"Economic Growth defines the quality of life of people but "growth is devilishly hard to predict" (The Economist, Jan 9th 2016).

"*If we want to achieve things never before accomplished we must employ methods never before attempted*" **Sir. Francis Bacon**

Economic Fitness: Concepts, Methods and Applications

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What is Economic Fitness and Complexity (EFC)?

Economic Fitness and Complexity is the recent economic discipline and methodology developed in Rome by the group of LP (first at Sapienza University and ISC-CNR and now at the Fermi Center: www.cref.it) together with several collaborators from various institutions. EFC makes use and develops the modern techniques of data analysis to build economic models based on a scientific methodology inspired by the Science of Complex Systems (https://www.europhysicsnews.org/articles/epn/pdf/2008/06/epn2008603.pdf) with special attention to quantitative tests and specific predictions that provide a sound scientific framework. It consists of a ***data based*** **and** ***bottom up*** approach that considers specific and concrete problems without economic ideologies and it acquires information from the previous growth data of all countries with **Artificial Intelligence (AI)** methods, in particular **Complex Networks, Algorithms and Machine Learning**. Its main characteristics are the **scientific rigor, the precision in the analysis and in the forecasting, transparency and adaptability**. The Fitness algorithm overcomes the conceptual and practical problems of the early attempts in this field and sets the basis for a testable and successful implementation of the field of Economic Complexity. In particular it gives the proper relevance to the **fundamental concepts of products diversification and complexity**. EFC also represents a fascinating and effective **bridge between the methods of hard sciences and the problematics of humanistic, social and economic sciences**. It permits to address some of the most important problems of humanity (quality of life) from a novel scientific and philosophical perspective with concrete results directly useful for the progress of the society.

A novel paradigm for the Economic Analysis

The ideological debate about which is the ideal economic theory for economic development is replaced by a **new paradigm**. There is no such a thing as the ideal theory valid for all situations. As in medicine one has first to carefully identify the pathology and then implement the appropriate therapy, there is no universal medicine valid for all problems. Similarly for the economic development of a country there is no 'one size fits all' definition for the strategy of development. The different strategies are inherently context-dependent and will vary according to each economy unique challenges and circumstances. The EFC methodology permits a detailed analysis of the situation of each country at a given time, it defines its level of competitiveness for each Industrial Sector and it identifies the possible realistic lines of development. These are characterized by a measurable **Feasibility** (success probability) and the relative **Complexity Gain** (increase of Fitness). These concepts have similarities with the **New Structural Economics** of Justin Lin, former Chief Economist at the World Bank and now at the University of Peking and are also related to the vision of Mariana Mazzucato. In a recent podcast on "Fitness-Growth Mechanisms" within the program "Computational Macroeconomics in the Digital Era" organized by the China Association for AI with an on line audience of 100,000 + :
https://www.bilibili.com/video/BV1B84y1s7AF/?vd_source=a0b1bcd72e0af592e24a2124adf07150

Justin Lin states that: “The Economic Fitness (EFC) provides a Metric to the new Structural Economics (NSE) and, on its turn, NSE provides an economic framework to EFC. **Our dream is that this joint effort will lead to sustainable economic growth and a world free of poverty**. In particular it will be essential for many of the 17 UN SDG objectives, and especially for the first three: 1. No Poverty; 2. Zero Hunger; 3. Good Health and Well Being”. In this perspective EFC provides a **scientifically grounded aware information** as a basis for the decisions of governmental policy makers but also for the business and the market. This leads to a novel perspective, modern and objective, for the **traditional dilemma between state and market**, often characterized by obsolete and ideological positions.

Scientific and Testable results

The Economic Fitness is defined as the diversification of the products weighted by their Complexity. The Fitness algorithm then leads to the Fitness of all Countries and the Complexity of all Products. The Fitness is by itself a very useful concept that characterizes the industrial competitiveness of countries in terms of capabilities to produce Complex products. However it leads to a particularly insightful framework of information when it is compared to the GDPpc as in the figure below.

