ECONOMIC COMPLEXITY

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MEASURING THE INTANGIBLES

A CONSUMER'S GUIDE

ECONOMIC COMPLEXITY MEASURING THE INTANGIBLES A CONSUMER'S GUIDE

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Economic Complexity

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, patters of evolution of productive systems which must impact finance in the medium/long term.

MEASURING THE ECONOMIC COMPLEXITY

The increasing interconnectedness and the growing complexity of economic and financial systems pose a growing challenge to mainstream economic theories. The subprime financial crisis, the economic recession that followed, and the slow recovery from stagnancy have dramatically demonstrated the need for a paradigm shift in economic thinking. Such new economic thinking must, in contrast to the current approach, be data-driven and falsifiable if it is to be capable of testing economic theories. Present economic theories are increasingly seen to be global and ideological paradigms which compete against each other. We conjecture that a more scientific foundation of economic thinking instead will lead to a scenario in which the effectiveness of differ-
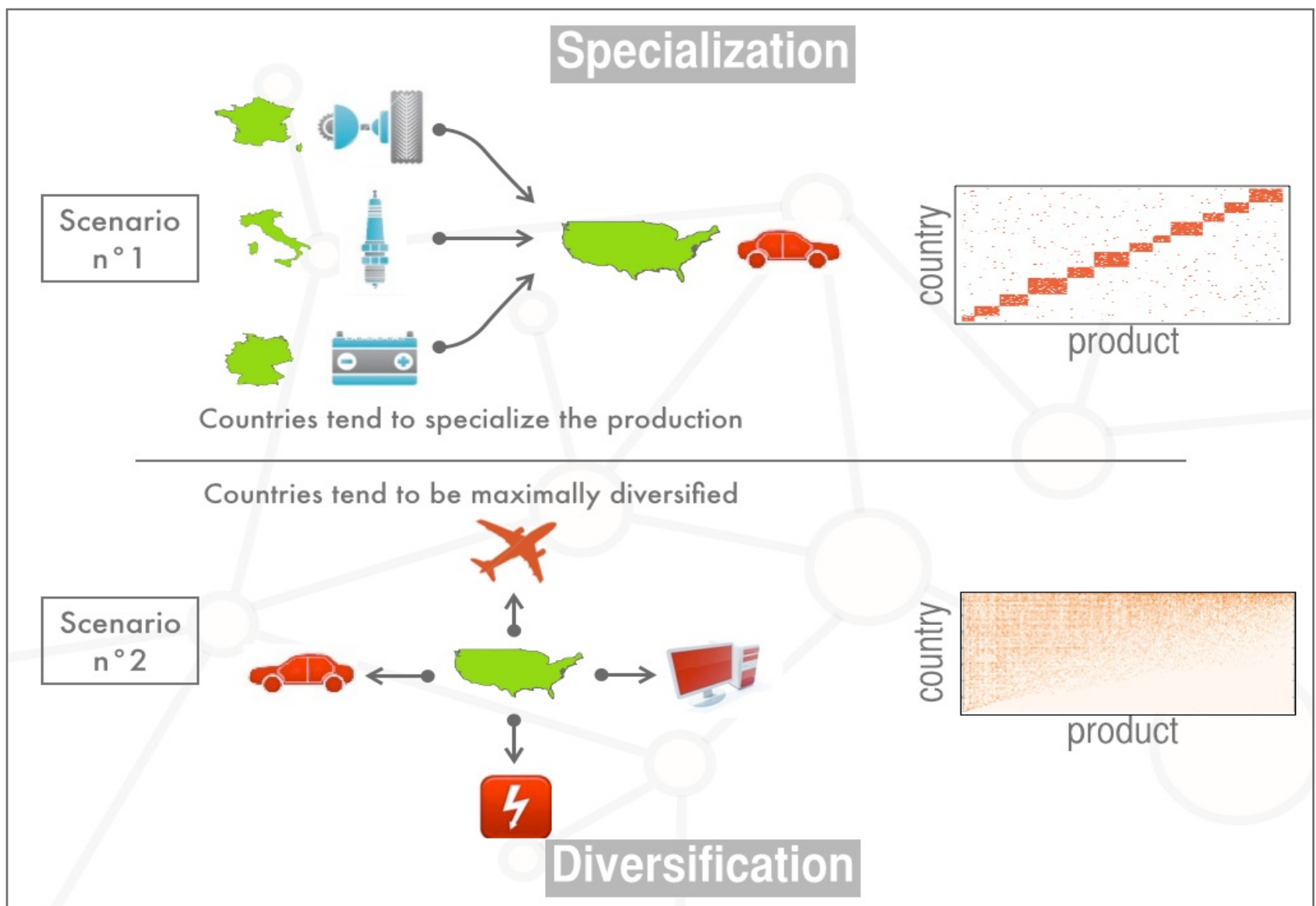
Fig. 1 Specialization vs Diversification

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

ent economic theories will depend on the specific regime of the economy as it happens for Natural Sciences. In this new perspective, concepts such as market efficiency and the degree of coupling between finance and economy could be tested and quantitatively assessed. In this perspective a crucial element is to empirically understand and measure the state of an economy in order to determine the most appropriate approach for that specific state. Using a medical metaphor, we need tools and methodologies to diagnose the economic state, and in light of this to choose the most appropriate protocol.

In the spirit of this new approach, we focus on the fundamental economic growth of countries, and introduce a new framework to measure the competitiveness of countries and the complexity of products [1-5]. These two measures represent an intangible information of country competitiveness and product complexity and the comparison with monetary figures, such as the gross domestic product, allows us to identify the hidden and future potential for growth. Both metrics are 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
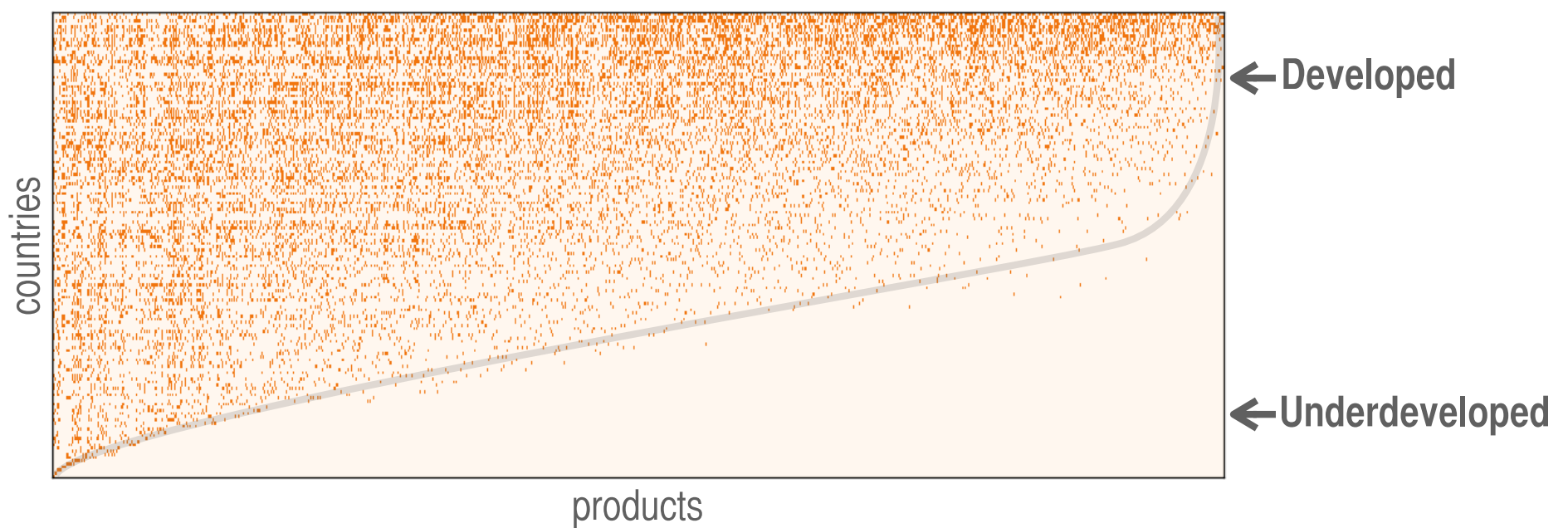
← **Developed**

←**Underdeveloped**

products

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

to uncover medium- and long-term investment opportunities, especially in frontier and emerging markets.

Traditional economic approaches, such as the Ricardian paradigm, predict that most successful countries should specialize in those 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 by each country of each product (expressed in US dollars). This data can be organized in a matrix in which rows represent countries while columns represent products. Therefore in such a matrix each entry M_{cp} specifies the export of product p of country c. Since we are interested in non-monetary and intensive metrics for a country's 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, we set $M_{cp}=0$. Ricardian theories would predict a block diagonal matrix corresponding to the concentration of the productive system on a few products (see the top panel of 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 production (see 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 quantitive by measuring

the nestedness of the matrix. We find a value significantly different from 0 which is the value we would have measured in the case of a non-nested matrix (i.e. economically speaking in the case of specialization). Therefore diversification appears to be the key to characterizing the competitiveness of countries, in contrast to what would be expected from standard approaches. In analogy with biological systems, in a swiftly changing environment (such as the present globalized economy), it is diversification rather than specialization that appears to offer flexibility and robustness with respect to innovation and dynamic competitors. Consequently, it is diversification that drives the long-term competitiveness and success of countries.

A detailed investigation of the economic foundation of the triangular and nested structure of the country-product matrix is beyond the scope of this paper. Indeed, we are currently studying this presence of this structure as a line of research in its own right.

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 system of production: 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 particular, this non-trivial structure implies the following about the complexity of products and the competitiveness of countries:

(i)   that a randomly chosen product is produced by a diversified country conveys little information about this product, because we expect such a country to produce a large fraction of the possible products;

(ii) on the other hand, that a randomly chosen product is produced by a poorly diversified country makes it likely that, due to the nestedness of the system, the product requires a low level of sophistication;

(iii) that a randomly chosen country produces a widely produced product (and therefore an unsophisticated product) is largely irrelevant

to the competitiveness of the country, as ubiquitous products are exported, by definition, by most countries;

(iv) on the other hand, that a randomly chosen country produces an exclusive product implies that the country is competitive (the triangularity of the matrix implies that only highly diversified - and presumably developed - countries can export the most exclusive products).

