THE FERMI COMPLEXITY HUB

PROJECT FOR THE INTERNATIONALIZATION OF THE STRATEGIC ACTIVITIES OF THE FERMI CENTER

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A cura di Luciano Pietronero, Presidente CREF - 2022

Executive Summary

The Fermi Center is a relatively new institution, oriented to the present and the future in the spirit of Fermi's original approach to novelty, innovation and the social impact of science. Our idea is to build an incubator for a new type of science beyond the traditional disciplines and oriented to the most challenging problems of today's science and society. The present project aims to give an international dimension to these activities so that the Fermi Center becomes an international Hub for some of the most exciting and challenging research topics, some of which already had an essential and recognized impact.
For example, Data Science and Artificial Intelligence represent a vast area which pervades all scientific disciplines but also most of the human activities of any kind. A mature example in this area is the development of the method of Economic Fitness and Complexity, which represents a novel Data Science and scientific approach to the economic analysis which is already been adopted by the World Bank of Washington and, recently, also by the EU Commission to evaluate the Recovery Fund projects (PNRR):
https://publications.jrc.ec.europa.eu/repository/handle/JRC124939

The famous Fermi group also faced a problem of internationalization. After all, they were all Italians and these problems were similar to today. They decided to orient their activities to scientific areas which, at the time, were novel and original and not really mainstream. In addition, they organized a series of events, extended visits and exchange of scientists. One of these events was the First International Conference of 1931 (photo) on the new subject of nuclear physics. We intend to take inspiration from these significant events and also give ***a solid international character to the strategic new projects of the Fermi Center*** *characterized by the aim of building a new type of science beyond the traditional disciplines.*

In this Executive Summary, we present a compact overview of the key elements that will be discussed extensively in the full text of the project. In the last pages, we present a detailed analysis of all the collaborations, both present and planned, with international institutions worldwide. The scientific discussion will cover mainly the areas where the collaborations are already mature, with the idea that others could be considered in future developments.

Economic Fitness and Complexity (EFC)

EFC 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 international collaborators. EFC uses and develops the modern techniques of data analysis to build economic models based on a scientific methodology inspired by the science of Complex Systems, with special attention to quantitative tests to provide a sound scientific framework. It involves 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 methods of Complex Networks, Algorithms and Machine Learning. According to Bloomberg Views: “New research has demonstrated that the "fitness" technique systematically outperforms standard methods, despite requiring much less data”.
Recently, it has been used by the IFC-World Bank Group to define specific economic actions tuned to open new markets for specific countries, particularly developing ones.
https://datacatalog.worldbank.org/dataset/economic-fitnes
The strong collaboration of CREF with the World Banks Group’s International Finance Corporation (IFC-WB) already led to the introduction of a knowledge network of economic, research, innovation and production activities. This knowledge network delivered unique academic results, including economic fitness, long-term growth forecasting, technology and research fingerprints, Recently an MoU was

signed between CREF and IFC-WB to implement a joint lab at the Fermi Center, which would become the international reference HUB for these activities, the FermiKnet (K=knowlerge) with two objectives:

- Operationalizing the big-data input pipeline to maintain FermiKnet and to extend FermiKnet with new activities (such as the analysis of firms and job skills, etc)
- Developing a web site of appropriate dashboards for scientists, government officials, international development experts, and other interested parties based on Fitness indicators, and activity fingerprints which are predictive of structural growth and medium- and longer-term development.

This project requires an investment in personnel, specific computer infrastructures and data acquisition, and it will represent a unique HUB of innovation and training of brilliant scientists.

Complexity and AI for the challenges of Sustainable Development Goals.

This project corresponds also to a second important international collaboration with the private sector. In fact, a joint Lab has already been implemented at CREF in collaboration with the Sony Computer Science Lab (Sony-CSL, https://csl.sony.fr/) in Paris, led by Prof. V. Loreto (also at Sapienza) The Sony CSL has been engaged for years in issues related to the goals of sustainable development, and this strategically important project is proposed for the creation of a new joint laboratory that can combine in a single space the sciences, the arts, and the business world for pushing innovation and aiming for concrete and applicable solutions on a large scale. The project will focus on the global innovation agenda, aiming to impact various sectors linked to the Sustainable Development Goals (SDGs) and will use the Sony know-how and the Economic Fitness and Complexity methodologies. This project is already in operation and it involves about 10 young scientists, part by CREF and part by Sony-CSL, located in the CREF building. The support of the present internationalization project will be mostly in terms of young scientists.

The Dynamics of Information in the Social World

Social media has revolutionized how we communicate and inform ourselves, becoming the primary source of information for most users. Facebook has more than two billion users, who generate more than three million posts per minute, informing themselves without the intermediation of journalists and experts, thus actively participating in

producing and disseminating news and content. Recent studies have shown how user groups are concentrated in echo chambers that formulate and confirm their favourite narratives, systematically countering any dissident information. In this situation, the effectiveness of fact-checking and debunking is highly questionable; instead, innovative tools are needed that address the problem of fake news using methods based on data analysis and the formulation of specific and dedicated algorithms with the same criteria of scientific and methodological rigour that led to the introduction of the Economic Fitness methodology.

Lab4News:

As a byproduct of this project, we intend to establish a specific laboratory to apply the AI methodology for generating and analysing information. These methods are already developed internationally but not much in Italy. The idea is to fill this gap in a joint collaboration with journalists and media producers. Also, in this case, the present internationalization project will support positions of junior scientists and extended stages of professionals.

Distributed laboratory of computational nano-photonics @CREF.

A bridge between the area of Data Science and AI and Physical Sciences is then represented by the field of Quantum Information and Photonics, for which the Fermi Center is organizing a dedicated laboratory directed by Prof. C. Conti (CREF and Sapienza), which has a well established international reputation in this field and will cosponsor this Lab with his own research grants. As an example of this initiative, it is proposed to create a laboratory at CREF to create classical and quantum photonic computing systems. This laboratory involves the University of St. Andrews in the UK, KAUST University, the CNRS, and other institutions through collaborations with Italian and foreign professors interested in creating and transferring their skills to Italy. As described below, a new laboratory will be created with various spaces dedicated to fundamental and applied interdisciplinary research. The use of photons for the transport and processing information is inherently less expensive than and devoid of consumption when compared with electrons, commonly used. The advantage is combined with higher speed, infinitely larger bandwidth, and compatibility with fiber optic backbones that already dominate world telecommunications. The laboratory will also include facilities for the fabrication and testing of devices. It will also be oriented to the technology transfer oriented

towards patents, spin-offs, and start-up creations to create jobs for young researchers.

