

# ECONOMIC

COMPLEXITY



## ECONOMIC COMPLEXITY MEASURING THE INTANGIBLES

A CONSUMER'S GUIDE

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[WEBSITE ECONOMIC COMPLEXITY](#)

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*New economic theories must be strongly data-driven in order to provide a more concrete scientific grounding for Economics.*

*In this perspective, we discuss two metrics for measuring intangible properties of the complexity of products and competitiveness of countries. The comparison of these measures with monetary figures, as the Gross Domestic Products or the Income per capita, uncovers new information to assess the hidden potential of growth and development of countries*

*This work is intended as an introduction to both the scientific activity and business-oriented applications of the framework and methodologies presented.*

*Economic complexity permits to acknowledge that Finance and Economics are two highly connected aspects of the same general problem and provides a framework to discuss, both from a conceptual and practical point of view, this bridge which is neglected by mainstream approaches.*

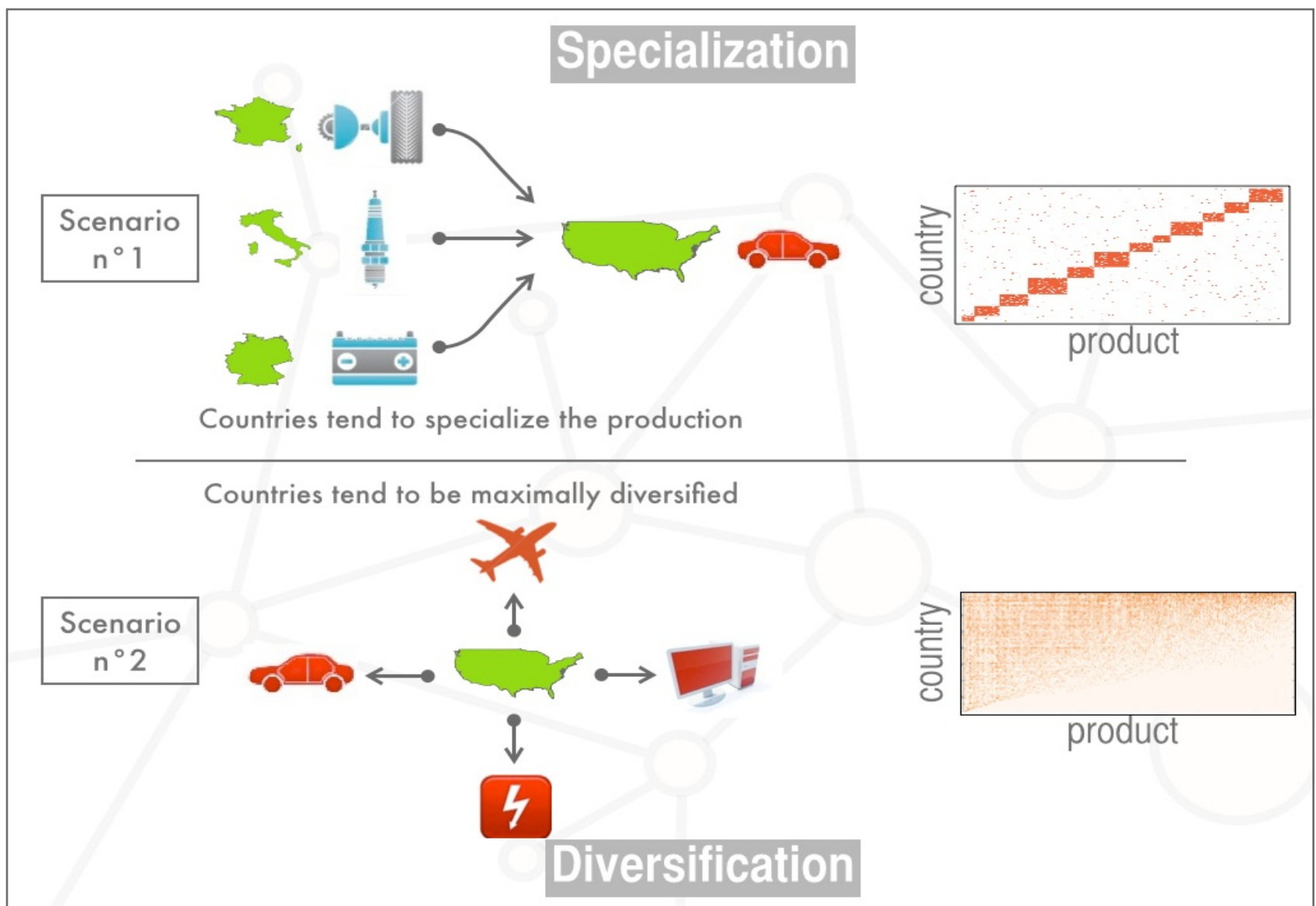
*In a business-oriented perspective, this new thinking, recognizing that Economics and Finance effectively interact, can disclose new fundamental information about sectors, countries, patterns of evolution of productive systems which must impact finance in the medium/long term.*

# FITNESS



## MEASURING THE ECONOMIC COMPLEXITY

The increasing interconnectedness and the growing complexity of economic and financial systems have challenged mainstream economic theories. The subprime financial crisis, the following economic recession of western countries and the slow recovery from stagnancy have dramatically showed how crucial is for the future of our society a paradigm shift of the present economic thinking in the direction of more concrete scientific grounding of this discipline. In contrast from standard approach we need that the new economic thinking must be strongly data-driven in order to scientifically ground and test economic theories. Present economic theories which have been introduced over the years are now considered as global paradigms which compete one

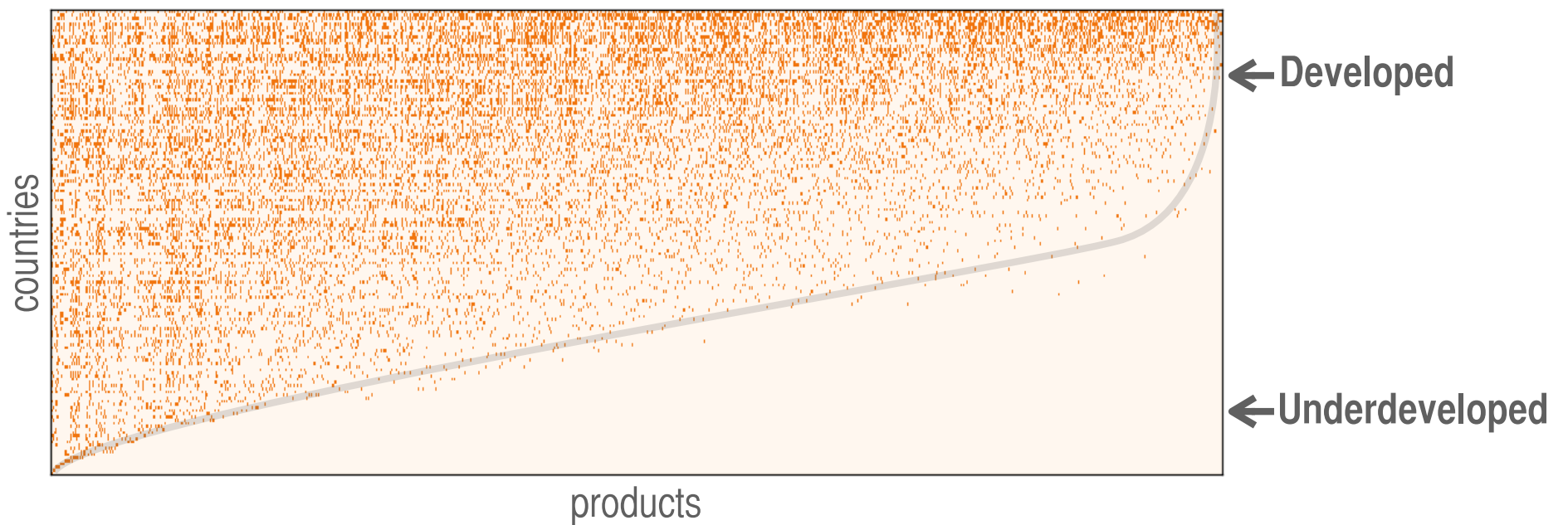


**Fig. 1** Specialization vs Diversification

**Economic theories compete as ideologies. We instead need a scientific foundation of Economics**

against the other as ideologies with the underlying idea that each of them could be right in any economic scenario. We conjecture that a more scientific foundation of economic thinking instead will lead to a scenario in which the various theories can be more or less suitable depending on the particular situation of the economy as it happens for Natural Sciences. In this new perspective, concepts as market efficiency and the degree of coupling between Finance and Economy could be tested, falsified and even quantitatively assessed. In this perspective a crucial element is to empirically understand and measure the state of economy in order to determine the most appropriate approach for that specific state. Using a medical metaphor, we need tools and methodologies to empirically diagnose economic states to consequently choose the most appropriate protocol.

In the spirit of this new approach we focus our attention on fundamental economic growth of countries and introduce a novel framework to measure the competitiveness of the productive system of countries and the complexity of products [1-5]. These metrics correspond to the measure of intangible information about countries and products and the comparison with monetary figures such as the Gross Domestic Product permits to identify hidden and future potential of growth. Both metrics are



**Fig. 2** Binary country-product matrix (2010), the triangular structure is a strong evidence in favor of diversification

groundbreaking with respect to the assessment of the hidden potential of growth of countries, the technological value of products out of monetary effects and - assuming that economy and finance are indeed coupled - a tool to uncover medium-long term investment opportunities, especially in frontier and emerging markets.

Traditional economic approaches such as Ricardian paradigm predict that most successful countries should specialize their productive set in those few products in which they score the highest comparative advantage as shown in the top panel of Fig. 1. It appears that a good proxy for productive capacity is represented by the export set of a country which provides an important empirical playground to test the prediction of mainstream approaches. Each year we know the exported flow product-by-product and country-by-country expressed in US dollars. These data can be organized in a matrix in which rows represent countries while columns products. Therefore in such a matrix each entry  $M_{cp}$  specifies the export of product  $p$  of country  $c$ . Since we are interested in a non-monetary and intensive metrics for a country productive system, we make the country-export matrix binary. We compute for each product the Revealed Comparative Advantage (RCA) and when the RCA is larger than 1 we say that a country is able to make that product (competitive on in international market) and we set  $M_{cp}=1$ , otherwise  $M_{cp}=0$ . Ricardian theories would predict a block diagonal matrix corresponding to the concentration of the productive system on few products (see top panel Fig. 1).

Most developed countries tend to maximally diversify their production

Visual inspections of the empirical country-product matrix reveal that specialization is not a path followed by countries, especially by the most developed ones which instead tend to maximally diversify their

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As in biological systems, diversification achieves long-term stability and competitiveness in a changing environment as the present globalized world

productive system (Fig. 1 bottom panel and Fig. 2 where we show the country-product matrix rearranged according to the metrics we have previously cited). This statement can be made quantitative by measuring the nestedness of the matrix. We find a value significantly different from 0, value we would have measured in the case of specialization. Therefore diversification, differently from what expected from standard approach, appears the key point to characterize the competitiveness of countries. In strong analogy with biological systems, in a dynamic and changing environment as the present globalized economy, diversification rather than specialization appears to achieve flexibility and robustness with respect to innovations and rapid changes of competitors and consequently drives the long-term competitiveness and successfulness of countries.

A detailed investigation of the economic foundation of the triangular and nested structure of the country-product matrix goes further the scope of the present paper and represent a standalone line of research which is currently under investigation.

In the present discussion we are interested in the quantitative assessment of the competitiveness of countries and the complexity of products given the empirical observation of a proxy for the productive systems, the country-product matrix. From a conceptual point of view this approach is similar to Google's PageRank: given the properties of the economic network, we introduce metrics to extract new information.

The nested structure of the country-product matrix implies that poorly diversified countries tend to produce only those products which are made by almost all countries while only the most diversified ones are able to produce the most exclusive products. In detail this non-trivial structure implies the following information about the complexity of products and competitiveness of countries:

- (i) the fact that a randomly chosen product is produced by a diversified country conveys very little information about this product because we expect that this country produces a large fraction of the products;
- (ii) instead the knowledge that a randomly chosen product is produced by a poorly diversified country means that very likely, due to



the nestedness of the system, the product requires a very low level of sophistication being exported by a scarcely diversified country;

- (iii) the information that a randomly chosen country produces a widely diffused product (i.e. poorly sophisticated product) is almost irrelevant to determine the competitiveness of the country, as ubiquitous products are exported by definition by most of countries
- (iv) instead the fact that a randomly chosen country produces an exclusive or non-ubiquitous product is very informative on the level of development of the country as the triangularity of the matrix implies that almost only highly diversified and presumably developed countries can export most exclusive products.