From a mathematical point of view, the nested structure calls for a strongly non-linear and extremal coupling between the level of sophistication of products (hereafter Q, the complexity of products) and the competitiveness of countries (hereafter F, the fitness of countries). Consistent with this 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 which we want to include in our algorithm. On the one

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

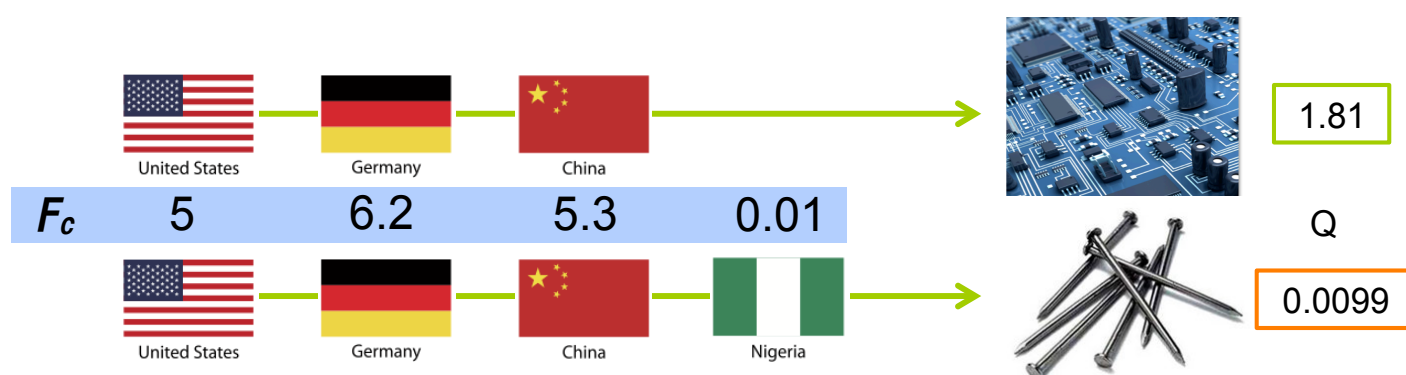| Fitness of Countries	Complexity of Products
$$\tilde{F}_c^{(n)} = \sum_p M_{cp} Q_p^{(n-1)}$$ $$F_c^{(n)} = \frac{\tilde{F}_c^{(n)}}{\langle \tilde{F}_c^{(n)} \rangle_c}$$	$$\tilde{Q}_p^{(n)} = \frac{1}{\sum_c M_{cp} \frac{1}{F_c^{(n-1)}}}$$ $$Q_p^{(n)} = \frac{\tilde{Q}_p^{(n)}}{\langle \tilde{Q}_p^{(n)} \rangle_p}$$

F_c: diversification weighted by complexity

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

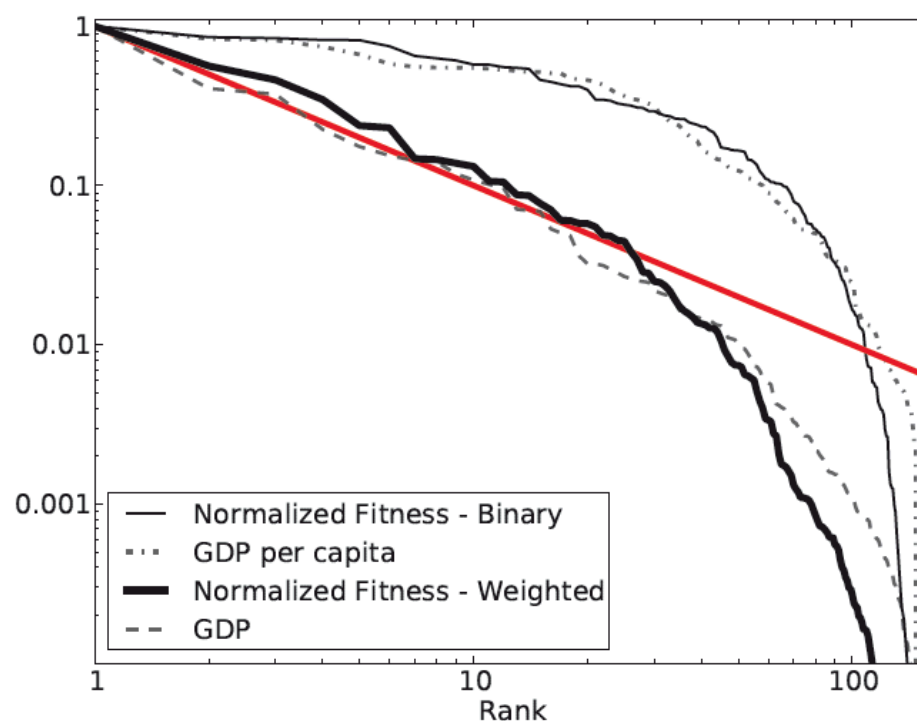|	United States	Germany	China	Nigeria		
						1.81
F_c	5	6.2	5.3	0.01		Q
						0.0099

hand, the more ubiquitous a product, the less complex it is likely to be. On the other hand, the need of extremal coupling results from the observation that the complexity of a product must be driven (and bounded) by the fitness of the worst producer. As illustrated in the bottom panel of Fig. 3, let us consider two products, chips and nails, which differ by only one producer which is poorly competitive (namely, Nigeria with a 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.

The algorithm combines iteratively successive measures on matrix rows and columns, in a spirit comparable to Google's PageRank, refining at each iteration the information for F and Q. However, unlike Google's method - at least in its original manifestation - in the present case we deal with a bipartite network (the world wide web instead is a mono-partite network), and the nested structure requires a strong non-linearity (PageRank in contrast is a linear algorithm). The metrics for country fitness and product complexity is defined as the fixed point of these coupled equations which are obtained self-consistently and asymptotically by the iteration of the maps reported in Fig. 3. It is possible to show the unique-

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

Fig 4 Rank plot for intensive and extensive fitness.

Normalized Fitness - Binary
GDP per capita
Normalized Fitness - Weighted
GDP
Rank

ness 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 new non-monetary and non-income based metrics which measure 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. In this figure we also report an extension of the fitness (weighted fitness in Fig. 4) 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 coherent formulation with respect to the empirically-derived economic principles of the nested country-product matrix. In principle, these formulae can be generalized but a more refined body of data is needed in order to to set proper benchmarks to test generalized formulae for the measure of country competitiveness and product complexity.
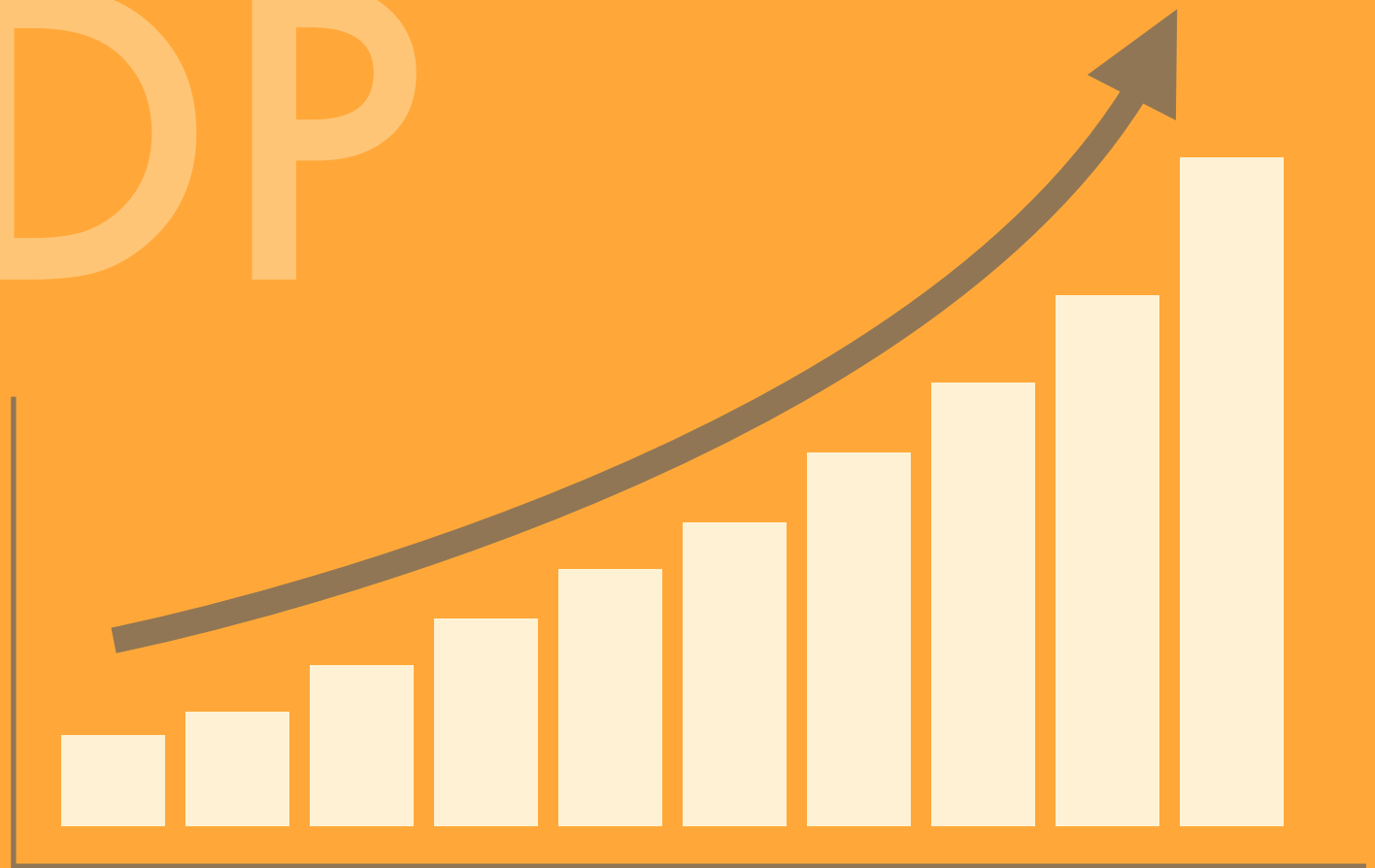
HETEROGENEOUS DYNAMICS OF COUNTRY GROWTH

