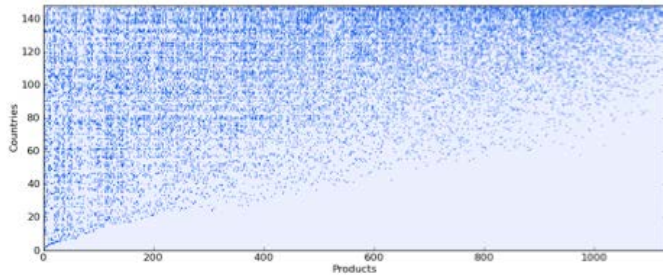
NEW:

SCIENTIFIC COMPETITIVENESS OF COUNTRIES

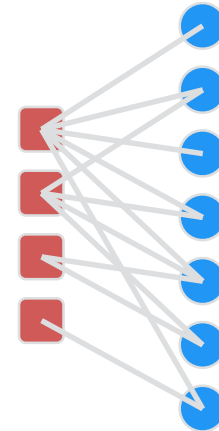
Do countries specialize or diversify their research
Activity?

NEW: Munoz et al, Nature Scientific Reports 2014

Economics

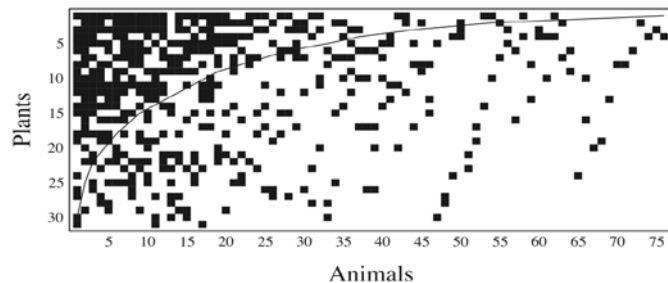


Countries Products

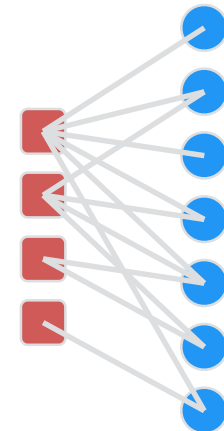


M. Munoz et al, preprint 2014

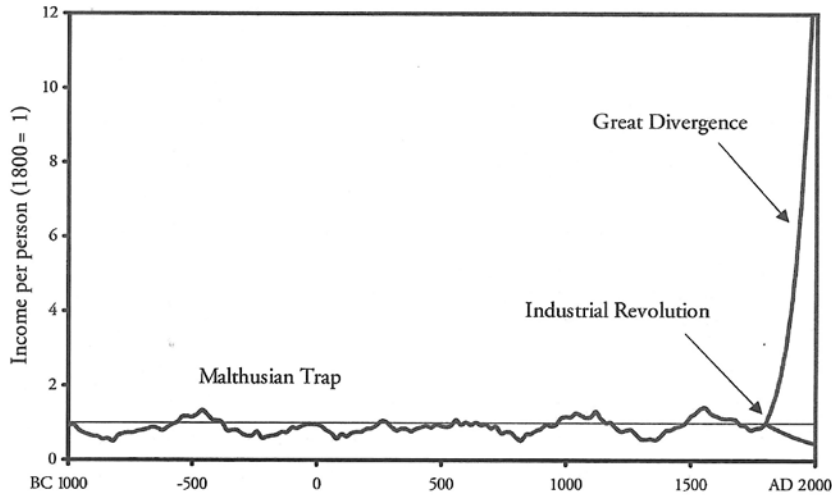
Ecology



Plants Pollinators



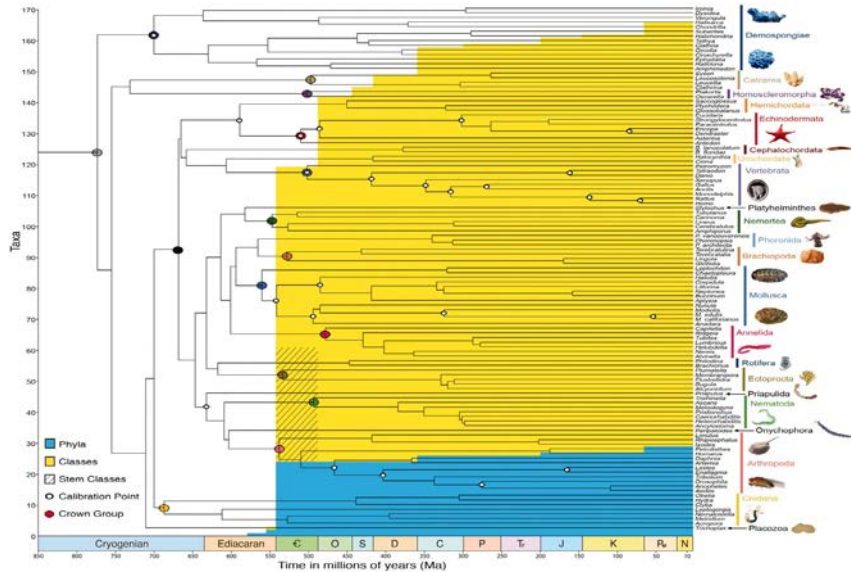
Economics



Great divergence

DIVERSITY

Ecology



Cambrian Explosion

DIVERSITY

BIG DATA AND ECONOMIC COMPLEXITY

L. PIETRONERO

Aspenia on line June 3rd 2015

Take home message 1: as soon as you have a new idea and a new algorithm you immediately realize that the data available (originally collected for different purposes) are not optimal and you want more data of a new type. There is no infinite dataset one may collect *a priori* which is good for all problems.

Take home message 2: Big data science in the sense we have indicated can indeed produce a revolution in our knowledge in many fields. But for each area there should be a clear understanding of what the relevant information is and how to extract it from the data. This cannot be a single recipe for all fields of analysis: instead, it should be studied and tailored to each problem.

ENERGY AND SUSTAINABILITY

Possible joint program with IIASA

Add Energy variable to each product and assess sustainability of each basket of products

Policy implications and collaborations:

- **Boston Consulting Group (New York)**
Report of development perspectives of Sweden
Algorithmic analysis of the competitiveness of Companies
- **Royal Dutch Shell (NL)**
Report on South Africa Industrial Perspectives (2014)
- **IPPR Institute of Public Policy Research**
Report for UK Government on UK Industrial Competitiveness
- **Alibaba Research for Complexity Science, Hangzhou Business School, China**
Analysis of the Internal Regions of China; Analysis of the Recommendation Strategies
- **Ministry of Foreign Affairs of Italy**
Analysis of the mutual Industrial Opportunities of China and Italy
Analysis of the Italian Opportunities in the ASEAN Markets
- **Azimut Investment Group,**
Development of an Asset allocation Fund based on Economic Complexity (2015)