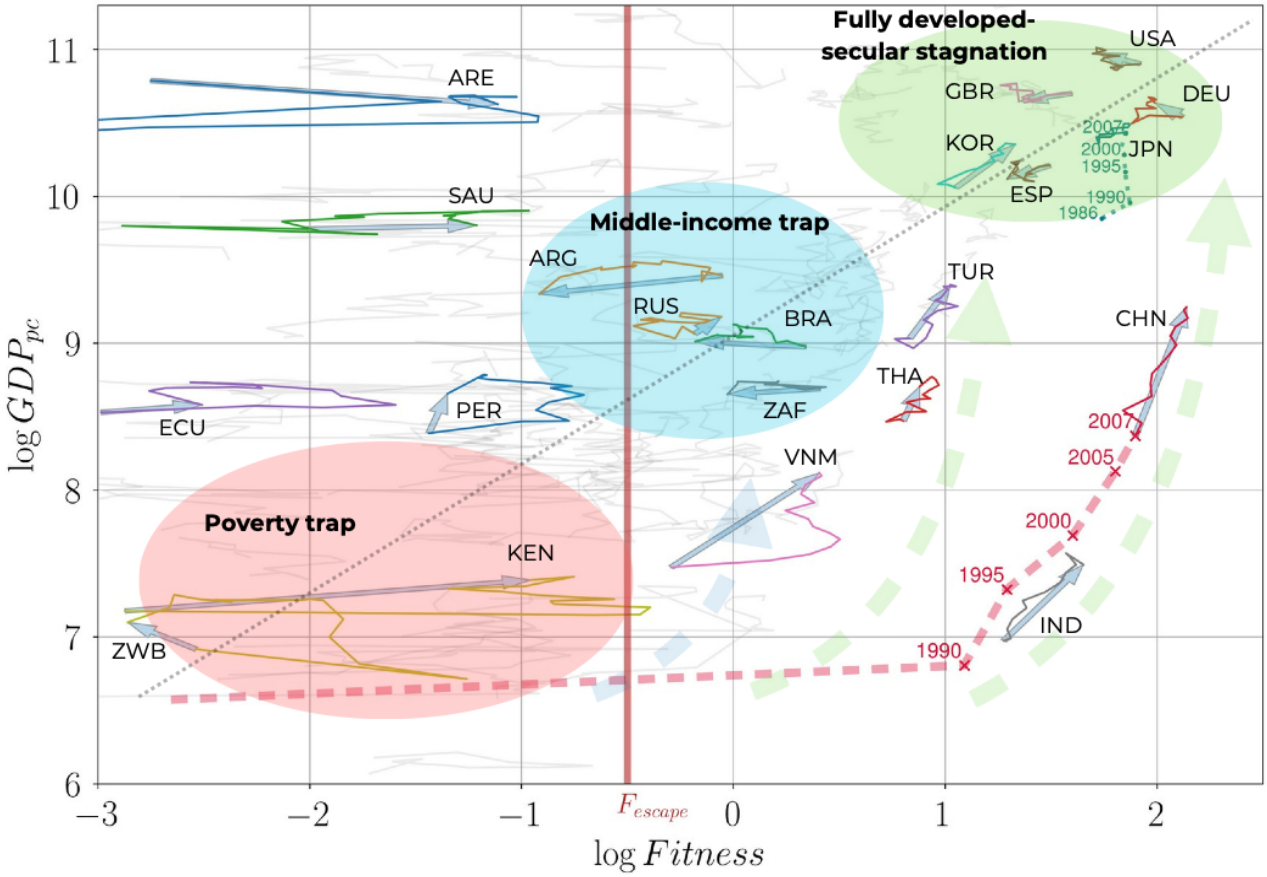

Fig. 1: Country trajectories in the GDPpc vs Fitness plane. Data are more stable on the right and more fluctuating on the left due to fact that in this zone the products are very few and little fluctuations in the data lead to large fluctuations in the value of the Fitness. These flows and trajectories are extremely informative about country growth and provide a quantitative an visual interpretation of various generic definitions like the Middle Income Trap, the Poverty trap etc. One can also define a **minimal level of the Fitness (F_{escape} = 0.4)** which is necessary for a country to become industrial and get out of the Poverty Trap. A large part of the world population lives in countries which are in the so-called **Middle Income Trap**. This is actually a stage of development, defined not only by income. From our plot it is clear for example that China and India are not near the MIT, even if their incomes are in this range. Also we can see that Thailand and Turkey are in a virtuous trajectory while the situation of Brasil, Russia and South Africa is more problematic.