Fundamental Physics in Space.

Prof. I. Ciufolini coordinates this research group and it is dedicated to studying and testing General Relativity and fundamental physics using dedicated satellites, among which LARES (launched in 2012) and LARES 2 (ready for launch in June 2022). The Fermi Center has the scientific leadership of this research with scientists from University of Texas at Austin, University of Maryland, NASA, Helmholtz Centre Potsdam/GFZ Wessling, University of Oxford, Yerevan State University, University of Missouri and Sapienza University of Rome.

Science and Business, Tech Transfer in the digital industry.

Various analyses (including ours) indicate that Italy has a strong potential in the broad area of AI, but this is not yet fully developed. One of the reasons is the limited relations between academia and industry for various structural reasons of the Italian economic system. One of the strategic objectives of the Fermi Center is to build a bridge between Science and Business or Industry; we have already developed various concrete collaborations. We believe this plan is especially suitable in the vast area of Data Science and AI, which now touches in various ways the whole productive ecosystem. In Italy, there are already essential examples and even more important opportunities. Together, we intend to build a new type of scientist which will be the basis for the scientific and economic development of the country. **Translated.com** represents one of the most successful companies in the field of automatic AI translations. Founded about twenty years ago by Marco Trombetti, it developed rapidly into an international leader with most of its clients international and, in particular, from Silicon Valley. This success has been reinvested in about 50 Start-Up companies in the area of AI (https://picampus.it/).

We already have various collaborations, and the plan is to evolve these into a stable joint Laboratory to develop a new type of trans-disciplinary science that also builds a bridge between scientific and humanistic disciplines. This project will also prepare young scientists for the challenges of a continuously evolving world in a fully international framework.

About the PI and the essential strategy of this project.

Luciano Pietronero has vast experience with three key elements of this project: Internationalization, Science and Business, and Interdisciplinarity and Complexity

Internationalization: After the Laurea degree, LP has worked for 16 years in four different countries: France, USA, Switzerland, and The Netherlands, where he was Full Professor before coming back to Italy in 1986-7.

Science and Business: Within these 16 years, 10 were in industrial research centers - Xerox in USA, and Brown Boveri in CH -and also in the Italian period there was a constant connection between academia and industrial environments.

Interdisciplinarity and Complexity: In 2004 LP established the Italian Institute for Complex Systems of CNR (ISC-CNR) and was its director for 10 years, until 2014. This institution represented an original and successful scientific enterprise at the national and international levels and gave rise to a generation of young scientists who are now leaders in this field at the international level. In 2014, an external evaluation committee classified ISC-CNR as a “world-class” institution and rated it first among the 12 CNR Institutes in the area of Physics.

The development of the Fermi Center is now an opportunity to exploit all these elements at a higher level with the present internationalisation project. CREF will become an international HUB for original and challenging research areas with a robust social impact. The planned scientific initiatives will also forge e new generation of young scientists, which is particularly relevant for Italy's scientific and economic development.

Budget and financial structure of the project

Only recently, the Fermi Center has acquired the famous building in Via Panisperna and it can develop into a fully accomplished institution with its own original strategies and projects. The Fermi Center must undergo strong and stable growth in the following years to fully develop its strategies. The present project will make a significant contribution in terms of establishing an international Hub in various areas. As for the international collaborations, we plan to attract talents and funds given the originality of our projects and these are in general, implemented on a 50/50 basis.

Budget requested (K euro)	First Year	Second Year	Third Year
Infrastructure	650	600	550
Personnel	1150	1350	1650
Total	1800	1950	2150

Scientific Strategies of the Enrico Fermi Research Center

The Enrico Fermi Research Center (CREF) was founded by a 1999 law but only recently (2019) the famous building in Via Panisperna has been completely restored and can be used for its new scientific purposes. The idea was to return this famous building to a scientific purpose that would honor the memory of the fundamental discoveries of the Fermi group that took place in that place. The first element would have been to establish a museum in the building with the original finds of Fermi's experiments integrated by appropriate modern audio-video systems that would make the understanding of these historical events accessible to the new generations as well.

In addition to this dutiful homage to the memory of prestigious past events, however, something more original and current was also thought of. Fermi was a scientist oriented to the future and to a particularly innovative vision of science. In this perspective, it was decided that, in addition to the historical aspect oriented to the past, CREF also had its research activity oriented to the present and the future. As in Germany, for example, the memory of Max Planck is mainly honored by an extensive network of prestigious scientific institutes, so it has been proposed that CREF also become a nucleus of particularly original and innovative research, precisely in the spirit that has characterized Enrico's activities. The present project aims to highlight and exploit these activities within a strong international framework. The Fermi Center will become an international Hub for various subjects characterized by originality, novelty and impactful research. Some of these subjects are already mature and well-recognized, while others are in an initial stage. For these, the Fermi Center will be a sort of incubator of Scientific Start-Ups.

The CREF must not be a small replica or a collateral support of the activities already carried out by other institutions. Wanting to do something original and high-level, it is natural to focus on the new scientific issues that appear on the horizon with increasing frequency. Most of these new areas are interdisciplinary and often in the area of Complex Systems.
In the Italian scientific world, disciplinary groupings tend towards a sectorization of research that does not favour interdisciplinarity. It is interesting to note that the traditional scientific disciplines like physics, chemistry, mathematics, biology etc. have been defined a few centuries ago, and the frontiers of science and society have greatly evolved since then. In this perspective, the agile CREF can play the original role of quickly orienting itself towards new, particularly current and innovative activities. CREF can therefore seize this strategic opportunity to be an institution that stimulates innovative scientific issues, a sort of incubator for start-ups of a scientific nature.
From this point of view, however, the idea is to be totally open to new developments and proposals that can also come from the outside. As regards the specific issues, it is clear that reference will be made to the principles and style of Physics but interpreted in a modern key and with a focus on social relevance and possible collaborations with companies and other institutions. This attitude leads to two important connections: an important link between public research and the private sector and a link between scientific and humanistic disciplines.