**Fig. 3** The iterative non-linear coupled maps defining the metrics for the fitness of countries and the complexity of products

From a mathematical point of view the nested structure calls for a strongly non-linear and extremal coupling between the level of sophisti-

Fitness of Countries

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

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

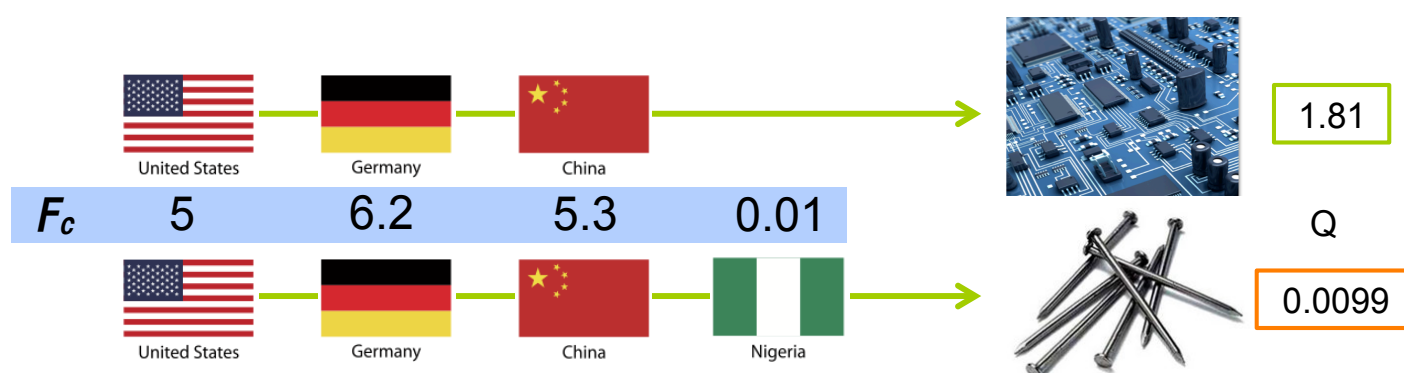
$F_c$ : diversification weighted by complexity

Complexity of Products

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

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

$Q_p$ : Extremal non-linear complexity of products.  
A **single low fitness producer** implies low complexity





cation of products (hereafter  $Q$ , the complexity of products) and the competitiveness of countries (hereafter  $F$ , the fitness of countries). Coherently with the previous observation, the fitness of a country, at each iteration, is simply defined as the diversification weighted by the complexity of products. Concerning product complexity we must take into account two features we want to include in the algorithm. On one hand the more ubiquitous is a product, the smaller is its complexity. On the other hand the need of extremal coupling derives from the fact that, as discussed, the complexity of a product must be driven (and bounded) by the fitness of the worst producer. As illustrated in Fig. 3 bottom panel, let us suppose to consider two products (chips and nails) which differ by only one producers which is poorly competitive (in the specific case Nigeria with an hypothetical fitness two orders of magnitude smaller than the other three producers). The resulting complexity of the two products after one iteration, although they have 3 out of 4 producers in common, will be dramatically different since the nail complexity will be mainly driven (and bounded) by Nigeria's fitness.

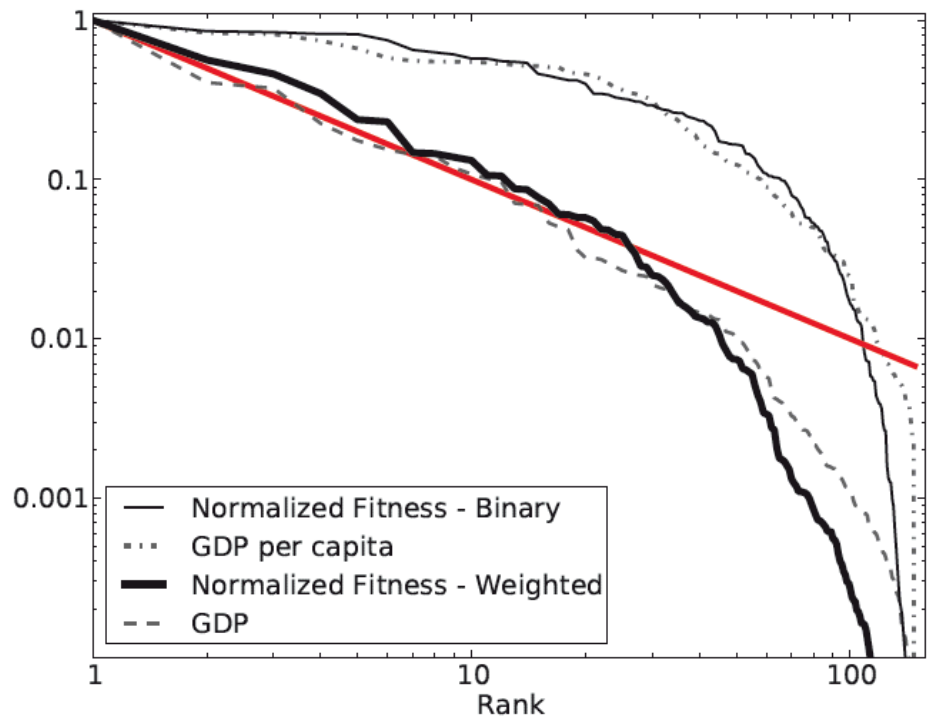
Country	Fitness (2005)	Rank
Germany	7.4	1
USA	5.6	2
Japan	5.5	3
China	4.8	6
Spain	3.6	12
India	2.9	15
Sierra Leone	0.081	100

From a conceptual point of view, this approach is similar to Google's PageRank: given the properties of the economic network, we introduce metrics to extract new information

The algorithm combines iteratively successive measures on matrix rows

and columns, in a spirit assimilable to Google's PageRank, refining at each iteration the information for  $F$  and  $Q$ . However, differently from Google's method - at least in its original version - in the present case we deal

Fig 4 Rank plot for intensive and extensive fitness



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Country fitness and  
product complexity are  
non-monetary and non-  
income based metrics

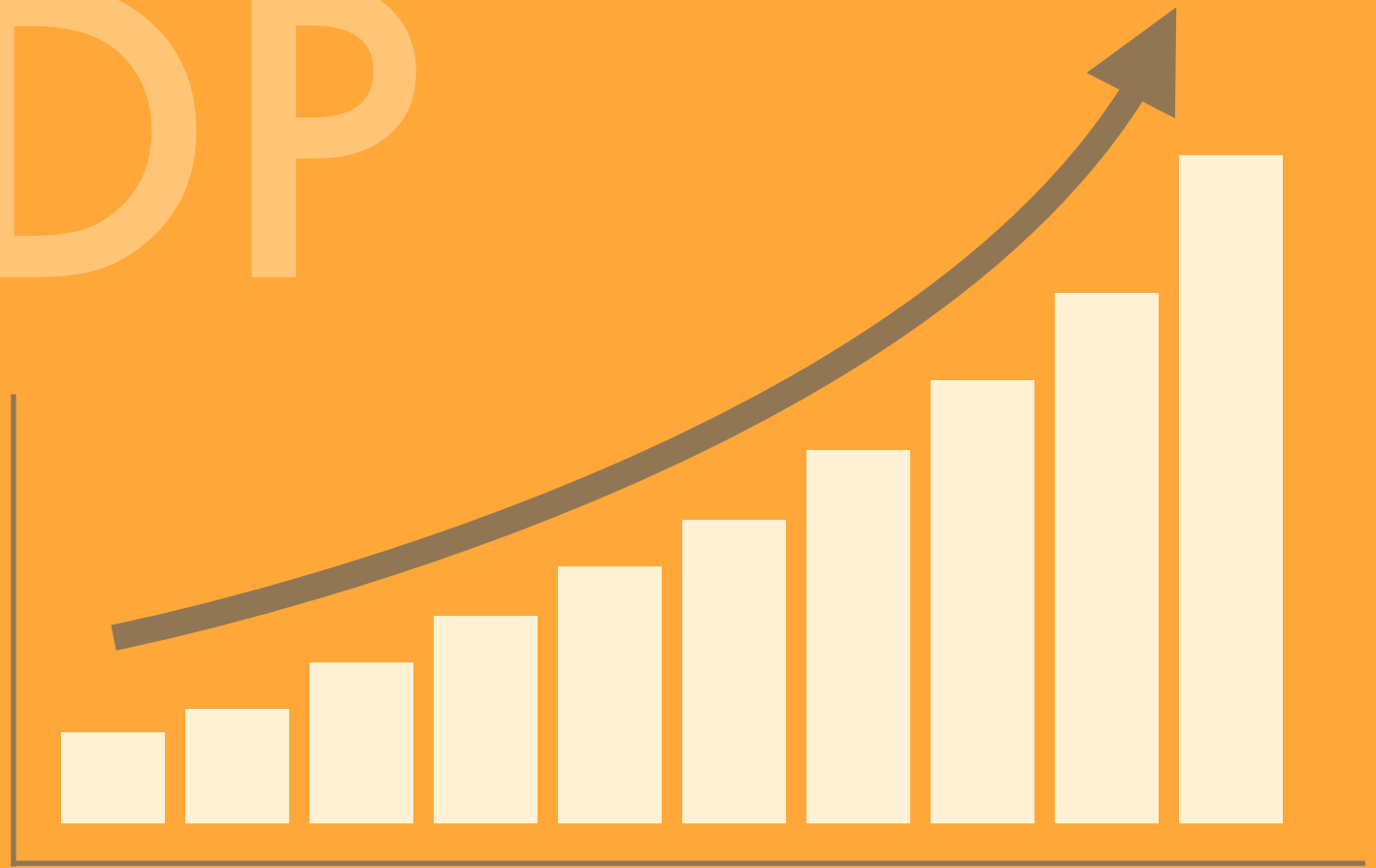
with a bipartite network (the world wide web instead is a mono-partite network) and the nested structure requires a strongly non-linearity (the PageRank is instead a linear algorithm). The metrics for country fitness and product complexity is defined as the fixed point of this coupled equations which is obtained self-consistently and asymptotically by the iteration of the maps reported in Fig. 3. It is possible to show the uniqueness and independency on the choice of the initial conditions of the fixed point defining the metrics. At each step  $F$  and  $Q$  are renormalized such that their means are always 1.

The metrics  $F$  and  $Q$  constitute a new non-monetary and non-income based metrics which measures the level of complexity of a productive system and the level of sophistication of a product. Concerning countries, we argue that fitness is a measure for those intangible assets which set the level of competitiveness and resilience deriving from the productive capacity of a nation.

We observe the Pareto-like behavior of fitness in the rank plot reported in Fig 4. The weighted fitness is the metrics in the case in which the binary matrix is generalized to entries ranging from 0 to 1 according to the export volume. This graph suggests the correct monetary counterpart for the intensive metrics (binary matrix) is the GDP *per capita* as expected, while the GDP is the one for the extensive fitness.

As a final comment, the algorithm here discussed represents the simplest and, at the same time, coherent formulation with respect to the empirically-derived economic principles of the nested country-product matrix. In principle, these formulas can be generalized but a more refined body of data is needed in order to set proper benchmarks to test generalized formulas for the measure of country competitiveness and product complexity.

# GDP



## HETEROGENEOUS DYNAMICS OF COUNTRY GROWTH

Several economic analyses can be carried out in the framework of our approach. In this section we discuss some relevant results concerning the metrics for country competitiveness, while in the next one we focus on the complexity of products [1,2,6].