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 section we focus on the complexity of products [1,2,6].
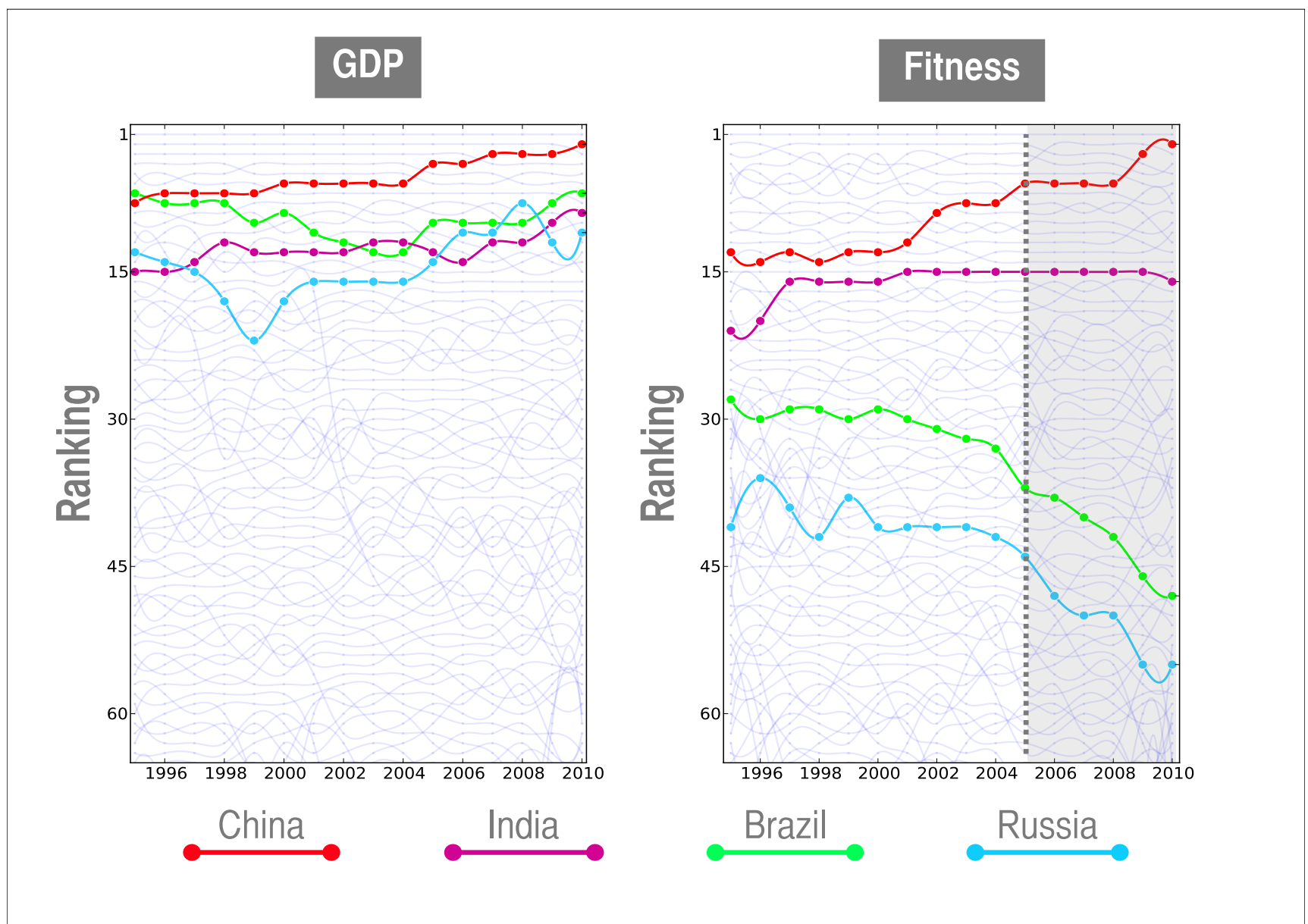
As previously discussed, the fitness of countries, especially in its intensive version (i.e., binary country-product matrix), represents a non-monetary assessment of the level of complexity of a productive system. In fact the method discussed in the previous section is an analysis of what a country is able to produce. We want to point out that such 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 descriptor about a specific economic system, but the key to understanding 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 the 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 from a GDP-based analysis.

The expression BRIC countries was first used in a report of Goldman Sachs in 2001 to indicate the countries Brazil, Russia, India and China, which were supposed to dominate the world economy by 2050. The 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 (BR) would have highlighted the different development paths of BR with respect to India and China (IC) 10 years in advance. Only the latter are undergoing an industrial and technological development and in general increased complexity of their economy in the last 15 years. While for Russia, even standard analyses clearly spot a growth strongly relying on the primary sector, the future growth perspectives of Brazil are now hardly debated and only in the last few years some reports considered the scenario in

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

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

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

While for Russia this analysis is not surprising, the analyses of 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 BRIC report. 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 overcoming the competitiveness of all Western countries. Russia fitness is instead falling, revealing that Russian GDP growth is largely fueled by the price bubble of fossil raw materials. However, the most valuable information emerging from our fitness analysis is the evolution of the Brazilian competitiveness because of very different behavior with respect to monetary information. Brazil's competitiveness shows a behavior similar to Russia's. 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 the export of primary products.

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

More accurate analyses of the export volumes confirm that Brazil is becoming 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. By country spectroscopy we mean 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 the next section for further details about country spectroscopy).

The key point is that our method is able to highlight the decreasing trend of Brazil at least 5-10 years in advance with respect to the standard analysis of and common wisdom on BRIC countries. As a final observation, we see that India, after a strong growth between 1995-2000 shows a constant competitiveness rank. We conclude that India ap-
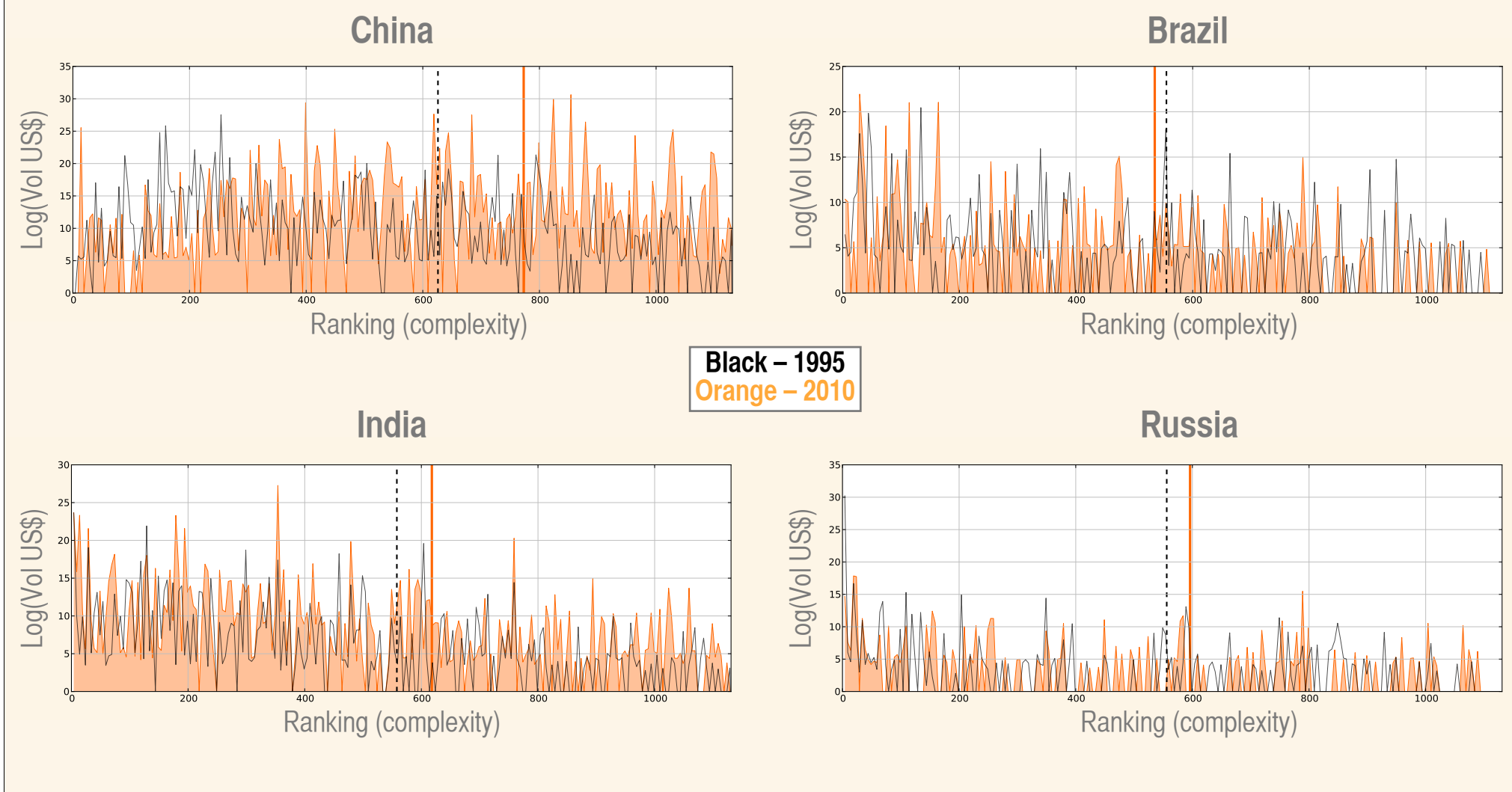
China

Brazil

Black – 1995
Orange – 2010

India

Russia

2. The Selective Predictability Scheme: the weather forecast for economics.

pears to exhibit a deceleration 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 forecasts? 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]. Nevertheless, addressing this question would have a large societal impact and significant value for economic policy making. One of the principal and ultimate goals 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, GDP, inflation rate, and so on, in order to provide criteria and indicators for economic interventions, stimuli and growth incentives.