1.1 Social and Economic Complexity

Ettore Majorana in 1930, wrote an article entitled: “The Value of Statistical Laws in Physics and Social Sciences”. This visionary article, published posthumously in 1942, posed a problem that is particularly relevant today, especially when considered from the perspective of Big Data. The article discusses the following problem: To what extent can the rigorous methodology of physics be exported to other disciplines to make them more scientific and objective? Perhaps not all the rigor of physics is exportable, but these other disciplines, such as economics, have great importance for our society, as well as great intellectual value. So even if the degree of rigor rate is only partial, an increase in science in these disciplines would be a result of the utmost importance. Furthermore, from an intellectual and scientific point of view, a link would be created between the disciplines of the so-called hard sciences and those of the socioeconomic sciences which in itself would have great cultural and scientific value. This is one of the areas that we intend to explore from the concrete perspective of the science of complexity. Therefore, in addition to themes characteristic of more traditional

physics but selected for their originality, we intend to develop themes such as Data Science, Machine Learning and Artificial Intelligence, of which Complexity and Economic Fitness represent a very current example.

1.2 The new challenges and opportunities of the Hyper-connected world

In recent years, we have witnessed the emergence of completely unexpected phenomena with respect to which traditional scientific disciplines and analyses appear completely inadequate.

- Internet, Google, and the digital economy
- Facebook, social media, and the dynamics of information and disinformation
- The economic and financial crisis of the past ten years
- The remarkable and surprising growth of the Chinese economy
- Disintermediation and the development of the blockchain
- Sustainability, real well-being, social inequalities, and green and circular economies
- Smart cities and smart nations
- Artificial Intelligence and Machine Learning
- COVID-19, a tragic crisis but also an opportunity to rethink the economy

The common elements of the listed phenomena are an integration of connections and events on a planetary level and the speed with which they evolve and develop unpredictable emergent properties. The inadequacy of traditional concepts and analyses is evident, and the need for new scientific methodologies to analyse, understand, and control these phenomena is clear. The aim is to understand and monitor society in a conscious way to transform these challenges into opportunities. The fundamental idea is to treat these phenomena with original methods, overcoming disciplinary barriers and interacting across the spectrum with academic and political institutions and companies' productive world.

1.3 Interdisciplinarity and Complexity

The traditional disciplines like physics, Chemistry, Mathematics, Biology etc. have been defined two or three centuries ago and their boundaries are totally obsolete. The most important problems in science and society are often much broader than any of these disciplines and require a problem-solving approach with a much broader horizon with respect to those of these individual disciplines. In addition to this cultural problem, there is a practical one. Especially in Italy, the scientific sectors in the university are rigidly separated and this represents a serious handicap to

be considered by policymakers. The new world of the Internet, Data Science, precision medicine and a scientific approach to economics, to mention a few, all require a different mindset. The traditional barriers between disciplines are simply obsolete and do not represent any more the complexity of the present world. This means that many important problems of science and society are simply ignored or not addressed in the appropriate perspective. The idea is that the Fermi Center can address these problems in a novel and original way.

Already in 2004, LP established the CNR Institute of Complex Systems (ISC) to make a step in this direction. After directing it for ten years, since 2014 the new director is C. Conti, who is also the director of the Photonic project at the Fermi Center. This situation guarantees a very effective collaboration between the two institutions and now this project of internationalization of the Fermi Center will bring a new dimension to this enterprise. The perspective of LP about complexity can be found in: https://www.europhysicsnews.org/articles/epn/pdf/2008/06/epn2008603.pdf, which was written for the EU Commission and then became a sort of Manifesto for the foundation of ISC-CNR.

The scientific area of Complexity is somewhat complementary to elementary particle physics which is based on a “reductionist” approach. In fact, the traditional approach of physics is to consider relatively simple and isolated systems and study them in great detail. One therefore considers the elementary “bricks” that are the constituent elements of matter. This reductionist view can be successfully applied to many situations and implies the existence of characteristic scales: the size of an atom, a molecule, or a macroscopic object. However, there are many situations in which knowledge of the individual elements is not sufficient to characterize the properties of the entire system. Moreover, when many elements interact in a nonlinear way, they can give rise to complex structures and properties that cannot be directly connected to the properties of the constituent elements. In these cases, we can think of a sort of “architecture” of nature that depends in some way on the individual elements but also manifests some properties and fundamental laws that cannot be deduced from the knowledge of the microscopic elements that compose it.

“Techno-social” systems is the term commonly used to identify socioeconomic systems in which technology blends in an original and unpredictable way with cognitive, behavioral, and social aspects of human beings. The new communication and information technologies (ICT) play an increasingly pervasive role in our culture and our daily lives. This revolution obviously does not come without contraindications, and in our complex societies, new global challenges are constantly emerging that require new paradigms and original thinking to address. In recent years, the science of complexity has shown that it can play an important role in understanding social and economic dynamics. However, we

believe that this is only the beginning and that this field will develop in a powerful way into a new and fascinating scientific adventure with radically new transdisciplinary characteristics that are difficult to frame in traditional contexts. For this, one needs a specific reference point with new skills and characteristics suitable for the new situation.
This opens up perspectives, unimaginable until a few years ago, that skillfully mix diverse disciplines and factors. On the one hand, we can consider the theoretical and modelling tools of the physics of complex systems connected to the ability to analyze, interpret, and visualize complex amounts of data in an original way. On the other hand, the true essence of techno-social systems provides a unique opportunity to exploit new ICT technologies to monitor and quantify the digital traces of human behaviour and collective social and economic phenomena with unprecedented resolution. This situation also involves an original synergy between scientific and humanistic disciplines that aims to produce concrete and directly useful results. We believe the Fermi Center can play an important role in these new scenarios.
Italy can play an important role in these developments for various reasons. On the one hand, the science of complex systems is well present and widely recognized (i.e. Parisi's recent Nobel prize). On the other hand, the elements of creativity and originality associated with these developments are also one of our strengths. Finally, these activities do not require particularly expensive infrastructures and can give rise to important scientific and practical results in a relatively short time.

2. Economic Fitness: Concepts, Methods and Applications

Economic Fitness and Complexity (EFC) 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) together with several international collaborators. EFC represents the first remarkable example (to our knowledge) in which a radically new methodology, arising from Statistical Physics and Complexity Science, has been accepted and extensively adopted by mainstream economic institutions like the IFC-World Bank and JRC-EU Commission. In this respect, it represents a change of paradigm and we intend to take this opportunity to create a stable research activity at the Fermi Center, which will be the international reference (Hub) for these developments.