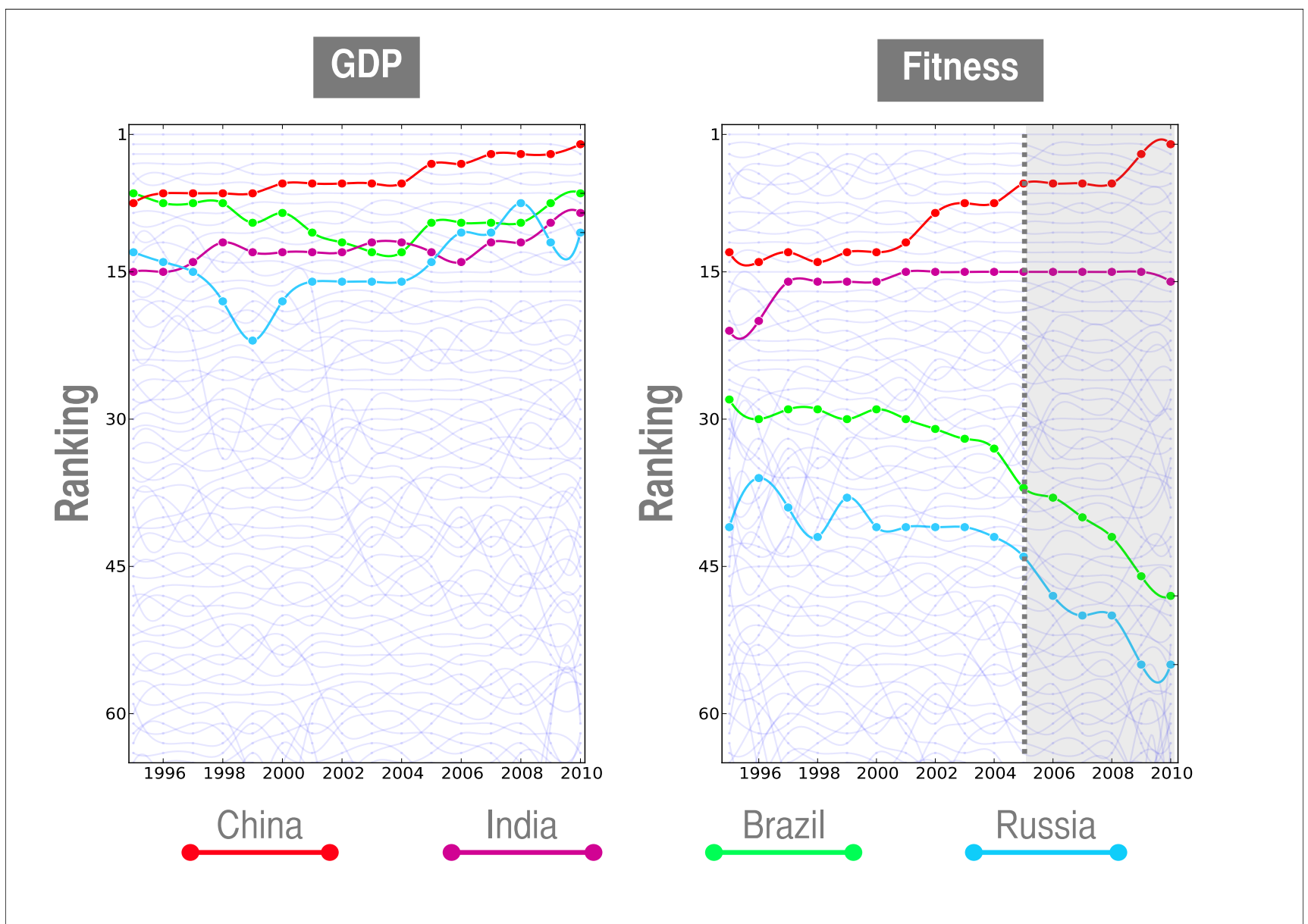
As previously discussed, the fitness of countries, especially in its intensive version (i.e. binary country-product matrix), represents a non-monetary assessment of the level of complexity of a productive system. In fact the method discussed in the previous section is an analysis of what a country is able to produce. We want to point out that such kind of intensive analysis allows for the direct comparison among countries characterized by very different size or population. The fitness of a country is certainly a standalone information about a specific economic system but the key point to understand how the fitness can be concretely used is that the deviations of our metrics from standard monetary and income-based indicators such as *GDP per capita* or *GDP* are strongly informative, especially for the assessment of economic and financial forecast about growth and stability of countries. As a first example we discuss the case of BRIC countries for which

our metrics would have found significant structural differences differently from a GDP-based analysis.

## 1. BRIC countries

The expression BRIC countries was first used in a report of Goldman Sachs in 2001 and this group is composed of four countries (Brazil, Russia, India and China) which were supposed to dominate the world economy within 2050. BRIC were originally grouped with respect to the similar perspectives of rapid and above world average growth of their Gross Domestic Product (GDP). Twelve years later, their growth outlooks are very different. A careful analysis of the export of Brazil and Russia would have highlighted the different development path of BR with respect to IC 10 years in advance. Only the latter are undergoing an industrial and technological development and in general a complexification of their economy in the last 15 years. While for Russia, even standard analyses clearly spot a growth strongly relying on primary sector, the future growth perspectives of Brazil are now hardly debated and only in the last two-three years some reports started to consider

**Fig 5** Evolution of the rank of GDP and fitness for BRIC countries



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The analysis of the fitness of Brazil and Russia would have highlighted the different development path of BR with respect to IC

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Brazil is not increasing the complexity of its productive systems, is mainly fueling its growth through export of primary products

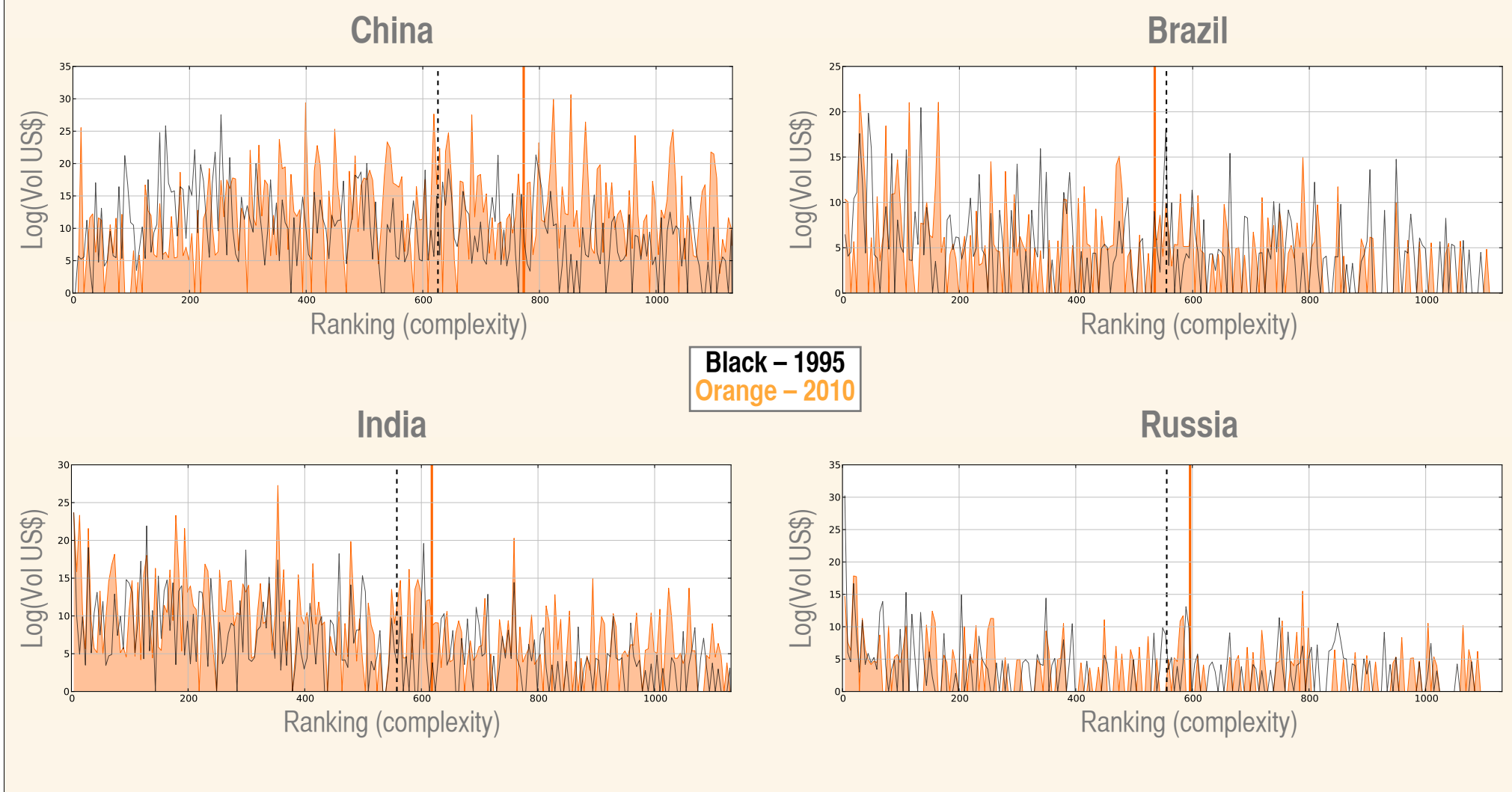
the scenario in which Brazil may not be able to maintain the present high rate of GDP growth in the next future due to its dependence on primary sector.

While for Russia this analysis is not surprising, the analyses on the degree of development of the Brazilian economy and the sustainability of the growth rate are controversial. We show in Fig. 5 that the heterogeneity in the development path of China and India with respect to Brazil and Russia could have been detected at least ten years ago, a few years after the first report on BRIC. While from a purely GDP-based point of view, the four countries are characterized by an above average growth (Fig. 5 left panel, BRIC countries have an increasing rank in the last 15 years when countries are ordered by their total GDP), a very different picture appears when the evolution of economic competitiveness of their productive system is investigated (Fig. 5 right panel). The evolution of the rank of the competitiveness as measured by the fitness confirms the extraordinary development of China which is eroding and overcoming the competitiveness of all western countries. Russia fitness is instead dropping down revealing that Russian GDP growth is almost fueled by the price bubble of fossil raw materials. However, the most valuable information deriving from fitness analysis is the evolution of the Brazilian competitiveness because of a very different behavior with respect to the monetary information. Brazil's competitiveness shows a behavior similar to Russia's one. Our metrics points out that Brazil is not increasing the complexity of its productive systems, it is mainly fueling its growth through raw material and in general export of primary product.

More accurate analyses of the export volumes confirm that Brazil is getting more and more dependent on primary products and reducing the average complexity of its productive systems as shown in Fig. 6 where we report the country *spectroscopy* for the four BRIC countries. We call country *spectroscopy* a graph where we report the export volumes of a country for those products for which  $RCA > 1$  ordered according to the complexity  $Q$  (see also next section for further details about a country *spectroscopy*).

The key point is that our method is able to point out the decreasing trend of Brazil at least 5-10 years in advance with respect to the standard analysis and common wisdom on BRIC perspectives. As a final observation, we see that India, after a strong growth between 1995-