Is our method able to offer indications in this direction and provide a scientific basis for economic forecast? Moreover, what, concretely, will be the growth of the GDP and the competitiveness of China, the USA, Vietnam and Sierra Leone in the next 10 years? The answer is '*it depends*':

14

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
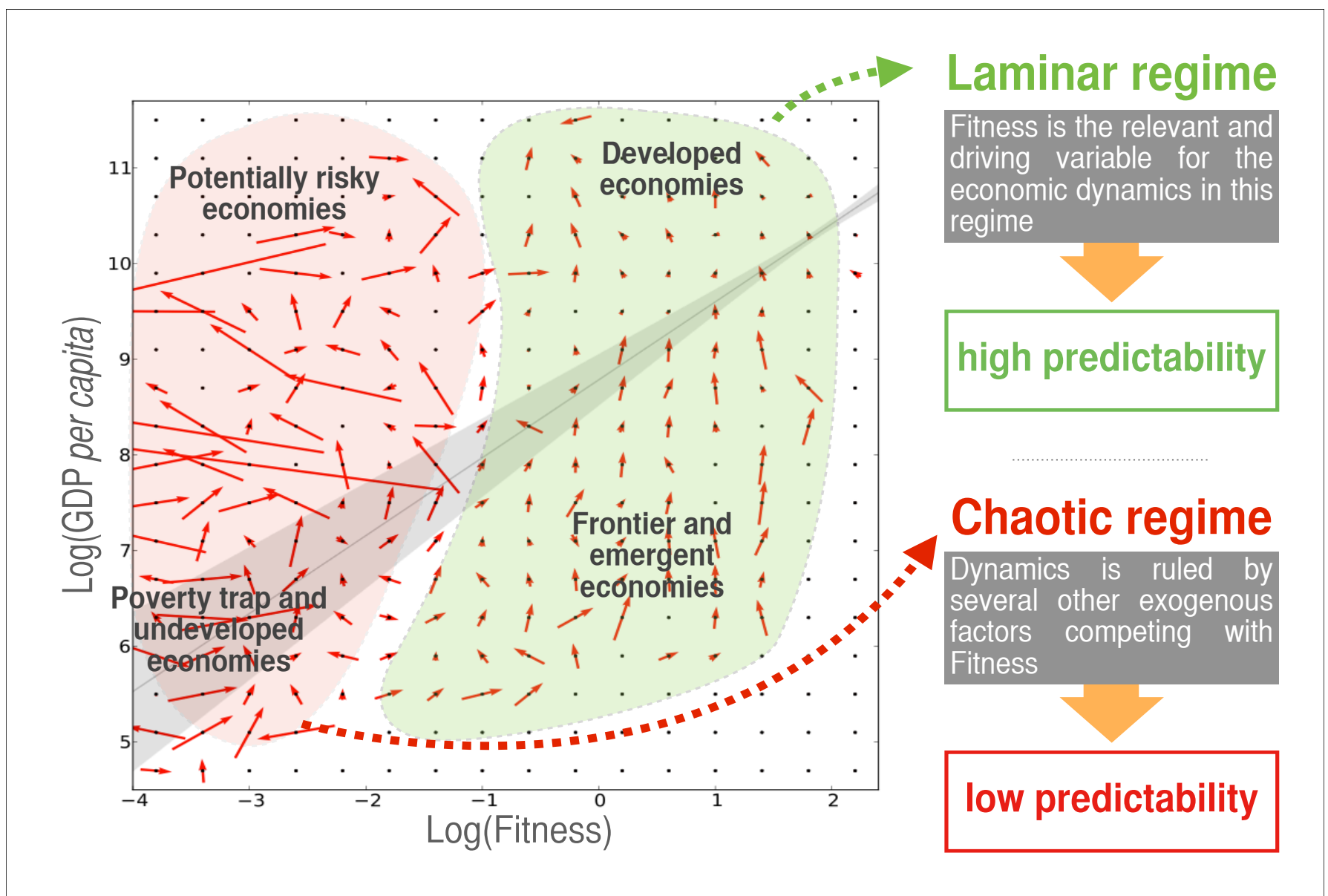
low predictability

Fig. 7 Heterogeneous dynamics of country evolution in the fitness-income plane.

Forecasting country growth faces hurdles not dissimilar to those in weather forecasting.

predicting the evolution of fitness and income is strongly dependent on the regime a country occupies. There exist economic regimes for which the fitness is able to effectively uncover the hidden potential of growth of countries. Forecasting country growth faces hurdles which are similar those found in predicting dynamical systems (i.e., the atmosphere, climate, wind and ocean dynamics). On this account there is 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 the fitness-income plane, as illustrated in Fig. 7. Depending on 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 at least informative, of country growth; and a chaotic regime in which the fitness is poorly or completely uncorrelated with the evolution of the wealth of those countries.

This empirical observation calls for a completely new framework for the predictability criteria, in which we recognize that standard regression-based approaches are not the appropriate tools to address heterogenous growth dynamics. In fact the underlying hypothesis when a regres-

sive 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 are 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 which we do not know the equations of motions (i.e., the rules for evolution) of the system. We borrow concepts and methods suitably adapted from dynamical systems theory to give a new scientific grounding to the 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 first introduced by Lorenz in 1969.

This approach for economics is called the *Selective Predictability Scheme* and was first introduced in [3]. The key advance of this new framework for economic forecasting is that the degree of predictability 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, in the medium- and long-term 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 GDP. In the chaotic regime, 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- and long-term financial strategies, especially in emergent or frontier markets.

PRODUCTS

Q=3.9

?

Q=0.1

Q=1.3

2.0 GHZ

Q=4.2

Q=4.6
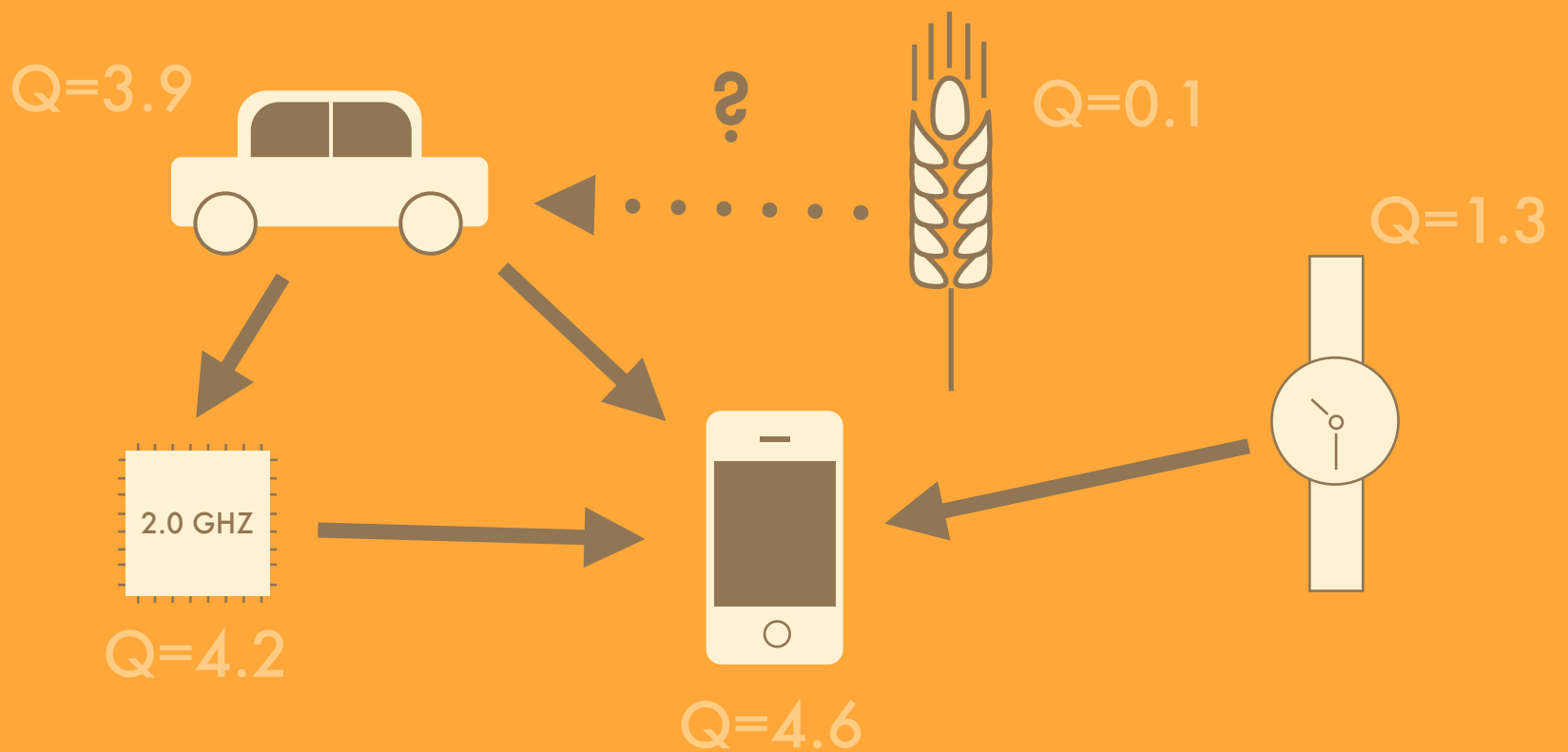
WHAT IS THE PRODUCT COMPLEXITY? HOW ARE PRODUCTS CONNECTED?

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? It is a proxy for the level of sophistication and technology required by a specific product. Consequently the complexity is, as in the case of fitness, a novel measure; we are not aware of the existence of economic indicators for the complexity of products which do not rely on monetary estimates. A standard measure adopted is the market value of products; however, this quantity suffers from strong bias due to market speculation, labor costs, etc. While it is reasonable to believe that products characterized by a high complexity are likely to have high market prices, it is easy to find striking counterexamples where simple products have anomalously high prices, for instance the 17th-century tulip mania. The complexity of products can be interpreted as a new synthetic indicator which enables us to quantitatively assess the complexity of products in a non-monetary and non-market oriented way.