EFC makes use of and develops the modern techniques of data analysis to build economic models based on a scientific methodology inspired by the science of Complex Systems, with special attention to quantitative

tests to 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 methods of Complex Networks, Algorithms and Machine Learning. According to Bloomberg Views: “New research has demonstrated that the "fitness" technique systematically outperforms standard methods, despite requiring much less data”.

The relevant scientific papers can be found here:
https://www.economic-fitness.com/en.
The basic idea is to develop and apply methods inspired by the criteria and scientific rigor of physical sciences to the economic analysis. The main point is to a great attention to the “experimental tests” and the reproducibility of the results. This brings the analysis and the results to a superior level of reliability, and the quality of forecasting has been tested in the most scientific way by us and by the most prestigious mainstream economic institutions like Bloomberg, the IFC-World Bank and the JRC-European Commission. It is fair to conclude that the Fitness is today the most successful and reliable methodology when compared to the other methods on the specific tasks where it is possible to have quantitative tests. The Fitness approach is based on a combination of concepts and methods in Data Science, Complex Networks and relative Algorithms and Machine Learning and permits the analysis and forecasting of a variety of properties at different levels of granularity and geographic scale. In the past years, we have mostly considered the analysis of countries that can be now considered a mature subject. The next challenge is the analysis of firms and companies, which requires different data and partially different methods. A collaboration with IFC-World Bank to develop these concepts is already planned as a project of the joint lab that will be located in the Fermi Center (see later).

2.1 The Challenge of Country Growth and the Fantastic Growth of China

Economic Growth defines the quality of life of people but “growth is devilishly hard to predict” (The Economist, Jan 9th 2016). In addressing a new field it is important to define clear and sharp challenges and benchmarks. This statement by The Economist certainly clarifies that the problem of country growth has this characteristic. In addition, the forecasting of growth (in terms of GDP or other parameters) can be considered as a sort of “experiment” to test the various models with “out of the box” back-tests on the historical data. This will be for us a crucial

test for our models. It is important to note that no other competitive model has been tested in this rigorous way and the usual approach is to present some correlations or regressions which are of much lower value conceptually and in terms of the risk involved in their practical use. It is well known that forecasting GDP growth is very difficult even for the most competent and prestigious institutions so, clearly, this is a very important benchmark for our economic analysis.
Within this framework, a particularly important and interesting challenge is to understand the fantastic growth of China in the past 40 years. In this period China's GDP has been growing more than 5% per year and often much more. This behavior is totally anomalous and never occurred before in any other country. Considering that China's population is about one-quarter of the entire world, it is clear that a scientific understanding of its growth is of fundamental importance. Since 1990 almost all economic analysts argued that the fast growth of China should stop soon but they were systematically disproven in the following years. David Pilling (Financial Times Nov. 19 2014) argued that "What goes up must eventually come down – even China". This opinion originated from an influential paper by US economists Lant Pritchett and Lawrence Summers (former Secretary of US Treasure and President of Harvard Univ.). For them, "the single most robust and striking fact about growth is regression to the mean of about 2 per cent" After this article, we pointed out that we could actually understand the persistent growth of China and predict that there would be no crash soon. Bloomberg reported our opinion which turned out to be correct in the following years. In fact, since 2014, China continued to grow by more than 5% and even now it has an impressive performance, considering COVID. So the understanding of China's growth also represents a major and well-defined challenge in which our new methodology offers an original and valid contribution.

2.2 Complexity, Physics and Economics

As we have seen Complexity refers to the new scientific area which is complementary to reductionism and focuses on the interrelations and interactions between the elements of a system. It is characterized by emerging properties which cannot be related to the properties of each individual element. Economics is clearly based on many elements, which can be people or institutions and they certainly interact strongly among themselves, so they constitute a Complex Network which is a natural playground for Complexity Science. This is the approach we consider for the Economic Fitness. For example, the paradigm shift introduced by the Google Page Rank algorithm, which focuses on the links between WEB sites, rather than on the individual properties of each WEB site, will be a

source of inspiration. However, a too-close analogy with Google is not suitable for economics and substantially new ideas are needed.
Also, the approach is inspired by the methodologies of physical sciences in terms of the careful tests and relations to experiments. This approach to detailed “experimental” tests is not common in economics where in most cases the analysis is strongly biased by ideologies and the tests are reduced to simple correlations or regressions. Rarely do people accept that a model or a theory is wrong on an experimental basis and sometimes the soft tests mentioned are little more than rhetoric.
In addition to specific tests for growth forecasting, the results obtained by the method of Economic Fitness and Complexity are statistically validated against non-trivial null models in the sense that we want to validate for instance the hypothesis that countries' fitness and product complexities contain more information than respectively diversifications and ubiquities.

2.3 Big Data and the Signal to Noise problem

More data does not necessarily lead to better analysis and forecasting. For example, as we have seen before, the fantastic growth of China has eluded most expert analysis. We are going to see that the Fitness methodology provides an excellent understanding of China with a specific and rather unique interpretation. Considering that all these prestigious institutions that have been wrong about China certainly considered all the available data but still, they were not able to understand its growth, our view is that the problem is not the availability of data but rather the way they are used. In making forecasting the dimensionality of the data set is a crucial element. Only if this dimension is rather low reliable predictions are possible. In economics, however, we have data in more than 100 dimensions which unavoidably introduces a large amount of noise in the analysis. For example, one has to decide how education competes with pollution in relation to growth. This is analogous to the well-known problem that one should not add apples to bananas. In practice, this situation implies the adoption of 100 or more arbitrary parameters. Even if these are defined by the best experts, this situation implies a large amount of noise and the essential irreproducibility of the results.
We decided therefore to go in a different direction, namely to decrease the noise to zero at the price of reducing the information. This means focusing on the single data set which gives the best information on the capabilities of a country which then leads to industrial and economic growth. The best data in this respect are those on the nature of exported products. This is not to focus on the export in the sense of how much a country exports, but from the quality of the exported products

we gain information on the capabilities, independent of the amount of the export. This type of data has the crucial advantage of being homogeneous for all countries, which is an essential element in our analysis. In principle, another interesting set of data would be those on labor which, unfortunately, at the moment are not homogeneous for all countries.
So the starting point will be the single set of export data but this implies that these data should be of the highest quality and reliable. In economic complexity, the actor-activities matrices (e.g. countries-products, firms-patents) are binary matrices, that result from binarizing some form of the Revealed Comparative Advantage matrix. The binarization procedure introduces a significant amount of noise: partly due to RCA values fluctuating across the chosen threshold, and partly due to larger fluctuations that might depend on data quality issues or other kinds of perturbations that don't actually imply that there has been a real change in the capability structure. To address this problem we propose a Hidden Markov Model approach that, differently from standard approaches that apply a static threshold to each snapshot of RCA, models the RCA time series in order to represent the production system of a country as a sequence of hidden competitiveness states. We validate this approach with the tools of Economic Complexity and we find that the performances of out-of-sample forecasting of GDP and industrial development are significantly improved. The GDP forecasting error goes from 1.85% with the simple RCA thresholding to 1.59% by using Hidden Markov Models. This procedure of data testing and optimization is very important for accurate results and also exclusive to the Fitness approach.