**Fig. 6** BRIC country spectroscopy, vertical lines represent the average complexity of the export basket

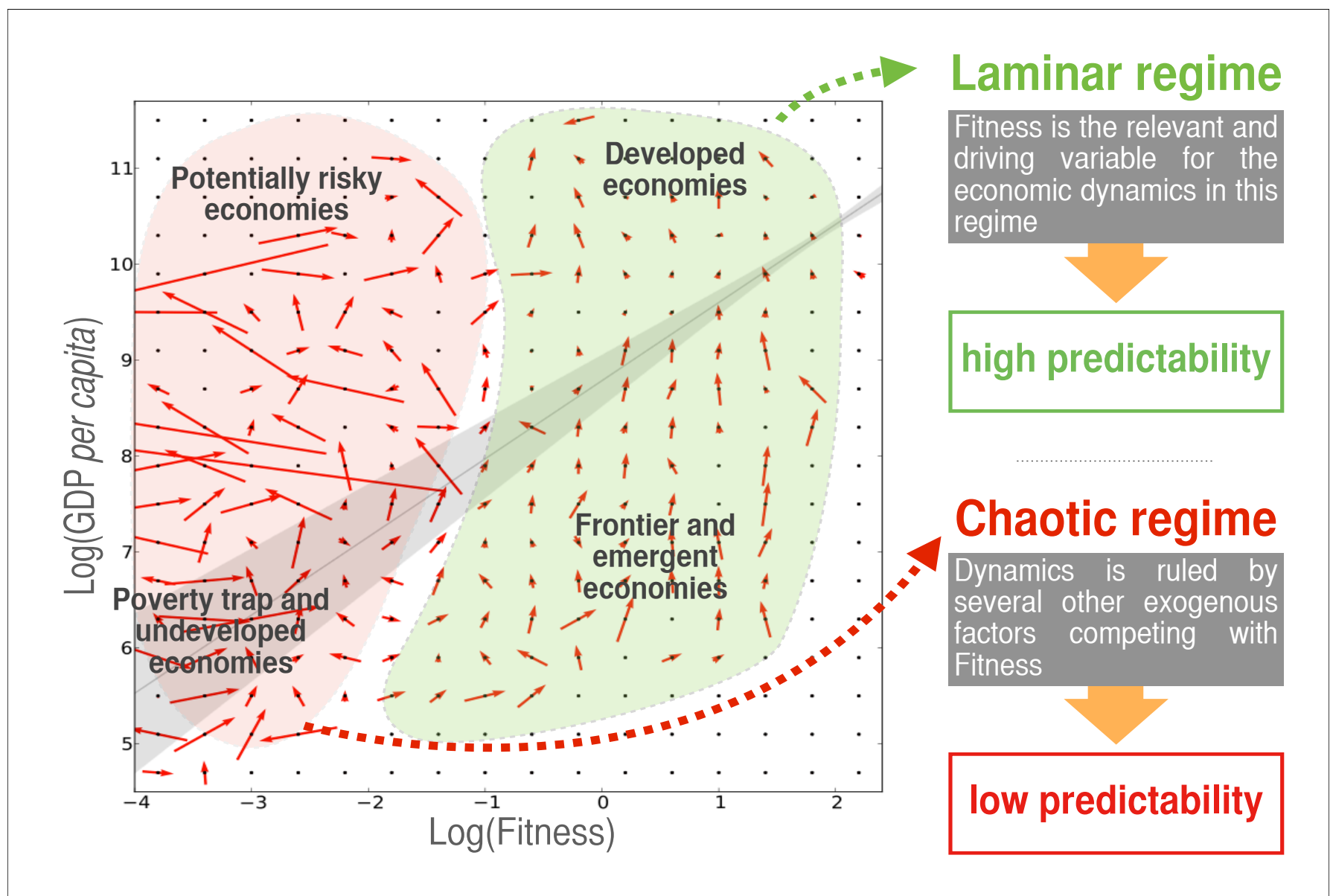
## 2. The Selective Predictability Scheme: the weather forecast for Economics

2000 shows a constant competitiveness rank. We conclude that India seems to undergo a slowdown of its technological and industrial development which may lead to a general slowdown of its GDP growth in the next future.

We have seen how the the fitness can give effective insights in the structural evolution of productive systems of countries, but what about country growth forecast? As a general comment, how to provide a scientific basis for economic predictability is still a very challenging problem as demonstrated by the so-called Excel-gate [7], despite this kind of question has a large societal impact and an extreme value for economic policy making. One of the principal and ultimate goal of macro-economic theories should be indeed the development of predictive methodologies in order to give a quantitative assessment of future evolution of economic indicators such as Income, Gross Domestic Product (GDP), inflation rate, etc in order to provide criteria and indications for economic interventions, stimuli, growth incentives, etc.

Is our method able to give some indications in this direction and provide a scientific ground for economic forecast? And concretely what will be the growth of the Gross Domestic Product and the competitive-





**Fig. 7** Heterogeneous dynamics of country evolution in the Fitness-Income plane

Forecasting country growth faces issues close to the problem of weather forecast

ness of China, USA, Vietnam and Sierra Leone in the next 10 years? The answer is '*it depends*': the predictability of the evolution of fitness and income is strongly dependent on the regime in which a country is. There exist economic regimes for which the fitness is able to effectively uncover the hidden potential of growth of countries. Forecasting country growth results to face issues which are very close to the problem of predictability for dynamical systems (i.e. atmosphere, climate, wind, ocean dynamics, and weather forecast etc). On this account there is a strong evidence for a high degree of heterogeneity in the growth dynamics of countries. We observe the emergence of different regimes of economic complexity and in particular there are several regimes for the patterns of evolution of countries in Fitness-Income plane as illustrated in Fig. 7. According to the position in the Fitness-Income plane, we are able to distinguish two main regimes: a laminar-like regime in which the fitness appears to be predictive or informative on the country growth and a chaotic-like regime in which the fitness seems poorly (or even) completely uncorrelated with the evolution of the wealth of those countries.

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The degree of predictability of the economic dynamic depends on the specific position in the Income-Fitness plane

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In the laminar regime the fitness is the only relevant economic variable which drives growth

This empirical observation calls for a completely new framework for the predictability criteria in which standard regression-based approaches are not the appropriate tools to address an heterogeneous growth dynamics. In fact the underlying hypothesis when a regressive approach is invoked is the existence of overall trends to uncover. Regression-based approaches are the right analysis tools when the system responds homogeneously to a specific set of variables, which should explain a certain amount of variance of the dependent variable. Regressions may be appropriate tools to analyze systems whose dynamics is homogeneous.

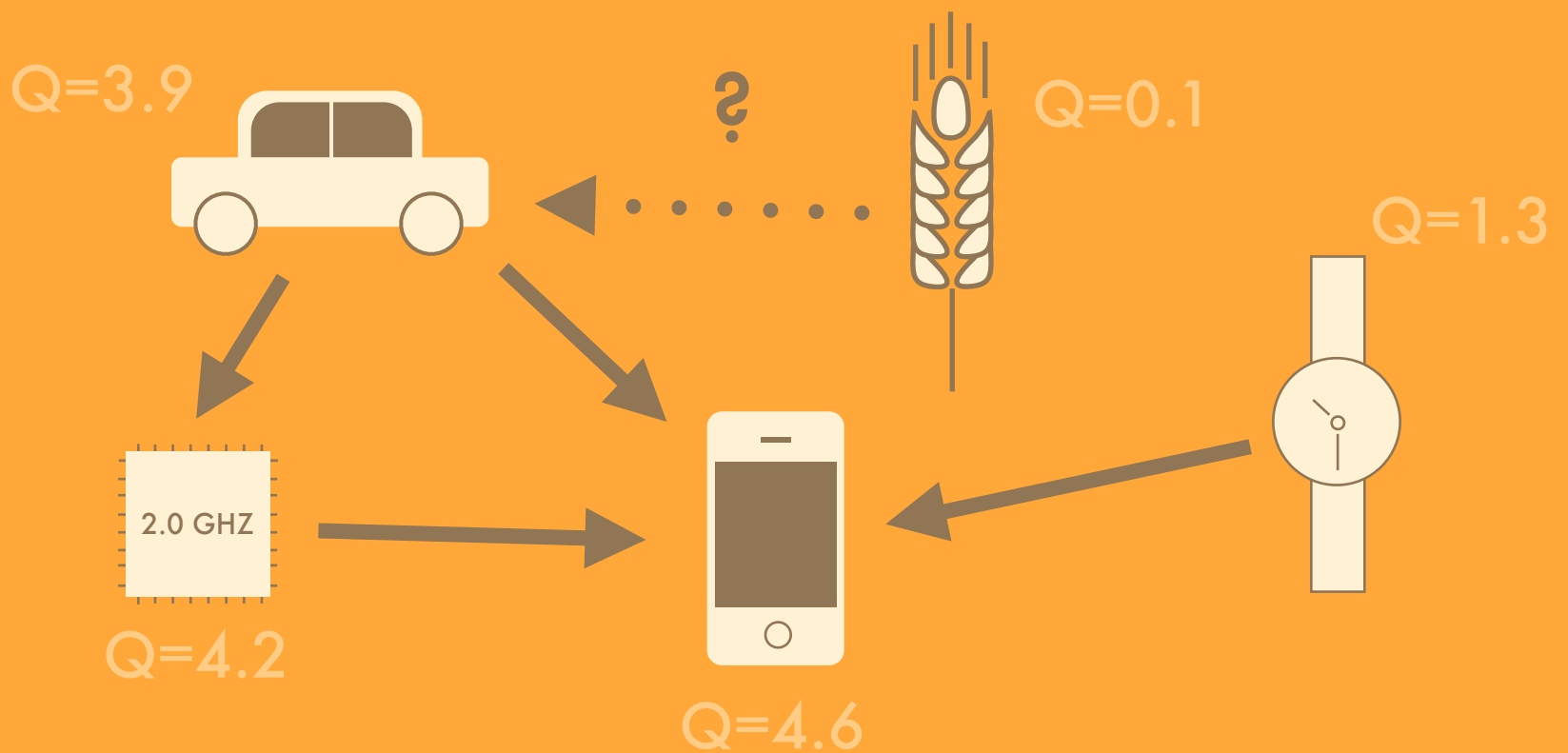
The predictive scheme required by the heterogeneous dynamics of economic complexity is conceptually similar to the problem of predicting the evolution of a dynamical system in the case in which we do not know the equations of motions (i.e. the rule of the evolution) of the system. We borrow concepts and methods suitably adapted from dynamical systems theory to give a new scientific grounding to the issue of economic forecast of growth. In analogy with weather dynamics, we argue that the best strategy is the prediction of the future from the knowledge of the past: this method is typically called *Method of Analogs* and was introduced for the first time by Lorenz in the 1969.

This approach for Economics is called *Selective Predictability Scheme* and has been first introduced in [3]. The breakthrough of this new framework for economic forecast is that the degree of predictability of the economic dynamic depends on the specific position in the Income-Fitness plane.

We find that in the laminar-like regime, as expected, we have good candidates for building analogs and we find strong statistical validation and robustness of the predictive power of the scheme. From an economic point of view, this mathematical picture implies that the income growth in this laminar regime, a priori, depends on many factors but, a posteriori, on the medium-long time horizon the fitness is the only driving variable of the growth of countries. In other words, in the laminar regime the fitness is the relevant economic variable in order to understand the dynamics of the income and in general the growth of the GDP. In the chaotic regime instead the dynamics is ruled by several other exogenous factors which compete with the fitness in driving the evolution of countries.

In the last section we will discuss the financial implications of the *Selective Predictability Scheme* and the importance of the fundamental assessment of competitiveness of countries for medium-long term financial strategies especially in emergent or frontier markets.

# PRODUCTS

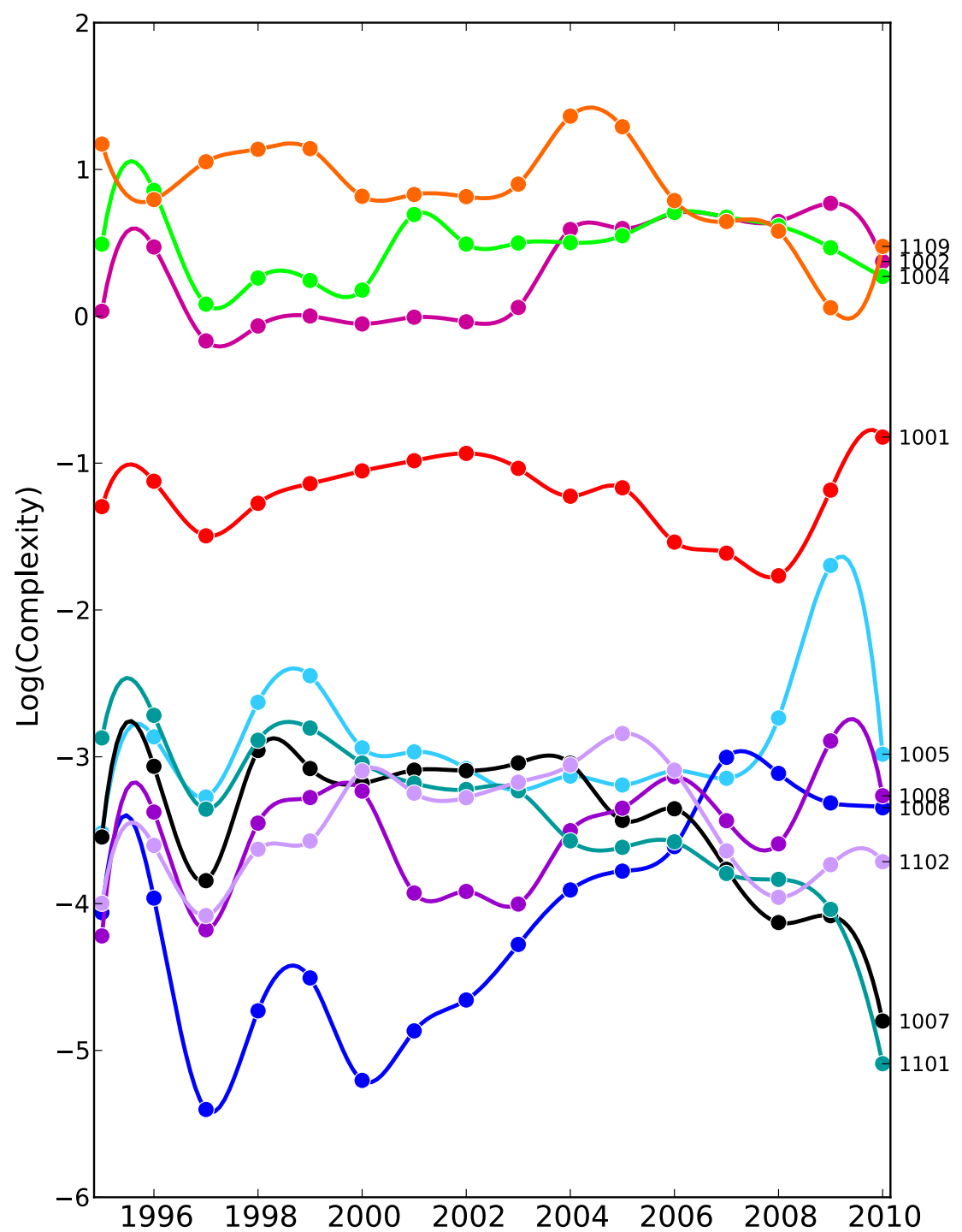


## WHAT IS THE PRODUCT COMPLEXITY? HOW ARE PRODUCTS CONNECTED?

**The product complexity: a synthetic indicator to assess the value of products in a non-monetary and non-market oriented way**