In this respect a large variety of analyses can be performed: detailed analysis of the export basket of countries, relative strength/weakness of countries with respect to the export of specific products and indices to quantify the complexity of economic sectors. In addition, in analogy to the evolution of country fitness, it is pos-
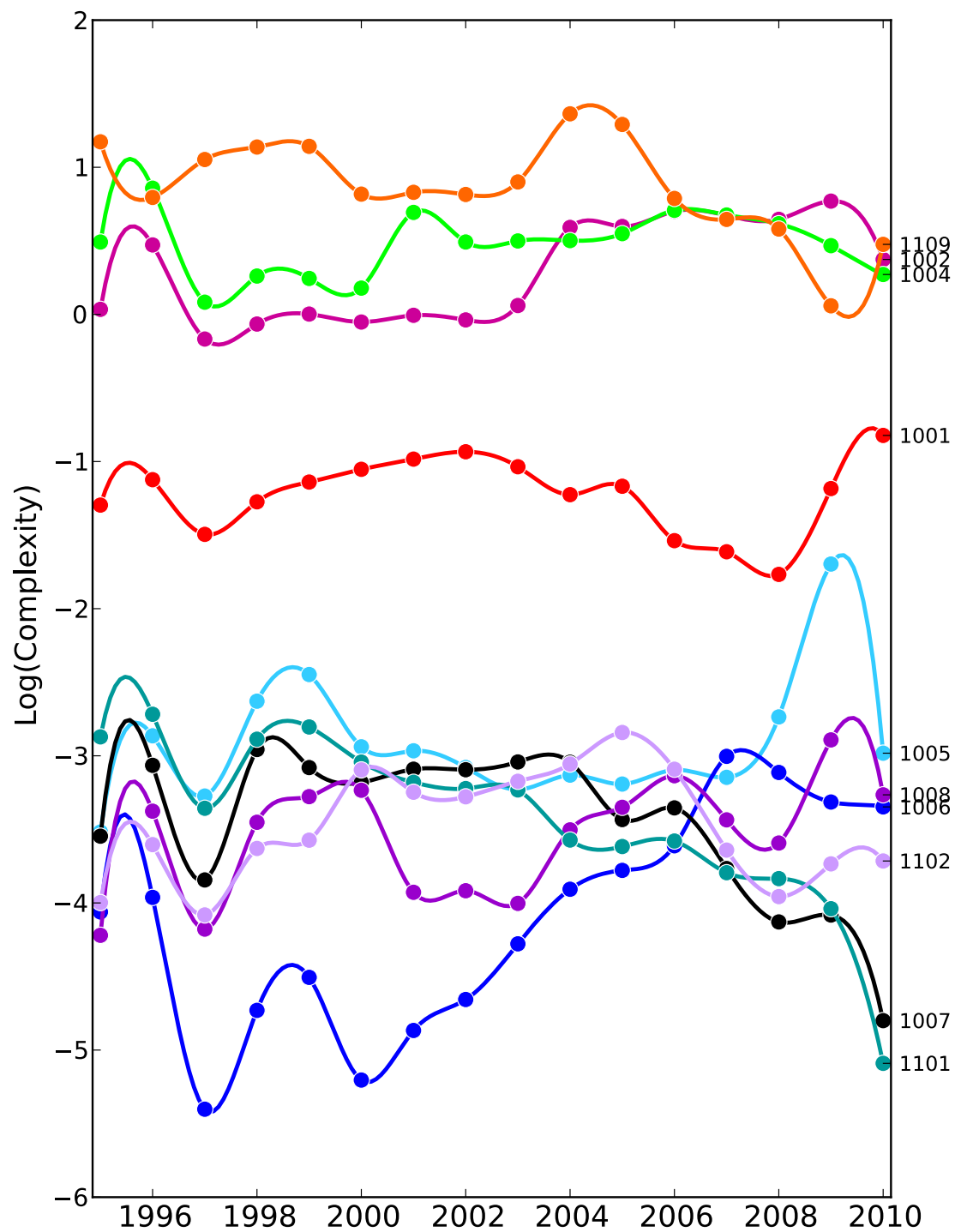
Fig. 8 Evolution of the complexity of cereals in the period 1995 - 2010.

HS2007 code	Description of the product
1001	Wheat and meslin
1002	Rye
1004	Oats
1005	Maize (corn)
1006	Rice
1007	Grain sorghum
1008	Buckwheat, millet and canary seed; other cereals
1101	Wheat or meslin flour
1102	Cereal flours other than of wheat or meslin
1109	Wheat gluten, whether or not dried

sible 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.
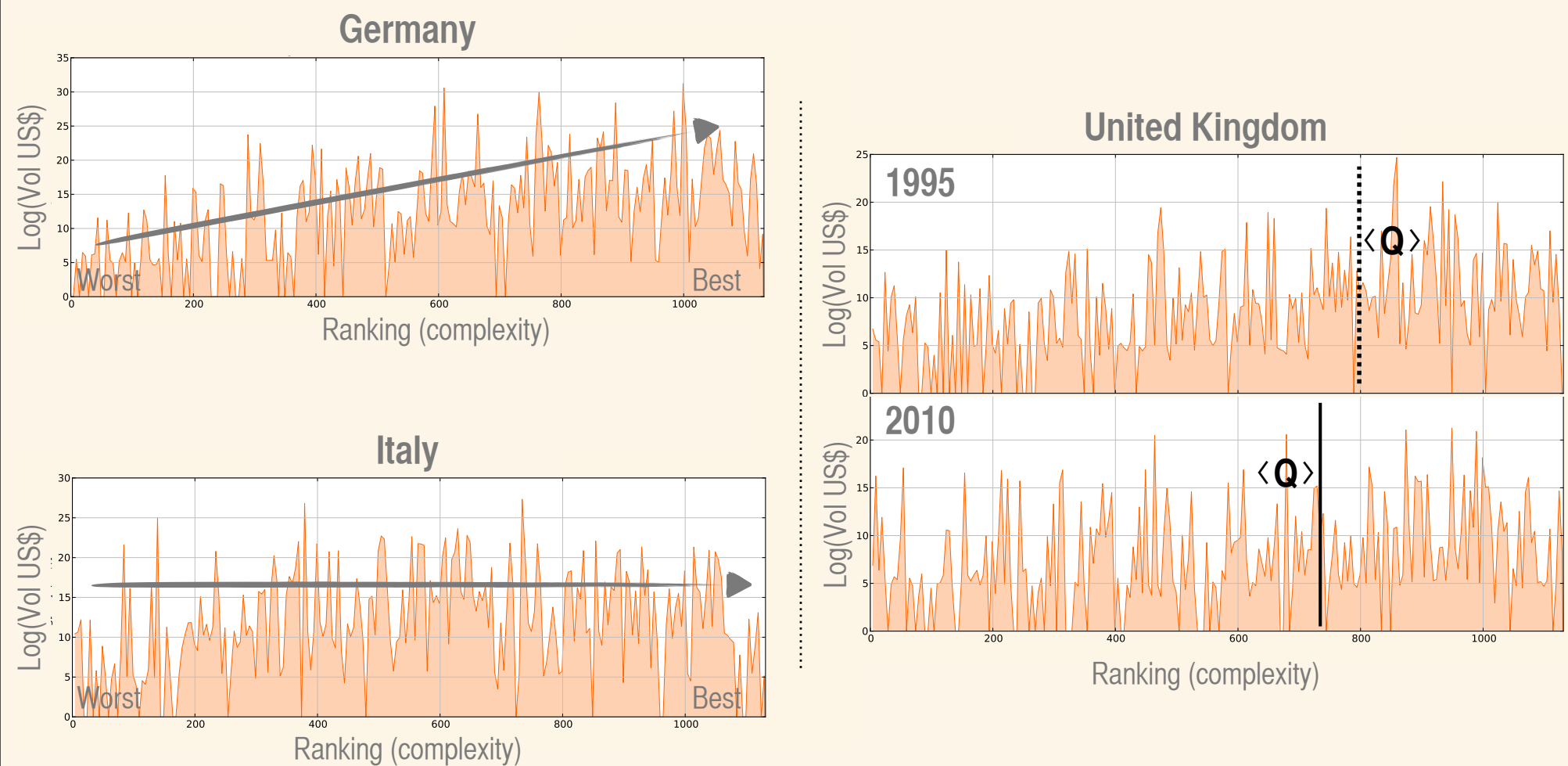
Fig. 9 Country spectroscopy.

As an example, in Fig. 8 we report the time evolution of the complexity for a selection of cereals from 1995 to 2010. Cereals are found 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 ($Q \sim 10^{-4}$ - 10^{-3}). 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, we find these two cereals are typical of developed rather than subsistence economic systems because they are usually used in livestock 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, unlike 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's 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 and 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 like the Italian one, but more oriented 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 also be represented using the complexity itself instead of the complexity rank of products as the x-axis in order to highlight the distance among products in which a country has significant export. The spectroscopy is also a powerful tool to track the structural changes in-

Fig. 10 Portion of the taxonomy network for Sweden. Green circles correspond to occupied products by Sweden, red to unoccupied.
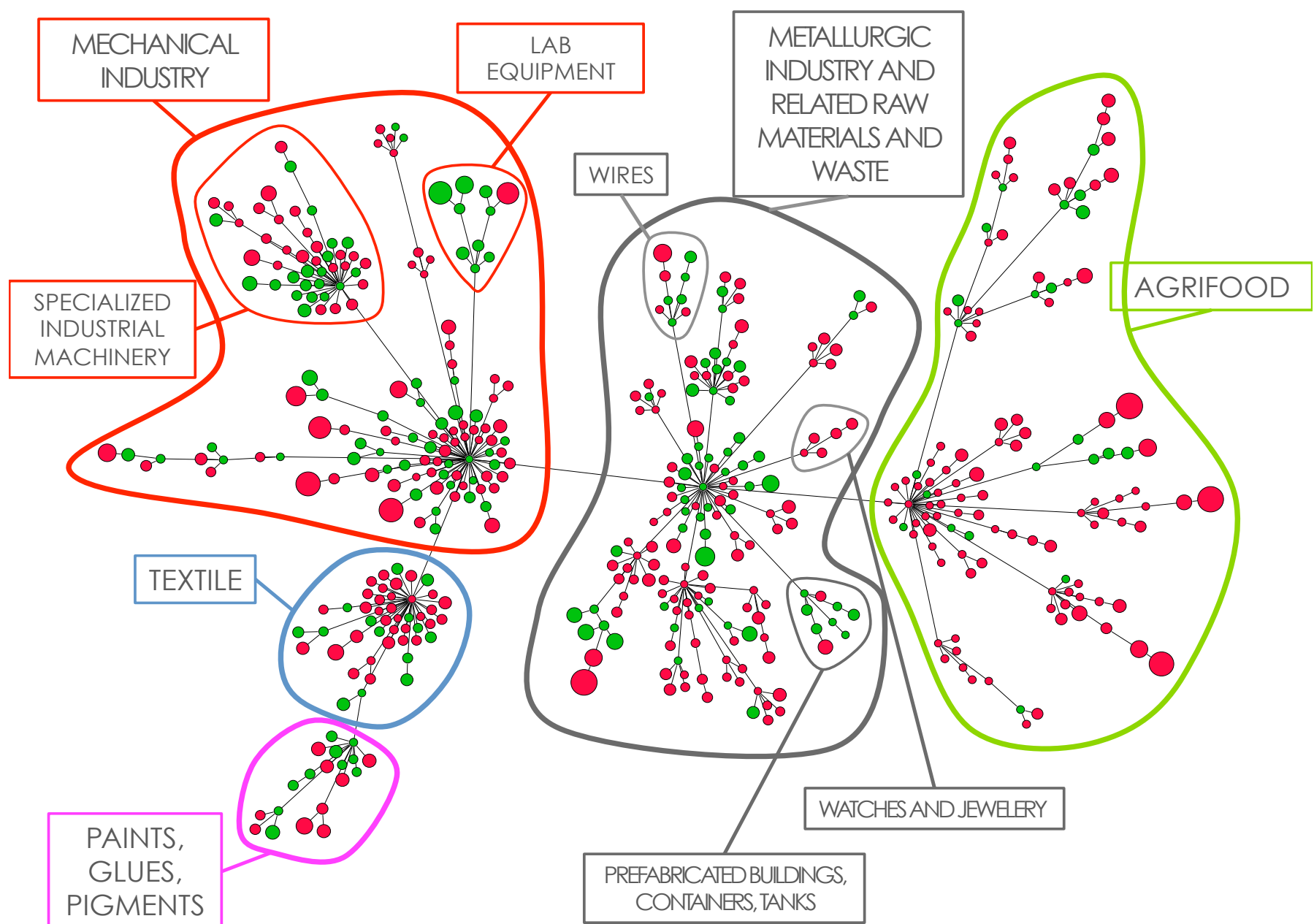
The taxonomy of
products: following the
dynamics of invasion of
the network of
products.