This binary matrix of countries and products represents the starting point of the Economic Fitness methodology to construct 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 methods of 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 new 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. The ideological debate about which is the ideal economic theory for economic development is replaced by a new paradigm. There is no such 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, one has to analyze its level of competitiveness and identify

the possible realistic lines of development. These concepts remind the New Structural Development of Justin Lin developed at the University of Peking for which EFC provides a scientific quantitative analysis that complements these general economic ideas. In this way, it is possible to develop scientifically grounded information as a basis for the decisions of governmental policymakers 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. The scientific power of the method has been tested in detail with respect to the forecasting of the growth of many countries with a back-test totally out of the box and far superior to the usual regressions. In addition, EFC has provided a detailed understanding and forecasting of the fantastic growth of China in the past forty years which has been a major mystery for most of the standard economic analysts.

2.4 Concrete and Specific Results

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 exclusivity and 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 to 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 technology transfer.

2.5 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 the EU in the post-COVID era.
On the website:
https://publications.jrc.ec.europa.eu/repository/handle/JRC124939
one can find a general methodological document with the analysis of the situation for 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 this analysis in various directions and optimize the projects accordingly.

The strategy of the EU Commission: At the Joint Research Centre of the European Commission analyses based on complexity techniques were developed with the focus on forecasting future macroeconomic dynamics to inform policy with respect to industrial and innovation policy, both at a European level, country level, and regional level. A relevant example is the country factsheets that were produced by the JRC for the 27 EU member states to assess country potential in the next five years, spanning from country growth to its export basket, up to innovation portfolio and regional specialization. To inform policy the factsheets span a mix of techniques: country fitness, product progression probability, assist matrix, and regional technological fitness. Different techniques were tried but did not perform as well for the specific task.
Indeed, forecasting tasks are inherently falsifiable, and therefore it is much easier to reach a hard-science level of confidence in the methodology. While measuring, for example, the impact of a policy requires econometric identification and/or subjective evaluation, the forecast of GDP growth or future export basket can be back-tested objectively with the usual toolbox of training and test set that are standard in machine learning and finance literature.
On one hand, there is therefore no need to identify the best algorithm, an ill-defined question as it would be to identify the best tool in a toolbox. On the other hand, it is trivial to identify the best algorithm for that task, as the tasks themselves inherently identify also a target function to test the different algorithms. For example, if one wants to identify the best algorithm to forecast GDP growth, one just needs to check the algorithm that would have performed better in the past in that specific task, with very few degrees of freedom left to the practitioner.

For a few years, it has been used by the IFC-World Bank Group to define specific economic actions tuned for specific countries, in particular for developing ones.

https://datacatalog.worldbank.org/dataset/economic-fitnes
One of the main targets is to identify the products or technologies which will enable to opening of 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/wps/wcm/connect/fb4761f5-809b-4685-8fd7-24bd23bad6d3/EMCompass-Note-88-West-African-Industrial-Development.pdf?MOD=AJPERES&CVID=ngxrg.e
In the Fermi Center we are establishing a joint research group with IFC-WB for the study and forecasting of the international market at the level of countries but also for firms. A similar collaboration has already started with Sony-CRS for the study of the UN Sustainable Development Goals.
In a recent collaboration with CNEL and ISTAT, we have made a specific analysis of Italy and its regions to define the present level of competitiveness and identify the possible lines of development. A number of well-defined patterns emerge from this study in particular about the industrial competitiveness of each of the Italian regions and the important problem of inequalities within the country. In this respect, the Economic Fitness could identify specific paths for the realistic development of the southern regions.

2.6 What can EFC do in practice and for PNRR?

Plan the industrial development on a 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 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 on the economic stability and competitiveness of the country. From this analysis it is also possible to estimate the growth of the standard GDP but also of different elements like 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 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 scientific control, may lead to disappointing results.

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 future generations.

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's Fitness. Then from the patents, one can obtain the technological network and introduce the concept of coherency for 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.

2.7 The Fitness Algorithm (technical discussion)

The first step to building the Fitness algorithm is to look at the data and get inspiration from them. If we plot the Country-product data already ranked for the fittest countries (on top) and the most complex products (on the right) these data show clearly the fundamental importance of diversification, namely the most competitive countries are able to produce highly complex products but they also produce medium and low-level products. This simple observation disproves the conjecture of David Ricardo according to which countries should specialize only in their high-level products. Also, we can see that the matrix is triangular or nested, a fundamental property shared with many other ecosystems.

From these data, we would like to extract a synthetic indicator that characterizes the global industrial capabilities of each country (Fitness). The first equation of the algorithm consists therefore of linking the Fitness of a country to the Complexity of its products. From the nature of the data, it is clear that diversification has to play a crucial role so the zero order equation would be simply to have the diversification as a starting point. However, if a country produces potato chips or computer chips this must lead to some more information, so we weigh the simple diversification with the Complexity of the products.
The second equation should instead describe the Complexity of a product in terms of the Fitness of the countries that are able to produce it. This is a bit more subtle. It is clear that if many countries are able to make a certain product, this must be relatively simple. So we put in the denominator the sum of all the countries that make a certain product. But now the Fitness of these countries must also have some role. The highly competitive countries produce almost all products so the fact that for example, Germany (high Fitness) produces water bottles is not at all informative. But if we know that a country with very low Fitness produces water bottles this is very informative and sets a sort of upper limit to the Complexity of this product. It is therefore natural to give weight to the terms in the denominator which is inversely proportional to their Fitness. The lower the Fitness of the country that produces a certain product the higher will be the handicap that this induces for the Complexity of this product. This situation implies a non-linearity of this equation which corresponds to the extremal nature of this information. If a product is produced by many countries with high Fitness and just one country with very low Fitness the dominating information is this last one and the Complexity of this product will be low. By iterating these coupled equations one can get the Fitness of all countries and the Complexity of all products. We are going to see that this algorithm eliminates all the fundamental problems of the algorithms previously proposed and sets the basis for a solid playground for Economic Complexity that leads to results that have been tested in detail with “experiments” about the growth forecasting capability and a variety of “null models”