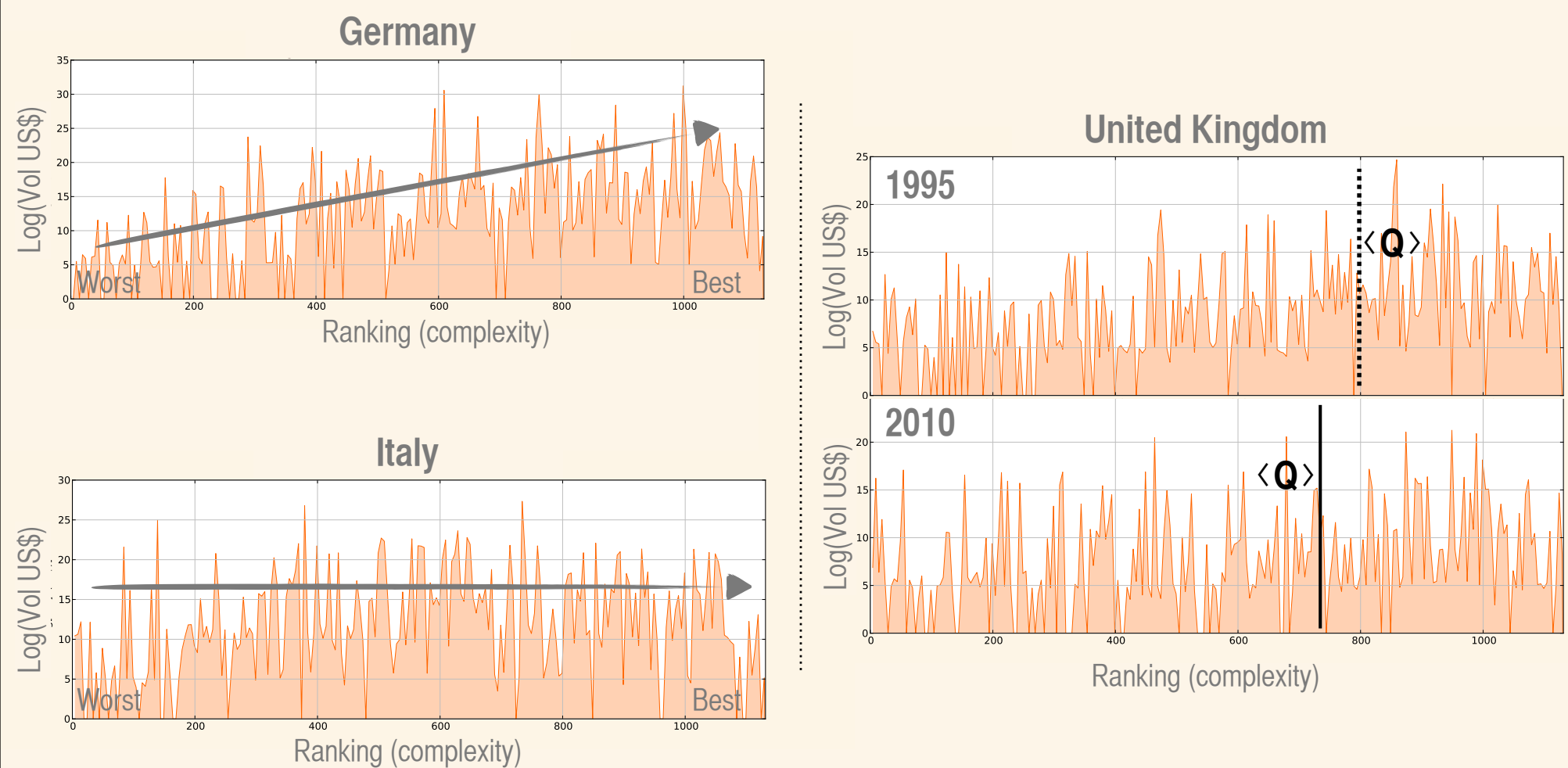
What is the product complexity measuring? The level of sophistication and technology required by a specific product. Consequently the complexity is, as in the case of fitness, a completely novel measure because we are not aware of the existence of economic indicators for the complexity of product which do not rely on monetary estimate. A standard measure adopted is the market value of products, however this quantity suffers from strong bias due to market speculation, labor cost, etc. While it is reasonable to believe that products characterized by a high complexity are likely to have high market prices, it is very easy to find striking counterexamples where simple products have anomalously high price, for instance the Tulip mania of XVII century. The complexity of products can be interpreted as a new synthetic indicator which permits to quantitatively assess the complexity of products in a non-monetary and non-market oriented way.

In this respect a large spectrum of analysis can be performed: detailed analysis of the export basket of countries, relative strength/weakness of countries with respect to export of specific products, indices to quantify the complexity of economic sectors, etc. In addition, in analogy to the evolution of country fitness, it is



**Fig. 8** Evolution of the complexity of cereals in the period 1995 - 2010

possible to investigate the evolution of the complexity of products, year by year, in such a way we may track the evolution of the economic cycles and the development or the technological contraction of specific sectors.



**Fig. 9 Country spectroscopy**

As an example, in Fig. 8 we report the time evolution of the complexity for a selection of cereals from 1995 to 2010. Cereals result to be organized into two main groups: the former has a complexity around the average of all products (i.e.  $Q \sim 1$ ), while the latter is formed of cereals whose level of sophistication is much lower than the previous ones as measured by our metrics ( $Q \sim 10^{-3}, 10^{-4}$ ). Cereal complexity reveals two different complexity regimes for cultivation. The two classes indeed correspond to a real difference in the level of technology of the country exporting them. In fact by analyzing the typical usage of oats and rye, these two cereals are not typical of a subsistence economic system differently from the other cereals and instead they are typically used in livestock industry and brewed-product industry. As a final remark, it is worth noticing that the knowledge of the intrinsic value of a product (i.e. the complexity) is critical for goods like commodities which are subject to strong speculative bubbles and whose market prices, differently from stock prices, are affected by strong inefficiencies, for instance the agricultural sector.

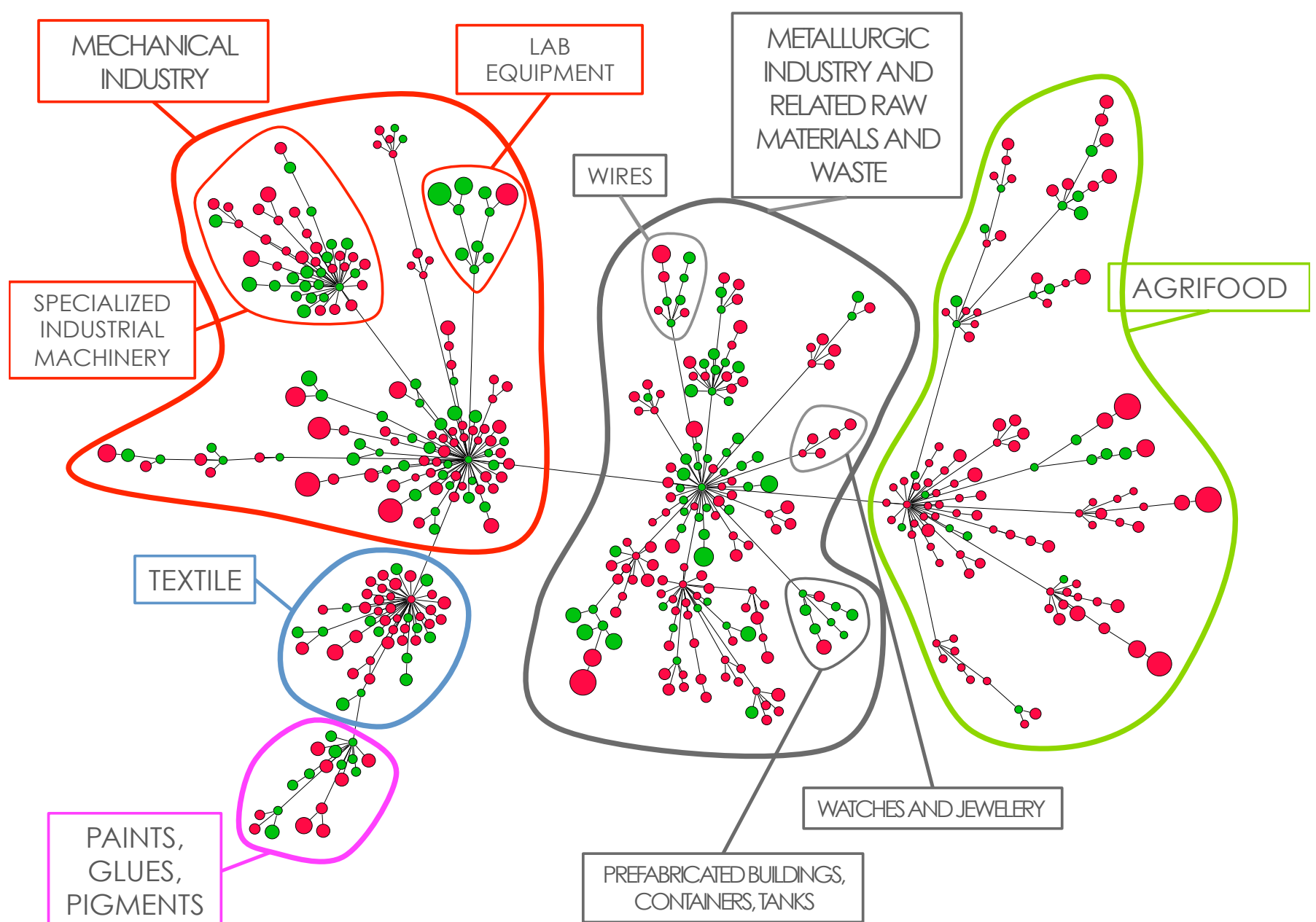
**The Spectroscopy: x-ray of a productive system**

A powerful methodology, both for visualization and quantitative analysis of the structural features of a country economic system, is the country *Spectroscopy* previously introduced to discuss BRIC countries.