side a country along time, as demonstrated by the right panel of Fig. 9, where we show the 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, illustrated in Fig. 10. A first non-trivial result of this network is a bottom-up classification of products in sectors different from the top-down approach used for product categorization like the harmonized system.

However, the 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 indicate 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 in 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 in these communities, so an effort to develop further competitiveness in this set of goods is advisable.

The taxonomy of products, the country *Spectroscopy* and so on can be used from the perspective 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 pp. 20-22 of Ref. [6]). It is also useful from 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
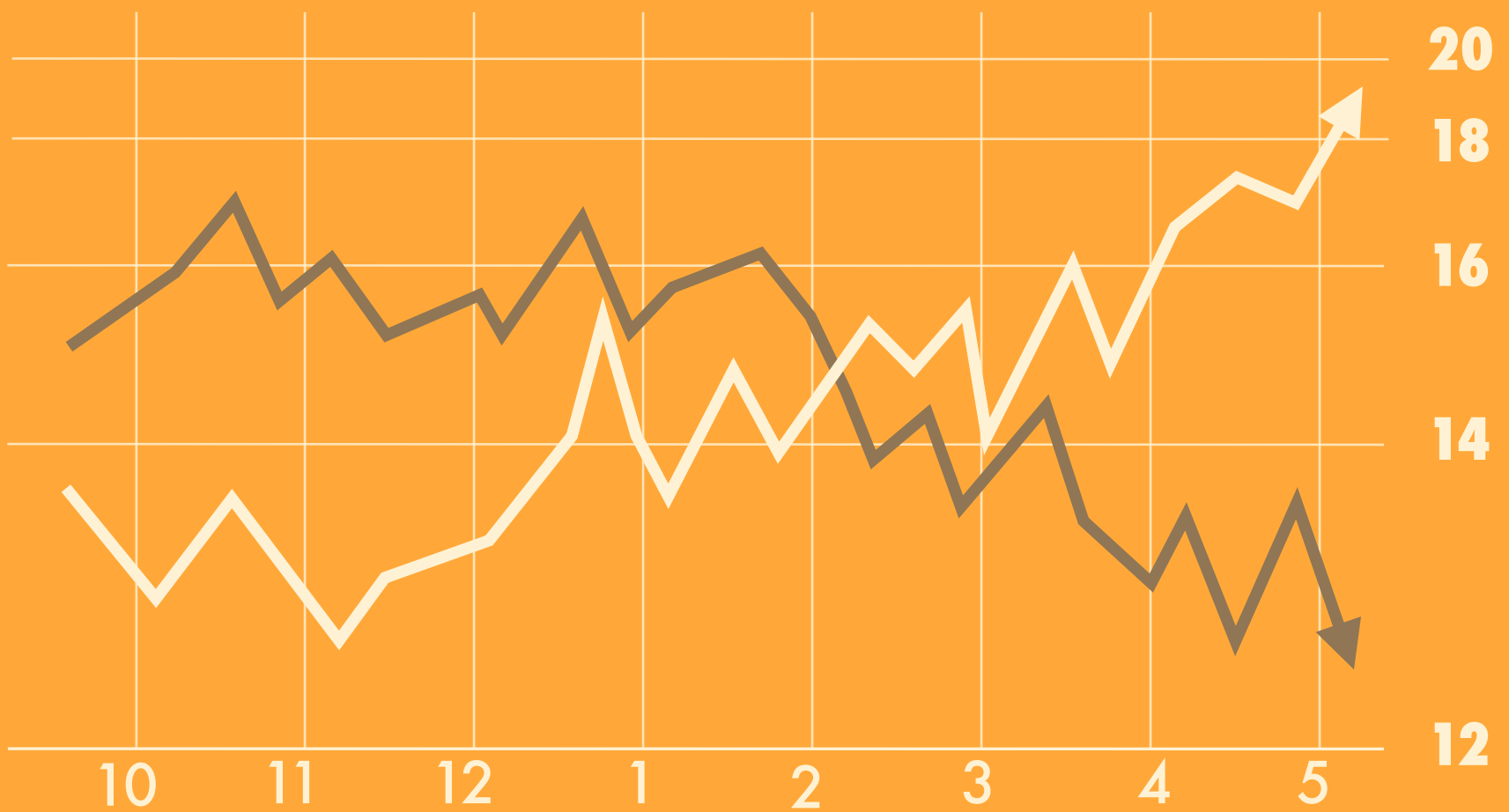
ECONOMIC COMPLEXITY INDEX: HOW FUNDAMENTALS DRIVE FINANCE

Are financial and economic systems coupled or not? Is the economy driving finance (in the long term) and, if so, how? Can financial fluctuations affect the economy and fundamental prices?

While to some extent the driving role of the economy for finance is compatible with standard approaches - at least in the long-term (black arrow in Fig. 11) - curiously mainstream theories do not predict any coupling between finance and the economy (orange arrow in Fig. 11) and finance and economics (red arrow in Fig 12).
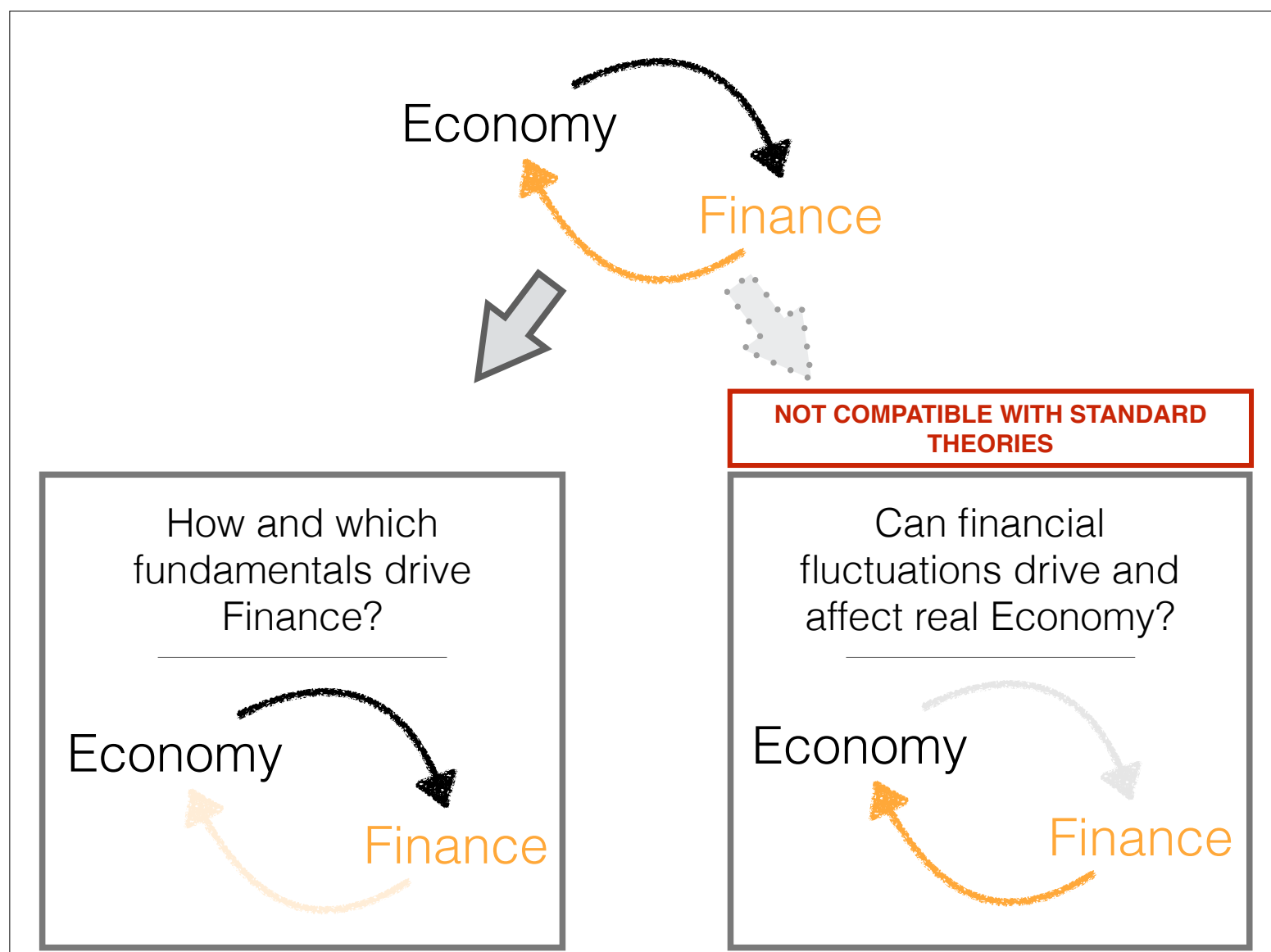
Fig. 11 The coupling between economy and finance.