The solution of the China mystery and its relation with Saudi Arabia

Among the many interesting results of the Fitness approach a particularly important one is the solution of the China mystery mentioned before. Most of the standard analyses, which led to incorrect results for the forecasting of China's growth, were based on the statistical analysis of the previous GDP growth rates of other countries. This was also the case in the paper by Prickett and Summers who argued in 2014 that the period of fast growth (more than 5%) for Brazil and some other countries lasted about 8 years. Since in 2014, the period

of fast growth for China was already more than 30 years, they argued that the most reasonable expectation should be that this period should terminate soon, even in the following year (2015). With the Fitness we can now understand why this argument was incorrect. In fact, this argument was purely based on the GDP statistics, but if one considers also the Fitness a different pattern emerges. If we consider the plane of GDP (vertical axis) versus Fitness (horizontal) we can that the Fitness of China was far superior to that of Brazil and other countries that ended up in the middle-income trap. This means that the comparison of China with Brazil only in terms of GDP is totally misleading and that it is natural to expect that the period of fast growth for China is much longer. With this very important example, we can see how the Fitness information provides a broader and more informative perspective on country's growth.
The analysis of the trajectories in the GDP-Fitness (Income is GDP per capita) plane, shown schematically in the figure, permits us to obtain a GDP forecasting much better than that of IMF and other standard methods. This analysis led Bloomberg View to the conclusion that Fitness is the best method.

2.8 Key Technical Elements of the New Fitness Methodology

The Fitness methodology is much more than just the Fitness algorithm that was only the first step which, however, has paved the way for a consistent and reliable implementation of the concepts of Economic Complexity. Here we list the key technical points with their characteristics and methodologies. In this note, we refer to the Fitness methodology as the ensemble of methods listed below.

- Focus on Links (Country-Product) rather than on Sites.
- From 100 to zero parameters. Results are reproducible and testable.
- Construction of the Fitness-Complexity algorithm (beyond Google).
- Each Big Data problem will require a suitable algorithm (Big Data are creative).
- Forecasting from the dynamics in the GDP – Fitness plane
- Heterogeneous predictability. Better than IMF forecasting.
- Hierarchical use of data. introducing also: Technological Fitness, Scientific Fitness and their interrelations.
- Taxonomic relations between products (Arrow of Time)
- Product Progression Probability: given present products we define the adjacent possible.
- Fitness plus Machine Learning.

- Technological Fingerprints: Technologies necessary to a given product.
- Radical innovation from the dynamics of technology clustering in a suitable space: it is possible to define the first time that different technologies may appear in the same patent.
- Countries, Regions, Cities
- Analysis of Fitness (industrial competitiveness) and growth (poverty trap).
- Economic, Technological, and Scientific Fitness, and their interrelations.
- Novel approach to Forecasting and optimization for optimal growth.
- Effects of OBOR, BREXIT, ASEAN on relative competitiveness.
- Product Progression Probability for developing new products.
- Analysis of a new database about Inequality, Sustainability,
- Green and Circular Economy and Radical Innovations.

2.9 Fitness for Companies: New Specific Questions

This is the new challenge at the moment that we intend to develop together with IFC-WB within the collaboration at the Fermi Center and the FermiKnet project.

- Identify relative Ecosystem: Block Nestedness (the nature of the data is to have blocks with a local nested structure)
- Competitiveness in present and potential markets. Geographic expansion and product diversification.
- Identify a NEW product that you could produce given your tech space. Opportunities in future markets considering the development of industrial sectors. Patent portfolio valuation in terms of technologies.
- Outsourcing in a country which has developed suitable capabilities
- Which NEW product you may plan to sell in a NEW country, which is close to importing that product
- Increase your Technological Fitness by acquiring new suitable technologies
- Merging and Acquisition: Evaluation of the Coherency between company acquisition and target. If you want to enter in a certain sector which company targets to buy
- Radical Innovation: Prediction of radical innovations from the dynamics of Technologies in the Tech Space. Data from patents.
- Which will be your firm's next Technology?

2.9 The Fermi Knowledge Net (FermiKnet)

The strong collaboration of CREF with the World Banks Group's International Finance Corporation (IFC-WB) already led to the introduction of a knowledge network of economic, research, innovation and production activities. This knowledge network delivered unique academic results, including economic fitness, long-term growth forecasting, technology and research fingerprints, Recently an MoU was signed between CREF and IFC-WB to implement a joint lab at the Fermi Center, which would become the international reference Hub for these activities, the FermiKnet (K=knowlerge) with two objectives:

- Operationalizing the big-data input pipeline to maintain FermiKnet and to extend FermiKnet with new activities (such as the analysis of firms and job skills, etc)
- Developing a web site of appropriate dashboards for scientists, government officials, international development experts, and other interested parties based on Fitness indicators, and activity fingerprints which are predictive of structural growth and medium- and longer-term development. This project requires an investment in personnel, specific computer infrastructures and data acquisition, and it will represent a unique HUB of innovation and training of brilliant scientists.

The Fermi Center introduced a knowledge network of economic, research, innovation and production activities while collaborating with the World Bank Group's International Finance Corporation, which built on several earlier research initiatives. This knowledge network delivered unique academic results, including economic fitness, long-term growth forecasting, technology and research fingerprints, as well as middle-income and poverty-trap dynamics. Such academic results created the need to continually and systematically update the knowledge network with new data and to extend the types of activities linked into the network which can be used to understand and forecast growth, inequality, the green transition, manufacturing and service trends, as well as the development impact of different capital allocation strategies. Several big-data activities are required to acquire, integrate, and denoise the activity data from their heterogeneous sources.
The outputs from using the network are currently accessible to those with very specialized skills. The other objective of this proposal is to develop an appropriate website suitable to academicians, development economists, and other interested parties.

Big-data Infrastructure supporting FermiKNet.

The infrastructure will consist of several data management pipelines, allowing CREF staff to interactively and quickly explore, profile, clean, enrich, and shape diverse activity data into the knowledge network, and into AI assets ready to generate complex system indicators and machine learning model development and deployment.