The trajectories of all countries over the years and their position in the diagram provide a **novel insight on country development with a clear visual interpretation**. These flows are at the basis of a radically new

methodology to predict the GDP growth which adopts the techniques of Dynamical System Theory. The scientific power of the method has been tested in detail with respect the forecasting of the growth of many countries with a back test totally out of the box and far superior to the usual regressions. The results have been compared in detail with the standard IMF forecasting and they are substantially more accurate.
Nature Editorial: https://www.nature.com/news/physicists-make-weather-forecasts-for-economies-1.16963
Bloomberg Views: "***New research has demonstrated that the "fitness" technique systematically outperforms standard methods, despite requiring much less data***"
https://www.bloomberg.com/view/articles/2017-10-01/a-better-way-to-make-economic-forecasts
In addition **EFC has provided a detailed understanding and forecasting of the fantastic growth of China** in the past thirty years which has been a major mystery for most of the standard economic analysts. In particular Larry Summers and Lant Pritchett have argued in 2014 that one should expect China growth to go below 2% for the following year (2015). The Fitness analysis clarifies why this expectation was not realistic as confirmed by the data of the following years. One can see in the Figure that the secret of China was to achieve a very large value of the Fitness already in 1990 with a low level of GDPpc.

"**Time to leave the GDP behind**" was the title of a Nature paper (Jan.16, 2014, p.283) in which a group of leading authors argue that: "Gross domestic product is a misleading measure of national success. Countries should act now to embrace new metrics". The Economic Fitness seems to represent the natural candidate for a new metric that measures the real progress in terms of the development of capabilities to make complex products and services in a rapidly evolving and globally connected complex world. Another change of paradigm is then that planning and monitoring of growth should be described any more in terms of GDP but rather in terms of **Complexity Gain**, which represents the microscopic step to increase the Fitness and is now adopted by various mainstream Economic Institutions and recently is also becoming popular also in Academia at various Universities. The first one to adopt the Economic Fitness and to to collaborate extensively with us has been the United Nations University of Maastricht to study the 17 Sustainable Development Goals defined by UN.

Another concept which is important in this field is that of **Relatedness** which describes the dynamics in the **Product Space**. The usual approach is often based in the co-occurrency of products in the basket of countries. The problem with this approach is that the products are 5200 while the countries are only about 150. This leads to a serious problem of signal to noise that makes this approach not far from a random choice. In order to obtain concrete and testable results it is necessary to resort to much more sophisticated **Machine Learning** methods. The validity of these methods has been tested in detail with out of the box approaches. In this way it is possible to identify the possible trajectories for development which are characterized by the **Feasibility**, which describes how easy is to go in that direction and the **Complexity Gain** which is essentially the microscopic increase of Fitness of a given trajectory. This information leads to a scientifically based knowledge which defines the framework for the decisions of policy makers.

Concrete and Specific Results

The Economic Fitness represents a synthetic measure of the **degree of competitivity** in terms of the capabilities to produce products and services. Mathematically the Fitness corresponds to the **diversification weighted by the complexity of the products**. The diversification provides stability and resilience while the complexity of the products represents the exclusivity and the relative wealth. From the financial point of view this approach is also **ethical** because it suggests investments based on the **development of capabilities** rather than on pure speculation. One can then define the Fitness specific to each productive sector and evaluate its possible evolution with methods of **Machine Learning**. Considering the range and completeness of the dataset analyzed in a scientific and systematic way one can then reach a level of **granularity** which is far superior than the usual methods and perform an analysis of competitiveness and possibility of development for each of the **5200 products** considered. The same can be done for the development of **technologies**, using the information provided by the patents and also for the **scientific activity** through the publications. This leads to **three platforms**, the first based on the products leads to the **Economic Fitness**, the second to the **Technological Fitness** and the third to the **Scientific Fitness**. From the connections between these three platforms one can then understand the **relations between science, technology and products** and address in a systematic way problems like **innovation and the technology transfer**.