Roughly speaking it represents a sort of x-ray of the production of a country. As discussed in Fig. 9, the Spectroscopy allows for cross country structural comparisons underpinning similarities and differences by analyzing the export volume distribution, ordering the products according to the complexity. In our first concrete example, we have already noted how BRIC structural differences can be detected by looking at country spectroscopy. In Fig. 9 left panel, we show spectroscopy for Germany and Italy in 2010 revealing, for the former, a productive system very diversified as the Italian one but much more orientated towards high complexity sectors. On the contrary, India which is still a very diversified country shows a spectroscopy where most volumes are concentrated on low complexity products (Fig. 6). The same spectroscopy can be also represented using the complexity itself instead of the complexity rank of products as x-axis in order to highlight the distance among products in which a country has significant export. The spec-

**Fig. 10** Portion of the Taxonomy Network for Sweden, green circles correspond to occupied products by Sweden, red to unoccupied



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### The Taxonomy of Products: following the dynamics of invasion of the network of products

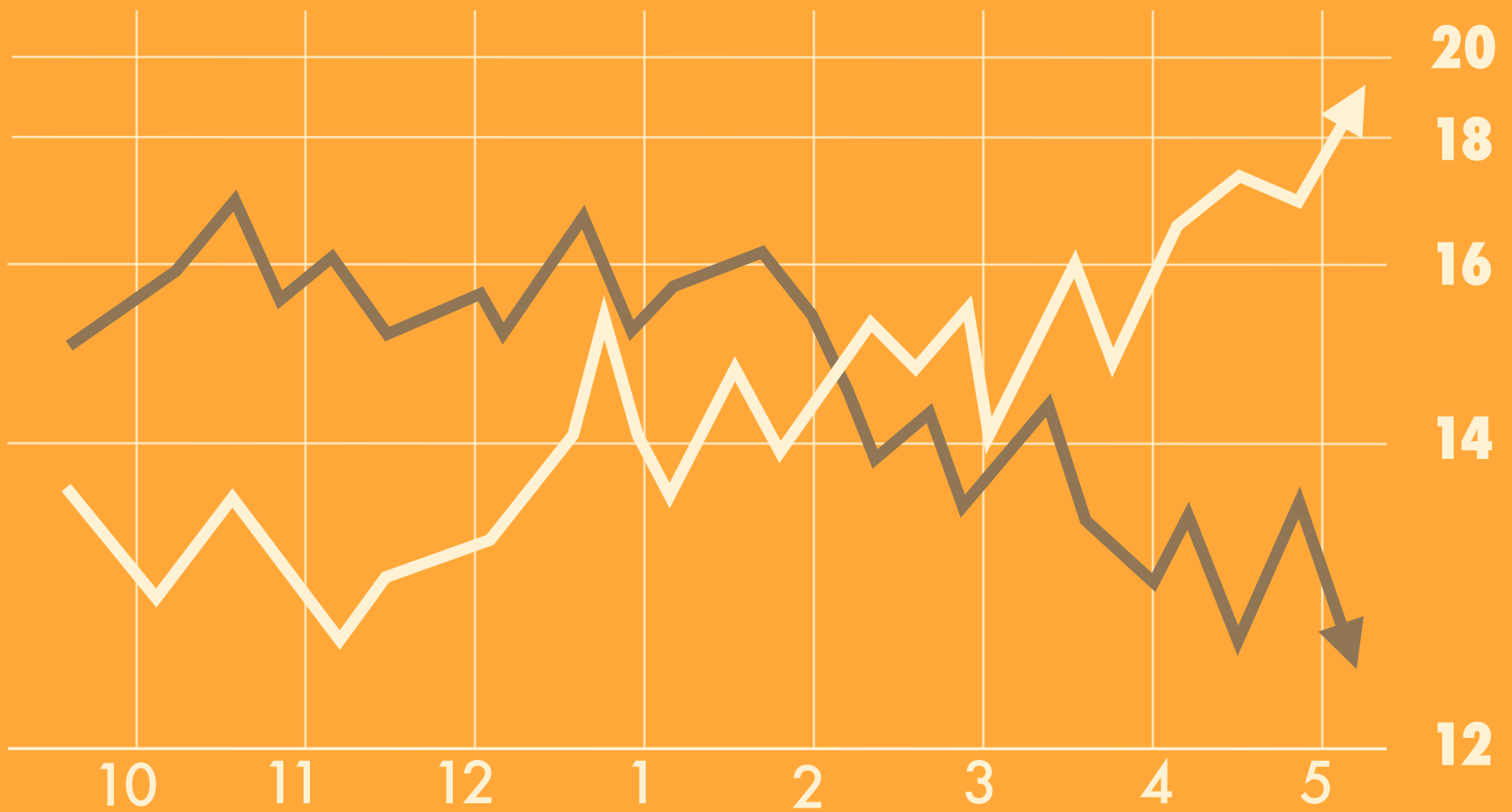
troscopy is also a powerful tool to track the structural changes inside a country along time as demonstrated by the right panel of Fig. 9 where we show United Kingdom's second de-industrialization by comparing spectroscopy in 1995 and 2010.

A complementary tool to understand the structural patterns of evolution of a productive system is represented by the Taxonomy of Products as illustrated in Fig. 10. A first non trivial result of this network is a bottom-up classification of products in sectors differently from the top-down approach used for product categorization as the Harmonized System.

However, the far more important aspect is that the taxonomy network gives insight on the future invasion dynamics of countries on this network. Roughly speaking, this network is built observing that close products are technologically related because they are often produced together in many countries. In Fig. 10 we report a representative portion of this space for Sweden in which the green sites are those in which Sweden is a relevant exporter ( $RCA > 1$ ), while the red sites represent products or sectors with less export activity ( $RCA < 1$ ). The size of the sites indicates the level of complexity of that product. Production tends to get organized in clusters in specific areas. Red colored products close to green colored circles represent expansion opportunities. Various communities can be identified in the network of products: products of these communities tend to be exported together by many countries. We can speculate that these products are technologically related and that synergies can be exploited when these are produced together. Sweden is already competitive in many specific products of these communities, so an effort to develop further competitiveness in this set of goods could be advisable.

The taxonomy of products, the country *Spectroscopy*, etc can be used in the perspectives of policy consultancy to plan and optimize national resource allocation as discussed in this section and in The Boston Consulting Group report for Sweden (see pages 20-21-22 of Ref. [6]). It is also useful in the perspective of fundamental analysis in order to detect opportunities for financial investments as discussed in the next section by analyzing the most likely unoccupied areas of the network a country will invade in the future.

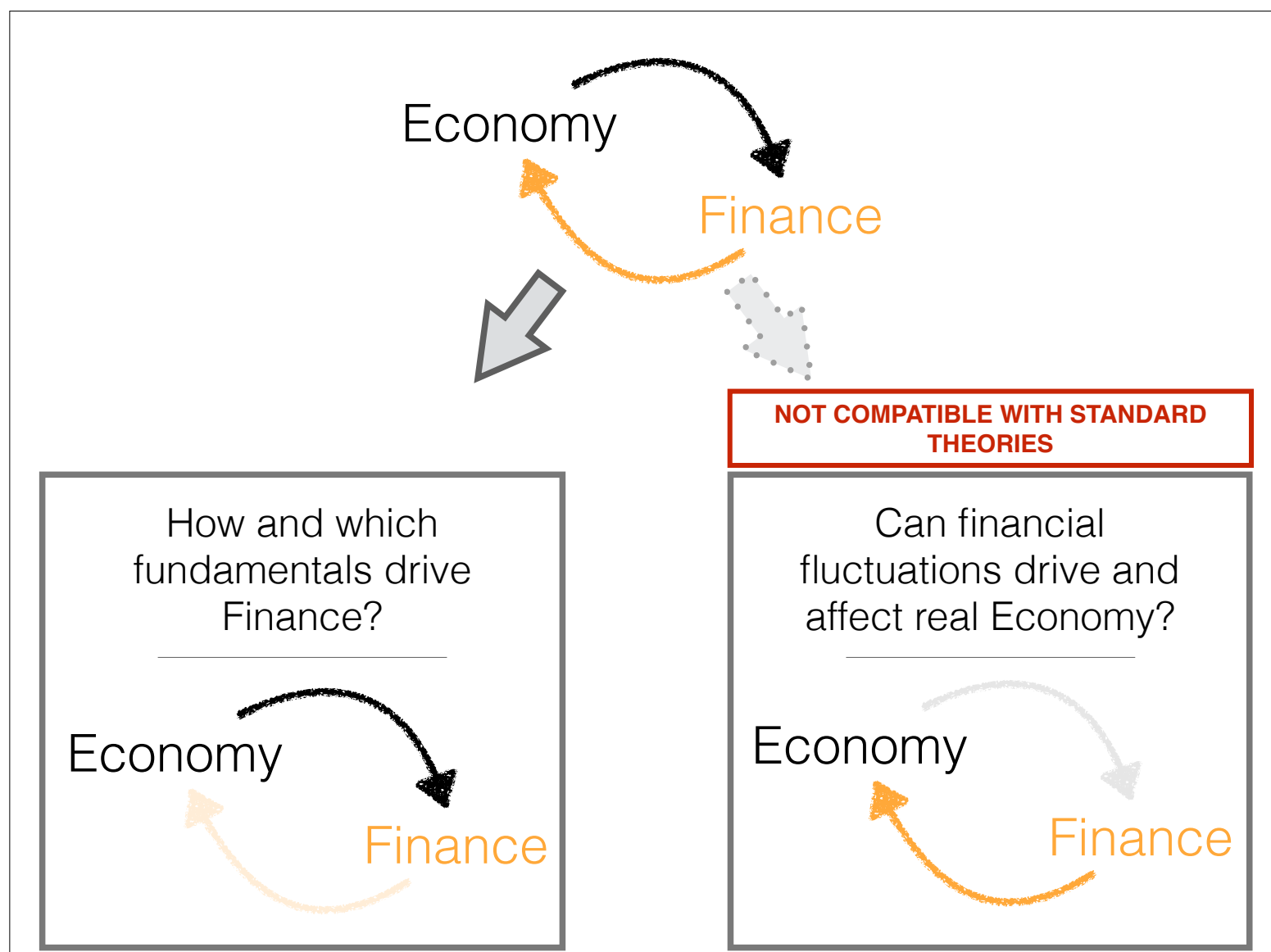
# FINANCE



## ECONOMIC COMPLEXITY INDEX: HOW FUNDAMENTALS DRIVE FINANCE

Are financial and economic systems coupled or not? Is Economy driving Finance (in the long term) and how? Can financial fluctuations affect Economy and fundamental prices?

While to some extent the driving role of Economy for Finance is compatible with standard approaches - at least on long time horizon (black arrow in Fig. 11) - curiously mainstream theories do not predict any coupling between Finance and Economy (orange arrow in Fig. 11) and Finance and Economics (red arrow in Fig 12).



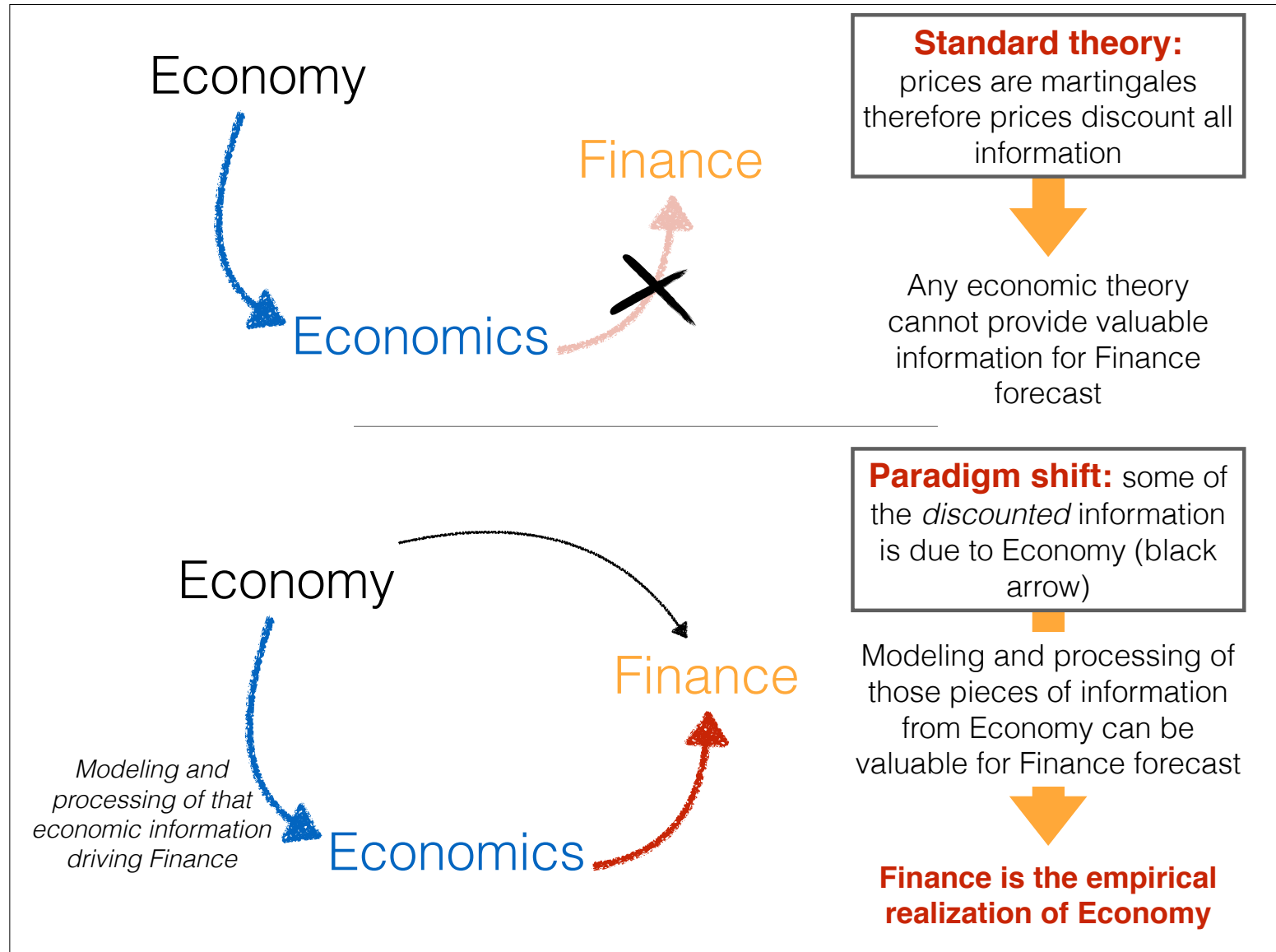
**Fig. 11** The coupling between Economy and Finance

### The financialization of real economy

One of the cornerstones of the new economic thinking is to acknowledge that Finance-Economy-Economics are highly connected aspects of the same general problem and to understand the origin and consequences of the coupling mechanisms.