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 then 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 evidence and arguments appear to point in the direction of financialization of the real economy (the orange arrow of Fig. 11), as for example in commodity prices and the speculation on sovereign debt.

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*
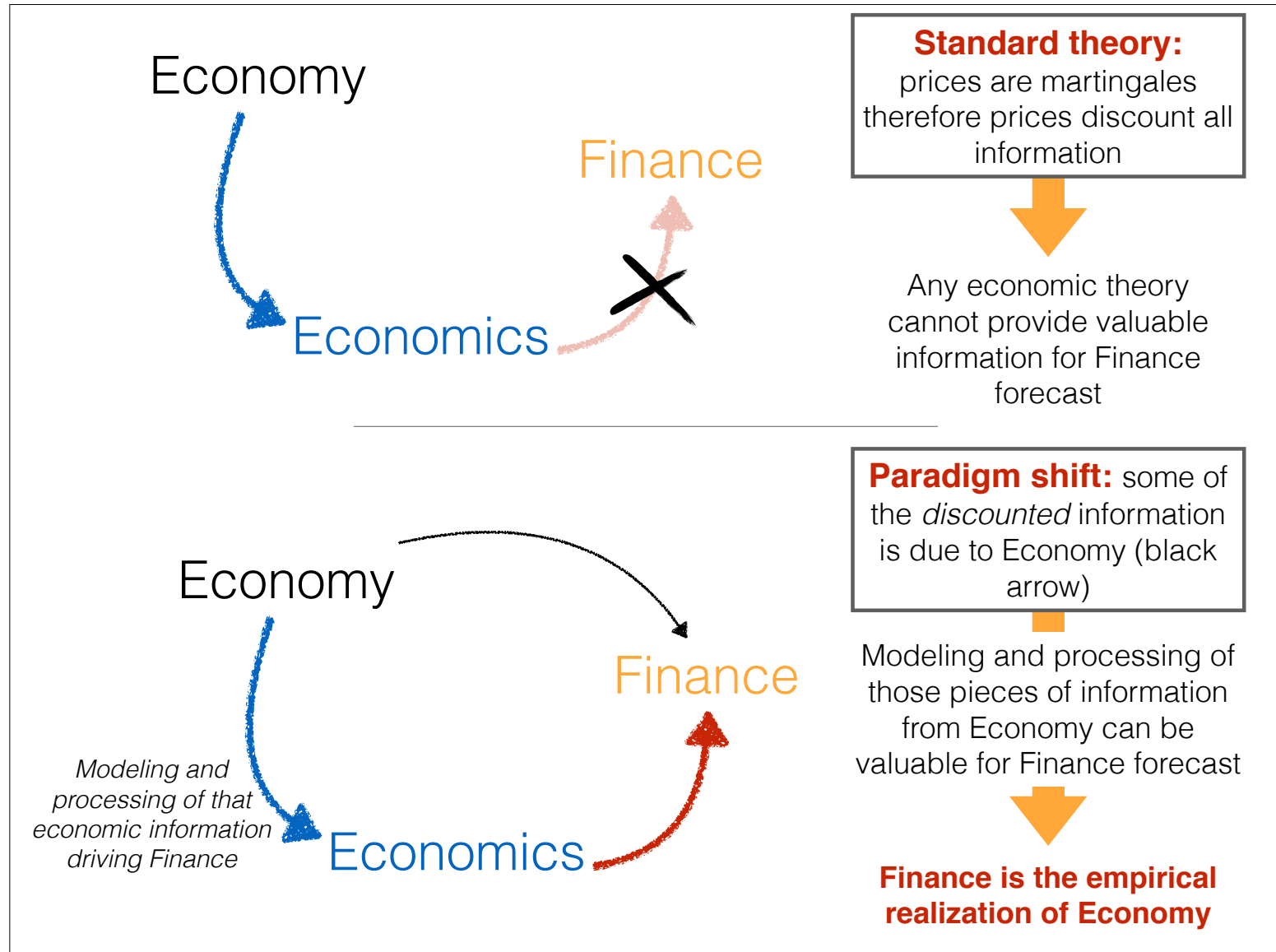
Standard theory: prices are martingales therefore prices discount all information

↓

Any economic theory cannot provide valuable information for Finance forecast

Paradigm shift: some of the *discounted* information is due to Economy (black arrow)

Modeling and processing of those pieces of information from Economy can be valuable for Finance forecast

↓

Finance is the empirical realization of Economy

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 aspects 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.

Modeling and processing economic information can be valuable for finance forecast even if prices are martingales.

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 a model of economic information, therefore should be completely decoupled from finance and this is witnessed by the almost complete absence of interaction between the economic academic world and the finance world.

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 perspective, must be deeply connected and finance, somehow, is the playground which represents the empirical realization of economy[1]. The applications discussed in the remainder 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 Indices.

[1]It is also worth noticing that according to the 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

Best stock

Best sector

Total Index
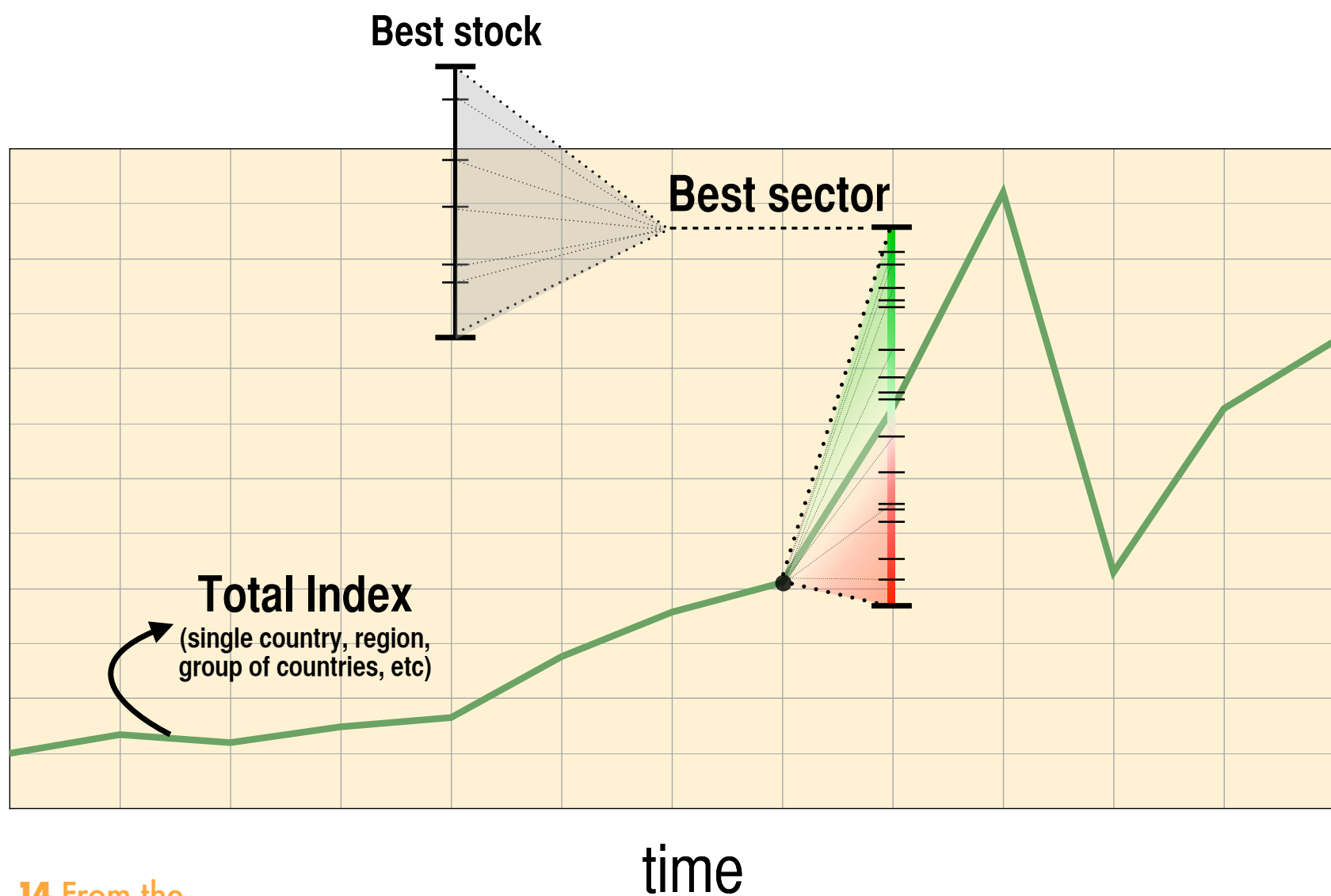(single country, region,
group of countries, etc)