Who uses EFC?

- **The European Commission (Joint Research Center)** has recently adopted these methods for the study of the 27 EU countries. It will be used to evaluate the best planning and the impact of the recovery fund projects (PNRR) to stimulate the economy of EU in the era post COVID-19
In the Website: https://publications.jrc.ec.europa.eu/repository/handle/JRC124939
one can find a general methodological document together with the analysis of each of the 27 countries performed with EFC methods that identify the present situation together with the possible paths of evolution in relation to the PNRR projects. With these methods it is also possible to extend these analysis in various directions and optimize the projects accordingly.
- Since a few years it has been used by **IFC-World Bank Group** to define specific economic actions tuned for specific countries, in particular for developing ones. One of the main targets is to identify the products or technologies which will **enable to open new markets**, considering the specific situation of each country. The IFC-WB has also supported the development of these methodology which is now officially adopted for the planning of its interventions. An example for African countries can be found here:
https://www.ifc.org/content/dam/ifc/doc/mgrt/emcompass-note-88-west-african-industrial-development.pdf
In the Fermi Center we are establishing a joint research group with IFC-WB for the study and forecasting of the international market. A similar collaboration has already started with Sony CSL for the study of the 17 UN Sustainable Development Goals.
- Recently we have been invited to collaborate with the **European Bank for Reconstrution and Development (EBRD)** that has adopted the Economic Fitness methodology to analyze and plan its strategic interventions. A first set of projects has been already developed and we are now discussing an extension.
- In a recent collaboration with **CNEL and ISTAT** we have made a specific analysis for Italy and its regions to define the present level of competitivity and identify the possible lines of development. These data are now discussed also with various Italian Ministries.
- We have also many interactions and collaborations with individual governments. For example at the moment we are considering a possible collaboration with **Saudi Arabia** which would consist in an investment analysis for the Public Investment Fund (PIF) associated to the acquisition of the technologies which would be optimal for the industrial development of the country.
- We have also collaborated on specific projects with the **Boston Consulting Group** (New York) and the **Institute of Public Policy Research of UK**.

What can EFC do in practice?

- **Plan the industrial development on medium long range.** It is possible to identify the specific opportunities for industrial development at a national and regional level, enhancing the technological capabilities already present to increase the international competitiveness. Also for the cities these methods permit a detailed analysis in view of the development of **Smart Cities** within a modern and sustainable development.
- **Economic Growth and Resilience.** These two factors are core elements of the EFC methodology. From the analysis of the various industrial sectors it is possible to make accurate predictions of the impact that new products or technologies may have for the economic stability and competitivity of the country. From these analysis it is also possible to estimate the growth of the **standard GDP** but also the **innovation and creativity**.
- **Research and Technology Transfer.** By considering the present situation of the research it is possible to identify which technological areas have the largest potential to impact on the industrial system in the medium term. It is then possible to identify the **specific opportunities** for a given country to enter **new sectors** in which there is a good perspective to become an important player in the market.
- **Green economy and Sustainability.** The EFC methodology permits a coherent long term planning for the evolution towards a **stable ecological transition**. This implies developing green products and technologies which are necessary for an economy which is at the same time **competitive but also green and sustainable**. Considering the complexity and interconnected nature of these elements a scientific approach based on complexity science is absolutely necessary. The risk is that even the best intentions, without a scientific control, may lead to disappointing results.
- **Artificial Intelligence and Chat GPT.** These revolutionary developments are expected to produce a huge change in the global industrial and economic structure. A first question we are considering is how the various Industrial Sectors and the whole Job Market will be most affected by these