Let us first discuss the missing link in mainstream theories from Finance to Economy as illustrated in Fig. 11. Market efficiency, perfect rationality, absence of frictions, etc would predict that indeed financial fluctuations cannot affect real Economy and prices. In the last years a growing body of arguments and evidences appear to point in the direction of financialization of real economy (the orange arrow of Fig. 11), as for example in commodity prices and the speculation on sovereign debts.

On this account we cite a part of the testimony given by George Soros before the US Senate Commerce Committee Oversight Hearing on June 3, 2008: *"Demand is reinforced by speculation that tends to reinforce market trends [...] In addition to hedge funds and individual speculators, institutional investors like pension funds and endowment funds have become heavily involved in commodity indexes [...]. Indeed, such institutional investors have become the "elephant in the room" in the futures market. Commodities have become an asset class*



**Fig. 12 Why Economics can provide valuable information for Finance**

*for institutional investors and they are increasing their allocations to that asset class by following a strategy of investing in commodity indexes."*

The new metrics for country fitness compared with monetary aspect may provide an ideal laboratory to investigate to what extent financial fluctuations can affect real Economy. In particular the analysis of the dynamics in the Fitness-Income plane can be useful to measure the interplay between financial fluctuations and real economy dynamics, therefore testing the robustness of mainstream theories and their predictions in real economic-financial systems where the effects of frictions, liquidity constraint, finite credit, non-rational expectation, etc cannot be neglected.

As a further consequence of the mainstream framework, any new economic theory should not provide any valuable information in the forecast of finance (see red arrow Fig. 12 top panel) because financial prices are martingales perfectly discounting all information. Economics, intended as modeling of economic information, therefore should be completely decoupled from Finance and this is witnessed by the almost complete absence of interaction between economic academic world and finance world.

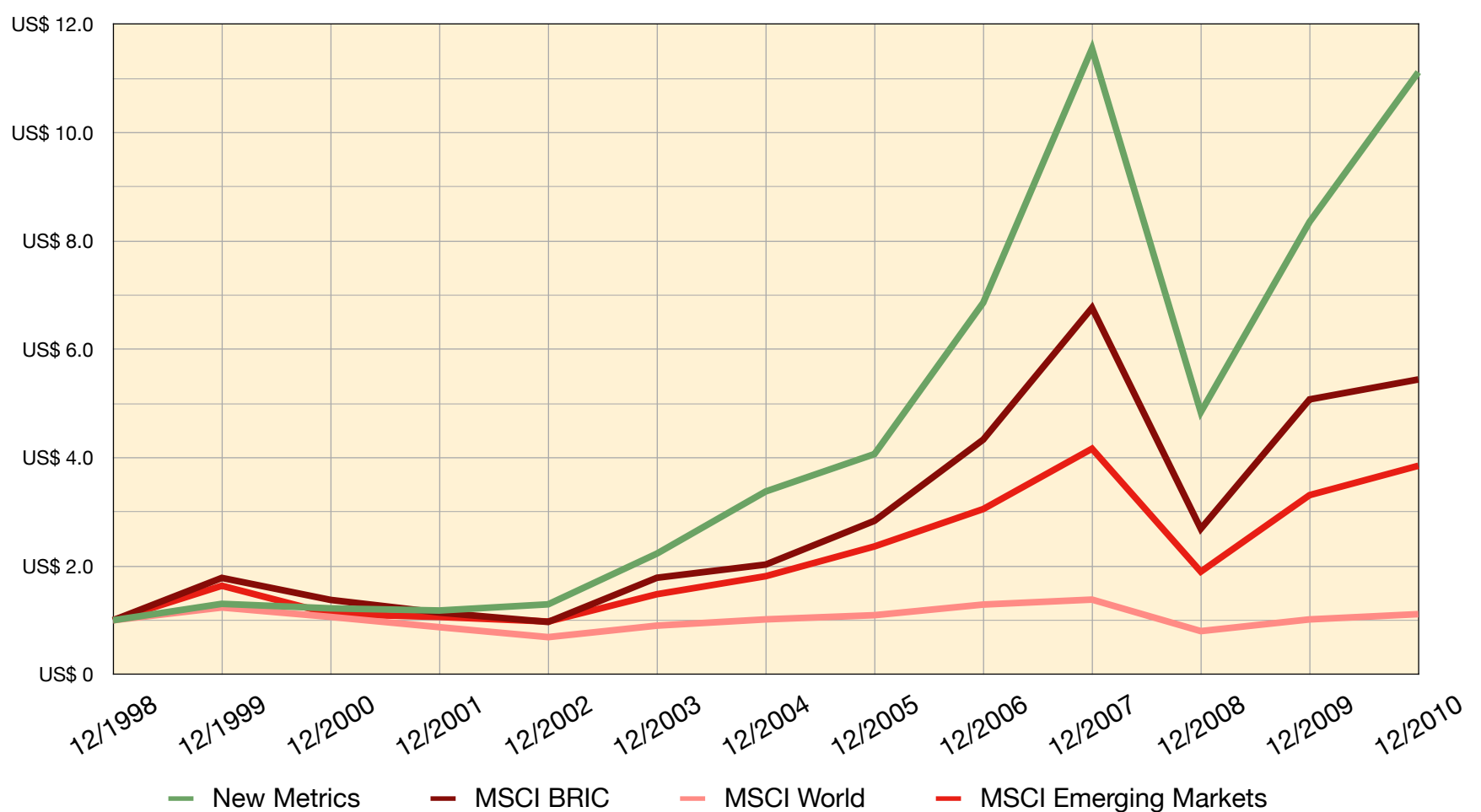
**Modeling and processing economic information can be valuable for Finance forecast even if prices are martingales**

Here we argue instead that, even if all information were *discounted* by prices, the key point is that some information from real Economy drives Finance (the existence of the black arrow in Fig. 11 and 12). Therefore the proper extraction, modeling and processing of those pieces of information coming from Economy and influencing Finance (i.e. what is called Economics in Fig. 12) must necessarily provide valuable information with respect to Finance forecast. Economics - intended as the modeling of the real Economy - and Finance, in this perspectives, must be deeply connected and Finance, somehow, is the playground which represents the empirical realization of Economy<sup>1</sup>. The applications discussed in the following of this section indeed demonstrate that the red arrow exists and that proper extraction and knowledge of information from Economy can be worthy for Finance both in a scientific and business/investment perspective.

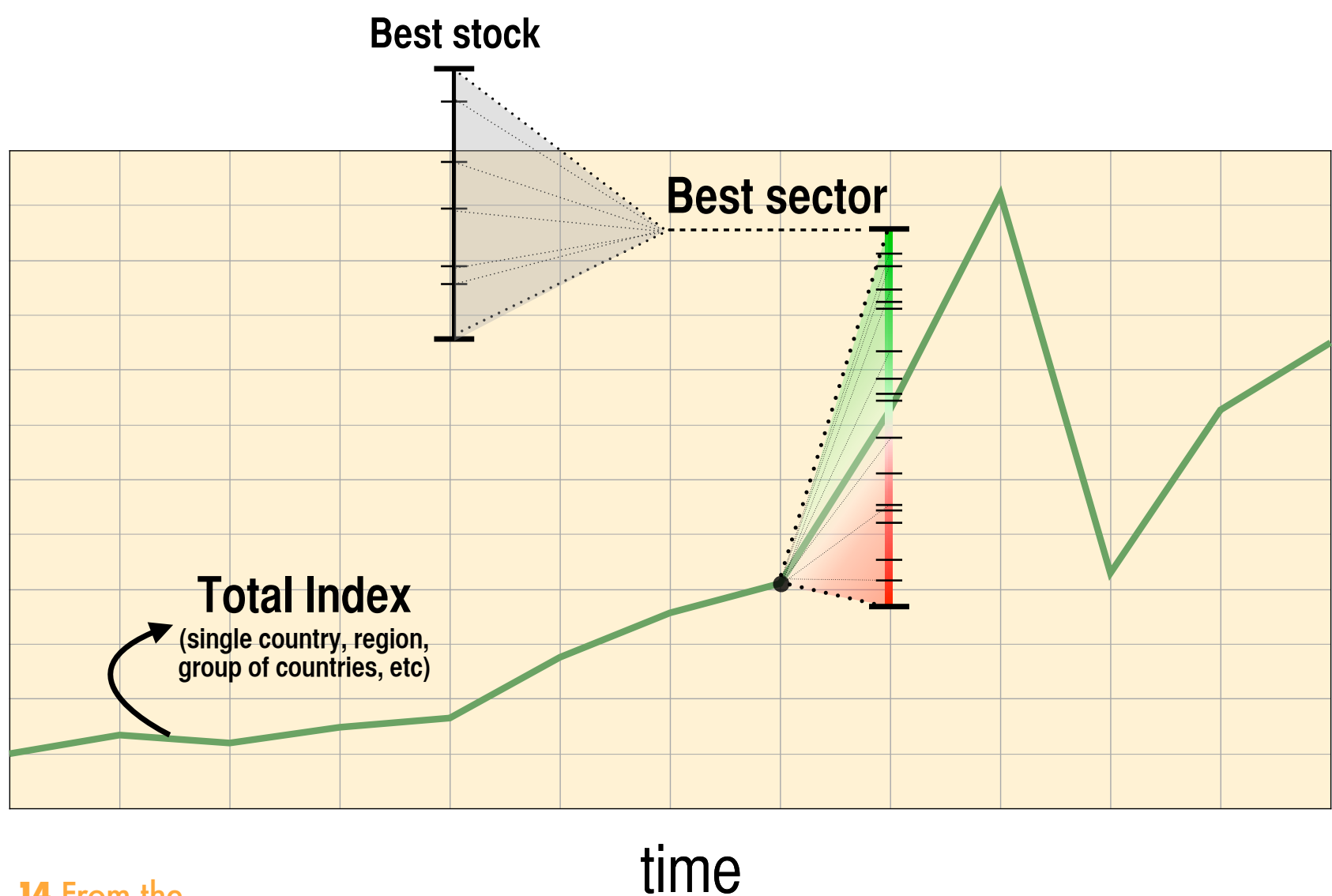
**Fig. 13 Comparison between the Complexity Index and Morgan Stanley Indexes**

<sup>1</sup>It is also worth noticing that according to standard scenario prices should almost always reflect fundamentals and therefore no speculative opportunities should be possible and Finance, as it is nowadays, could not exist. However, in the present presentation we do not discuss this point which has been deeply investigated in the last fifteen years.