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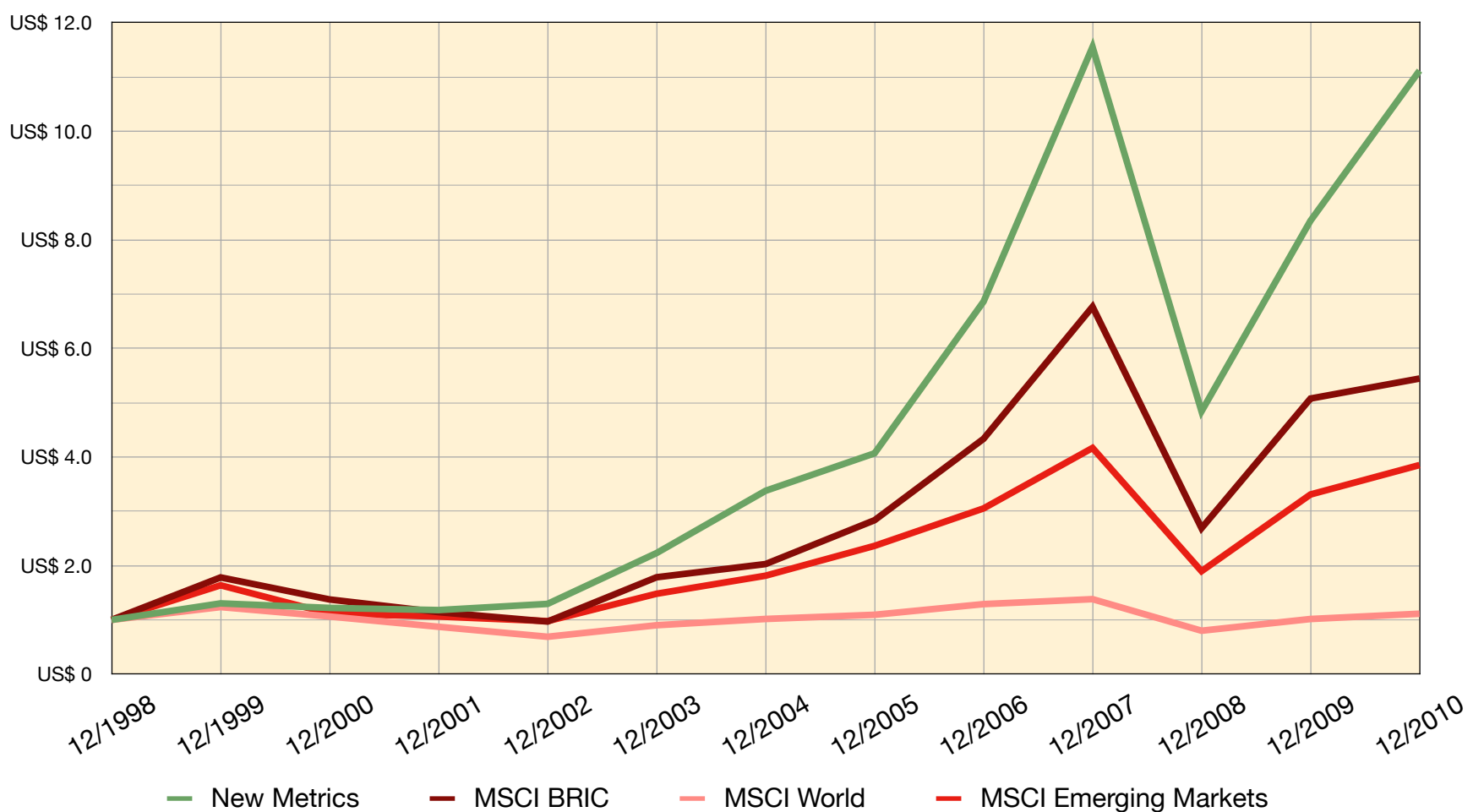
Fig. 14 From the
Complexity Index
towards investment
strategies.

The Economic
Complexity Index: a
fundamentally driven
index.

In particular, 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- and 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 indices according to the prescription we can develop from the *Selective Predictability Scheme.* The idea behind 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 and Emerging. We observe that in the medium and long run the Complexity Index outperforms even the most aggressive Morgan Stanley index,

i.e., Emerging. The Economic Complexity Index is, in this first basic implementation, a weighted basket of country indices from that 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 simple implementation the Economic Complexity Index points towards strong evidence for economic growth determining 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 allow us to assess the most promising sectors in terms of opportunity and in terms of risk.

This complexity approach allows us to identity long term opportunities of growth. Unlike the index definition, any investment strategy based on it must therefore be 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 term, 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.

The Fitness-Income analysis is not only a tool to detect opportunities in the medium and 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 the complexity of the productive capacity. This fact does not automatically and necessarily mean that these countries are risky economies for several rea-

sons, as discussed in the below. They are, instead, potential candidates 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 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 farthest 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 energy scenarios will change.

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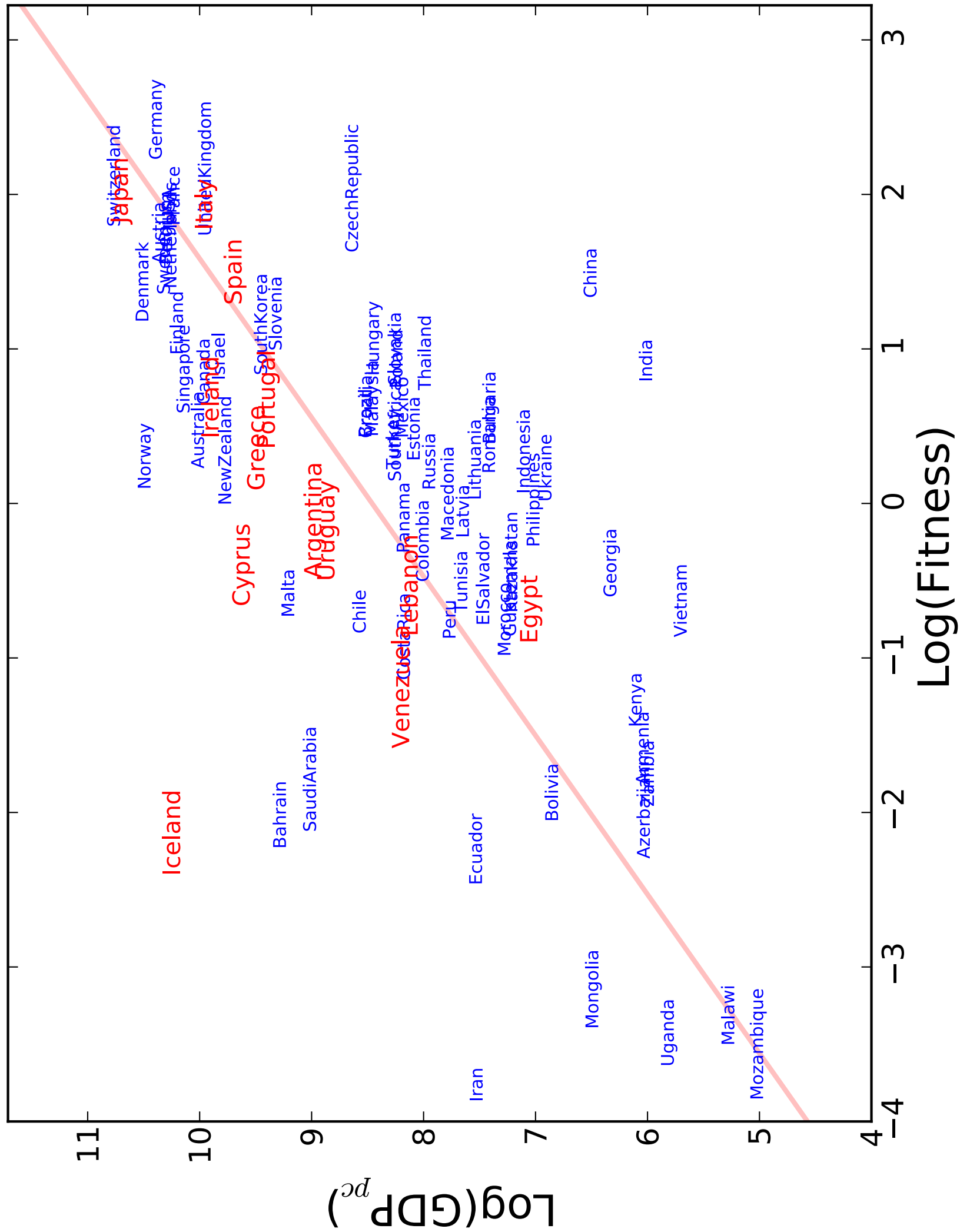
APPENDIX
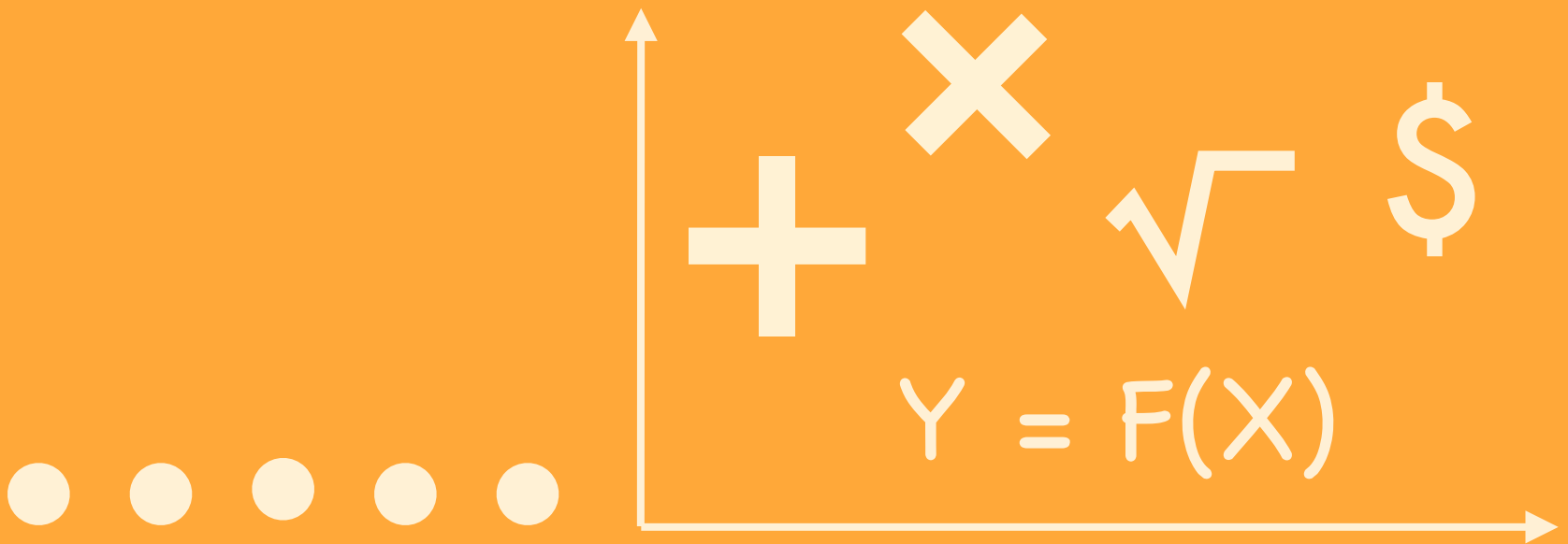
APPENDIX

1.Dataset

In the present analysis we used data extracted from the BACI dataset. In this dataset we have trading data for 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 the United Nations with a delay of approximately 1 year. (For instance, export data for all countries for 2012 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 significant fraction of countries are available before the end of the year from the UN website. It is worth noticing that the raw data released by the 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 a producer of a particular product or not 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 are obtained simply by replacing in the equation defining the algorithm the matrix M with the weighted matrix W whose elements W_{cp} range from 0 to 1 and are defined as $W_{cp} = q_{cp} / \Sigma_c \, q_{cp}$. 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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