developments. For the Job Market we have identified the **Skills of each Job** and, with the Fitness algorithm we can define the **Fitness of each Job and the Complexity of each Skill**. Then the AIOE data provide the opinion of experts on the exposure to AI of each Skill. This permits to compute the exposure of each Job. On average the exposure to AI is inversely proportional to the Fitness. However there are notable exceptions which stimulated us to improve the subjective nature of the AIOE data. To this purpose we have estimated this **exposure** not from opinions but **from the objective investment in Start Up** on any the given subject. This improves substantially the the results and **probably represents the most accurate analysis of the impact of AI on the Job Market** (in preparation).

- **Job Market and Education.** Considering the predictions for the development and growth in various sectors and in different regions, it is possible to predict which professional figures and related competencies will be necessary in the near future. Anticipating the needs of the job market is extremely important to orient the education system of the future generations.
- **Global value Chain analysis of the Automotive Sector under the lens of Economic Complexity** Project supported by the Joint Research Center of the EU Community.
- **EFC for Companies.** Also for companies the EFC analysis leads to a variety of original results. Companies show a **block-nested** pattern with respect to the matrix of the products which requires a different analysis with respect to the country matrix which is fully nested. The Fitness algorithm can be applied within each block to define the **Company Fitness**. Then from the patents one can obtain the technological network and introduce the concept of **coherency** for a groups of technologies related to a specific product. The Product Progression identifies the next product or technology that a company may be able to produce and its competitiveness in the various markets. Along these lines one can derive a number of results related to the opportunities to enter a certain market or to develop a new product. Also the analysis and optimization of the **Merging and Acquisition** process can be done with these methods.

Manifesto for a Scientific Economics

"*If it disagrees with experiments, it's wrong. In that simple statement is the key of science*" R. Feynman

The example of EFC represents an interesting case of **synergy between hard science (Statistical Physics and Complexity) and humanistic and economic disciplines**. We believe this could be a first step of a general rethinking of economic theories in a more scientific direction, with more attention to reality (tests and specific predictions) and less to oversimplified models. The problems of mainstream economic theories are well known and have been extensively discussed, especially after the financial crisis of 2008. The macroeconomic counterpart has also major problems in making reliable predictions of country growth and, in particular, it fails to understand the fantastic growth of China for the past forty years. In parallel to these problematic lines, the **Google Page Rank algorithm** showed which miracles can be made by a clever use of data interpreted as a Complex Network and with the appropriate Algorithm. The natural evolution of this approach led to the vast area of **Artificial Intelligence and Machine Learning**. In Economics this perspective is represented by the field of **Economic Fitness and Complexity**. Clearly the ideology of Complexity is not a guarantee of validity of any Complexity theory and its theoretical implementations should also be subject to the scientific criteria. We propose therefore a simple but radical point of view: **whatever theory is considered it has to be carefully checked with reality and experiments, interpreted as out of the sample predictions**. Contrary to some common wisdom, the counterfactual arguments also imply the capability of making predictions. We have made a step in this direction with the development of Economic Fitness and Complexity, which sets the basis for a scientific and testable approach to Economic Complexity. In particular it makes very good predictions for the growth of all countries and it provides also a clear understanding of China growth. This approach has a natural complementarity with the theory of **New Structural Economics**, developed by Justin Lin and collaborators. This implies a **radical change of the philosophical paradigm** because it overcomes the ideological debate of the search for *the best economic theory*. This is substituted by the search of the model appropriate to a certain situation at a given time. One natural outcome is that the **monitoring and planning of country development should be done in terms of the Fitness which replaces the obsolete GDP**. The present challenge is to extend these ideas also to smaller scales up to the individual firms and Start Ups. We believe that the scientific approach outlined here, with the many data available and the relative methodologies of AI, Machine Learning and suitable Algorithms, could lead to major improvements of the Economic Analysis especially in relation to the 17 Sustainable Development Goals of UN.