### Comparison with Morgan Stanley Indexes







**Fig. 14** From the Complexity Index towards investment strategies

### The Economic Complexity Index: a fundamentally driven Index

In detail, in this presentation we focus our attention on the black arrow of Fig. 11 and the red and blue ones of Fig. 12 discussing how the hidden economic potential of productive systems drives the medium-long term horizon of financial systems

As a reflection of the growing interests in the fundamental drivers for Finance, there is a growing literature and attention in non-market cap driven indexes, in particular fundamentally driven indexes. As a simple exercise, we build an index composed of national index according to the prescription we can develop from the *Selective Predictability Scheme*. The idea grounding such an approach is that in the laminar regime in which fitness is the driving variable for economic growth - especially in the region of frontier and emerging economies (laminar regime below the average line grey area in Fig. 7) - we expect that economic growth (and therefore fitness) is also the driver of the long term growth of finance in these countries. In support of this picture where finance is driven by economic growth in emerging markets, in Fig. 13 we report the performance of the Economic Complexity Index (green line) with respect to a selection of Morgan Stanley Indexes: World, BRIC, Emerging. We observe that in the medium-long run the Complexity Index outperforms even the most aggressive Morgan Stanley index,

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## Sector analysis: from the Economic Complexity Index to investment schemes

i.e. Emerging. The Economic Complexity Index is, in this very first basic implementation, a weighted basket of country indexes from the area in the Fitness-Income plane in which we measure a high degree of predictability and a high expected growth. The composition and the weights are updated each year when the export data are released.

Even in this very simple implementation the Economic Complexity Index points towards a strong evidence for economic growth determining a successive financial expansion in emerging countries where the financial system is not yet mature.

As illustrated in Fig. 14, the analysis can be deepened up to the sector level through the investigation of the patterns of invasion of the Taxonomy Network, the tracking of the time evolution of RCA coefficients of products and in general all the analyses discussed in the previous section can allow to assess the most promising sectors in terms of opportunity and in terms of risk.

This complexity approach permits to identity long term opportunities of growth. Differently from the index definition, any investment strategy based on it must be therefore complemented by standard short time analysis on both financial and economic aspects. As an example, these emerging economies tend to strongly rely on export towards developed countries. As a consequence they can be, in the short scale, very sensitive to fluctuations of the economic cycle. Therefore symptoms of economic recession or lowering of consumptions in western countries may be used as proxies to determine those periods in which a long position on these countries can lead to volatile pattern (see the drop of the Complexity Index in 2008). As a final note, the present methodology can also offer a quantitative measure for sectors which can be useful for investments in non-quoted companies.

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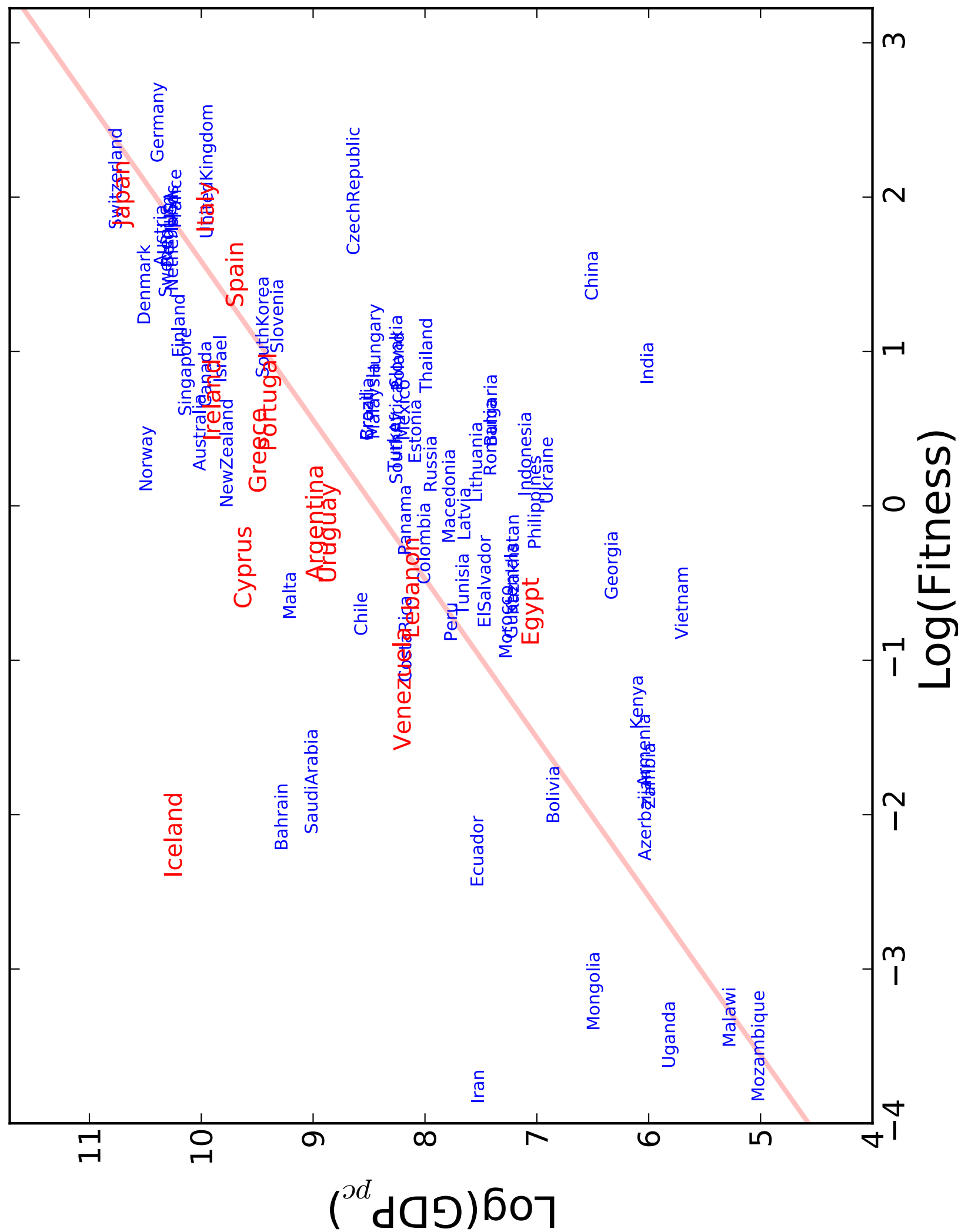
## Not only opportunities but also risk analysis

The Fitness-Income analysis is not only a tool to detect opportunities in the medium/long term but can also provide a risk analysis of economies. Having in mind that long run stability of economic systems is assessed by those intangible assets the fitness is measuring, countries in the chaotic regime or well above the level of expected income given their level of fitness (red line in Fig. 15) are in principle countries for which we are not able to explain the wealth in terms of complexity of the productive capacity. This fact does not automatically and necessarily mean that these countries are risky economies for several reasons

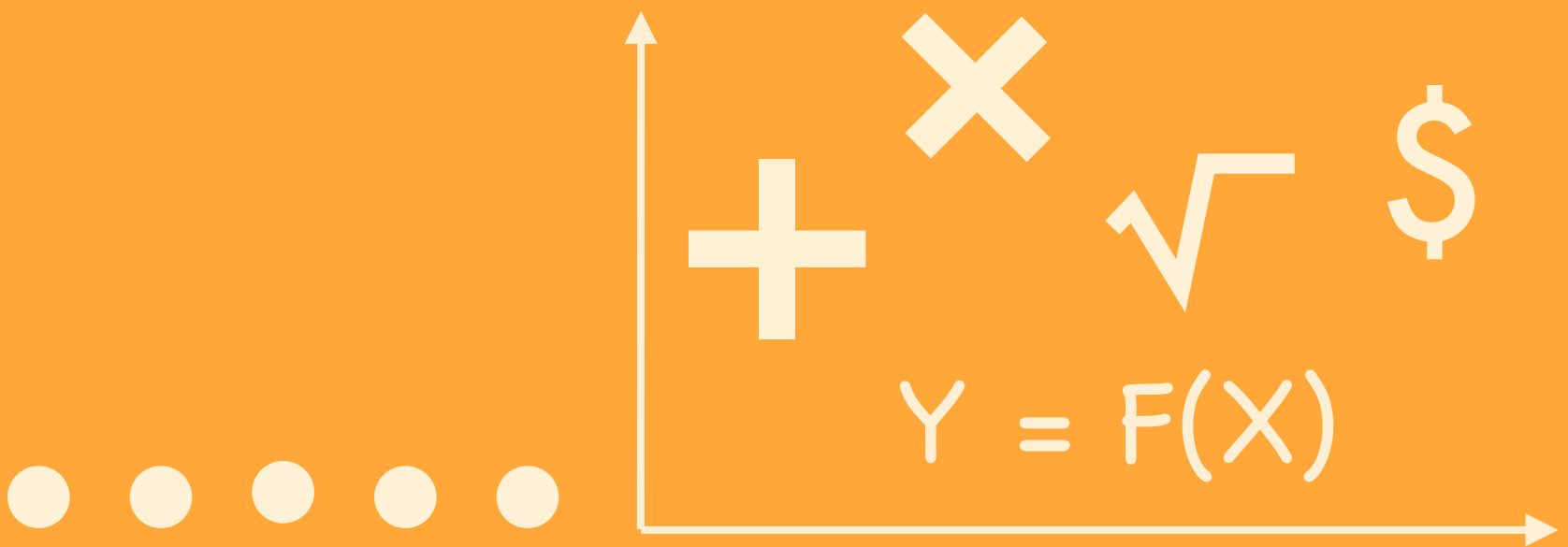
as discussed in the following. They are instead, potential candidate to be risky countries in the very long run. Many of these countries are for instance oil-exporters and therefore, even if they are in very good economic shape today, the method points out a critical dependence on low complexity products. It is worth noticing that Iceland in 1995 was the farthestmost country from the red average line and the method was signaling the risk for this economy, approximately ten years before rating agencies (in 1995 Iceland for a AA debt). The non inclusion of services and finance in our analysis - the fitness is only measuring the productive capacity of a country - can be for some countries the source of the mismatch, however standard economic information completing the present analysis can discriminate these cases.

In support of this body of considerations, we observe that most of the major downrating of sovereign debts in the period 1995-2012 took place in those countries for which fitness is not able to explain the level of income in 1995. The countries well above this red line are countries for which the complexity of the productive systems is not able to sustain the level of wealth they have in the long term. The origin of this mismatch can be due to several reasons such as strong dependence of the GDP on primary materials or on finance and services. However, this analysis allows for a criterion to underpin the potentially risky countries while complementary standard economic analyses permit to sort which economies have concrete criticality as Iceland in 1995 or, given the present scenario, Gulf countries when energetic scenarios will change.

**Fig. 15** Fitness-Income plane in 1995. In red we report major downrating of sovereign debt in the following 17 years



# APPENDIX



## APPENDIX

### 1.Dataset

In the present analysis we used data extracted from the BACI dataset. In this dataset we have trading data about more than 200 countries and 5000 products classified according to a six digit code (categorization: Harmonized System 2007). We coarse-grained such classification by considering only the first 4 digits, obtaining a set of about 1200 products and 150 countries. Data are collected by national customs and released by United Nations with a delay of approximately 1 year, for instance export data of 2012 for all countries will be released at the beginning of 2014. However, in principle a partial estimate of fitness and complexity with less than 1 year of delay can be given since, typically, reports from a significative fraction of countries are available before the end of the year from UN website. It is worth noticing that the raw data released by UN require a non trivial pre-processing in order to correct errors and inconsistencies present in the dataset by means of statistical methods.

### 2.RCA and binary matrix

The matrix  $M$ , whose elements are  $M_{cp}$ , is built by transforming the flows  $q_{cp}$  of US Dollars into unweighted links between countries and products. The criterion adopted in order to understand

whether a country can be considered or not a producer of a particular product is the so-called Revealed Comparative Advantage (RCA) which is the fraction of export of the product  $p$  by country  $c$  with respect to the global export of  $p$  done by all countries. This quantity is then divided by the fraction of the total export of  $c$  with respect to the whole world export. In order to build the binary matrix  $M$  from the  $RCA$  matrix, we consider  $M_{cp} = 1$  if  $RCA_{cp} \geq 1$  and zero otherwise.

### 3.Extensive fitness

The extensive metrics is simply obtained by replacing in the equation defining the algorithm the matrix  $M$  with the weighted matrix  $W$  whose elements  $W_{cp}$  ranges from 0 to 1 and are defined as  $W_{cp} = q_{cp} / \sum_c q_{cp}$ . According to this definition the weight  $W_{cp}$  is the fraction of export of product  $p$  held by the country  $c$ .



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