Fitness Dashboards

The evolution of geographic locations in terms of both fitness and wealth over time are of interest to policy-makers and development officials who wish to shape the development of capabilities in specific regions and countries. These predictions from specific AI assets need to be made available in an interactive and usable way by different public audiences. In surfacing predictions from the AI assets a number of basic functions will be needed:

- Visual dashboards with interactive elements (parameter selection, country, region, sectors, products, etc).
- Registration and profiling to understand usage patterns.
- Information push which generates predictions and delivers them electronically to individuals.
- Summary analyses with “drill-down” functionality into underlying detailed source data.

Functional Requirements

The system function model provides a high-level view of the CREF Fitness interactive information system and the functions needed to satisfy the two objectives. It partially describes the information flow, data pipelines, and interactive dashboards without depicting the navigational flow.

Approximate Costs

The system is estimated to cost around $800,000 using a set of baseline estimates from peer institutions and suppliers. It includes one-time licensing costs of software, source content, and two years of installation costs and a direct operating budget. The development process is expected to take 6 months for the scope defined in the functional requirements figure. The agreement we propose is to share this investment about equally between the present project and a similar investment from IFC-WB.

Lectures on Economic Fitness

As part of this project we intend to develop a series of lectures on the methodology of the Economic Fitness which are complete from the basic scientific ideas to the most detailed applications. These lectures will also be available as an online course and will facilitate the international adoption of these new methods in academia and industry. A few years ago R. Benzi (Rome Tor Vergata and member of the Board of the Fermi Center) has organized a Master's Course in Physics of Tor Vergata with a detailed set of hands-on lectures. These can be used as the basis for the broader lectures we are going to develop.

3. Complexity and Artificial Intelligence for the Challenges of Sustainable Development Goals and the Dynamics of Information

This project corresponds also to an important international collaboration with the private sector. In fact, a joint Lab has already been implemented at CREF in collaboration with the Sony Computer Science Lab (Sony-CSL, https://csl.sony.fr/) in Paris, led by V. Loreto (also at Sapienza) The Sony CSL has been engaged for years in issues related to the goals of sustainable development, and this strategically important project is proposed for the creation of a new joint laboratory that can combine in a single space the sciences, the arts, and the business world for pushing innovation and aiming for concrete and applicable solutions on a large scale. The project will focus on the global innovation agenda, aiming to impact various sectors linked to the Sustainable Development Goals (SDGs) and will use the Sony know-how and the Economic Fitness and Complexity methodologies. This project is already in operation and it involves about 10 young scientists, part by CREF and part by Sony-CSL, located in the CREF building. The support of the present internationalization project will be mostly in terms of young scientists.
Our environment and our societies are clearly in danger and are undergoing major structural transformations, particularly through climate change, globalization, and digitalization. In this context, the ongoing crisis linked to COVID-19 has done nothing but make the proposals related to the Sustainable Development Goals (SDGs) even more urgent and pressing. Although the paths out of the current situation are not yet visible, it is clear that the crisis we are experiencing has the potential to profoundly change our habits and our lives. This complex system of

challenges requires developing new tools and methods to devise new solutions, plan optimal solutions, and effectively manage emergencies.

3.1 Areas of Application and Impact

In particular, due to the growing level of urbanization globally, many SDGs are destined to address issues related to urban spaces to: improve accessibility and mobility (SDG 11.2, 11.7); optimize logistics and waste management (SDG 12.4); enhance inclusion (SDG 10.7, 11.7); and promote a green transition (SDG 13.2). Another set of relevant challenges is related to disinformation. In addition to the damage to social dialogue, disinformation can have a strong impact on several SDGs. For example, disinformation is undermining awareness about vaccinations (SDG 3: Good health and well-being), is hindering decision-making on climate change (SDG 13: Climate action) and is threatening the democratic process and social cohesion (SDG 16: Strong institutions for peace and justice).

This project will set a research agenda aimed at:
·developing data-driven, reliable modelling schemes for the problems underlying the SDGs;
·developing new AI tools for exploring the space of solutions to the problems underlying the SDGs;
·developing and implementing platforms that make it possible for all stakeholders to view the current state of the systems and to conceive and explore new scenarios, testing their effectiveness in real contexts.
The cited tools aim to accelerate the rate of innovation through assisted co-creation and co-design processes. The diagram shown here schematically illustrates the interaction between the various different activities that the project will carry out. The structure in the figure revolves around the following three pillars, whose constant interaction represents the real novelty of the approach. Appropriate and accurate modelling schemes will be devised, exploiting statistical inference approaches, data-driven modelling, and machine learning, through a combination of human intuition and automatic inference. AI assistants will help devise relevant solutions in complex landscapes. Interactive platforms will constitute an interface for users, stakeholders, and decision-makers to understand the present and to evaluate the effectiveness and relevance of specific solutions.

Specific Objectives.

The project will focus on the global innovation agenda, aiming to impact in this way various sectors linked to the Sustainable Development Goals

(SDGs). In particular, due to the growing level of urbanization globally, many SDGs are destined to address issues related to urban spaces to: improve accessibility and mobility (SDG 11.2, 11.7); optimize logistics and waste management (SDG 12.4); enhance inclusion (SDG 10.7, 11.7); and promote a green transition (SDG 13.2). Another set of relevant challenges is related to disinformation. In addition to the damage to social dialogue, disinformation can have a strong impact on several SDGs. For example, disinformation is undermining awareness about vaccinations (SDG 3: Good health and well-being), is hindering decision-making on climate change (SDG 13: Climate action) and is threatening the democratic process and social cohesion (SDG 16: Strong institutions for peace and justice).

3.2 Sustainable Cities

Urbanization is an irreversible trend in global demographic dynamics. The World Economic Forum (WEF) predicts that, by 2050, 68% of the world's population will live in cities. While cities can be more energy efficient, this poses a number of challenges due to the high concentration of people and the resulting demand for resources, congestion, social divisions, and other issues. Cities today are undergoing significant changes that require informed and strategic thinking to achieve the SDGs. Urban phenomena (e.g., social exclusion and gentrification, mobility and accessibility, management of public events, recovery from natural disasters, redesign and planning of city boundaries and functional areas) act all on very different spatial and temporal scales (see figure).

The response to the challenges of urban sustainability can only come from a coordinated and multidisciplinary approach that operates on very different spatial and temporal scales—from the short time scale of the present to long-term strategic thinking and from the microscales of intervention on the ground (transport systems, logistics, etc.) to the large scale of the more complex characteristics (inclusion, gentrification, vocation of specific areas). The project will contribute to these challenges through the development of cutting-edge methods, merging the sciences of complexity, artificial intelligence, machine learning, and data science into a single approach. Furthermore, it will aim to create metrics and visualizations, modelling tools, and AI assistants whose impact will consist of their adoption by institutional agencies and policymakers around the world, to plan local interventions and remodel the cities of the future.

- WHO and WHY: Rethinking mobility needs and corresponding priorities. This implies understanding who has to move (WHO) and for what reasons (WHY). All these studies will be the basis for the

conception of new mobility models that combine safety, inclusiveness, and sustainability.

● WHERE and WHEN: A crucial element in planning the transition to the mobility of the future will be careful monitoring of the demand for mobility, i.e., understanding where people have to go and when and under what constraints, such as costs, duration, security, etc. In this context, the project aims to provide: (i) a reference framework in which data can be collected and organized in such a way as to be able to answer questions related to the fine-grained resolution levels affecting both the spatial and temporal domain; (ii) a set of tools to expand the set of observables for mobility to include, for example, safety distance factors.

● HOW: Once the mobility question has been assessed, it must be investigated whether and how this question can be satisfied or not. In this context, the extraordinary explosion of means or modes of transport must be considered. Shared mobility is now a reality that encompasses a variety of modes of transport, including car-sharing, bike-sharing, peer-to-peer ride-sharing, on-demand services, microtransit, and other modes, not to mention electric vehicles (EVs), semi-autonomous or fully autonomous vehicles (AV) and all the hybrid variants of these technologies.

● Conceive new solutions for safe, inclusive and sustainable mobility through a modular “what-if” platform (see for example the what-if machine platform developed by Sony CSL-Paris: http://whatif.cslparis.com/) to conceive new possible solutions for the transition of mobility and to validate them through a rigorous data-driven modelling of the complex phenomena underlying mobility. To this end, it will also be important to evaluate the models of individual and collective adoption of the new solutions, i.e. the integration of the new solutions into the fabric of the needs and habits of users.

● Conceive orchestrated scenarios for a transition to a new mobility. This objective comprises the synthesis of all the previous objectives and consists of the orchestration of new global mobility scenarios. The scenarios will be presented through the online interactive platform and discussed in depth with scholars, planners, stakeholders, and decision-makers.

3.3 Green Economy and Inequality

The impact of human systems of production and consumption on the environment is increasingly at the centre of public debate. There is a growing consensus on the urgency to tackle climate change and reduce CO2 emissions. The ideas of a sustainability transition and of a Green Deal are gaining momentum and are now the top priorities of Europe's political agenda (EC, 2019) and of Italy's PNRR.
As countries face the need to transition to more sustainable production and consumption, they will need to take advantage of the new business opportunities that play to their comparative advantages and identify profitable entry points in which they can compete in emerging green markets. In particular, there is a broad consensus that competitive green technology development will play a crucial role in sustaining this process of structural change as well as in addressing climate change and greenhouse gas emissions. Despite being a relatively recent phenomenon over recent years we have witnessed an acceleration in the development of green technologies, especially in the energy and transport area and they are easily identifiable within existing patent classifications thanks to the Y02-Y04S CPC tagging scheme for environmental-related technologies.

These are complex and multi-faceted phenomena. The reductionist view and strong assumptions on agent homogeneity of general equilibrium economics will difficulty be able to disentangle the underlying mechanisms and configurations that may lead to desirable economic and social outcomes. We argue that an analytical framework rooted in the Economic Complexity literature – that describes the economy as a complex evolving system characterized by several interacting domains - is better suited to provide a set of tools able to account for the increasingly dynamic and interconnected nature of the socio-economic transformations and structural change that the sustainability transition will ensue, as some exploratory but promising attempts have proven.
The Economic complexity toolbox will allow us to provide an integrated, multi-level analysis of the preparedness for the sustainability transition by studying on the one hand on the green technological competitiveness of countries and regions (Green Technology Fitness). On the other hand, it will allow us to provide fine-grained analyses and identify specific areas of potential in the "green race" by focusing on the complementarity and interactions between green technological development and non-green knowledge bases at the single technology level (Non-Green to Green Technology Space), and on its inter-relation with the industrial and scientific production of countries by looking at single product export or publications in specific research fields (Green Multilayer Networks).

3.4 The Dynamics of Information in the Social World

This corresponds to a joint project between the Fermi Center, Sony CSL and the group of W. Quattrociocchi (Sapienza Informatics). Social media has revolutionized how we communicate and inform ourselves, becoming the main source of information for most users. Facebook has more than two billion users, who generate more than three million posts per minute, getting information without the intermediation of journalists and experts, thus actively participating in producing and disseminating news and content. Recent studies have shown how user groups are concentrated in echo chambers that formulate and confirm their favorite narratives, systematically countering dissident information. In this situation, the effectiveness of fact-checking and debunking is highly questionable; instead, innovative tools are needed that address the problem of fake news using methods based on data analysis and the formulation of specific and dedicated algorithms with the same criteria of scientific and methodological rigor that led to the introduction of the Economic Fitness methodology.

Lab4News: As a byproduct of this project, we intend to establish a specific laboratory to apply the AI methodology for generating and analysing information. These methods are already developed internationally but not much in Italy. The idea is to fill this gap in a joint collaboration with journalists and media producers. Also in the case of the present internationalization project will support positions of junior scientists and extended stages of professionals.

Our goal is the data-driven modelling, assessment, and validation of social and politically relevant issues, such as misinformation, the economic impact of policies, information fluxes, pandemic trends, new frontiers in medical sciences, and the healthcare system through big data analysis. Specifically, concerning information and misinformation in the media environment, we research innovative tools to tackle issues originating by fake news, debunking, echo chambers, and polarization, employing quantitative methodologies and developing specific and dedicated algorithms. We are also committed to the dissemination of scientific results to non-specific audiences.

The project is based on a team of scientists from different fields (computer science, physics, engineering, and math). We apply complex systems modelling to data to study societal processes from information spreading to mobility up to epidemics. The lab of Quattrociocchi (Bottega) started in 2013 when they started collecting data points on Facebook jokes to mock users. They end up collecting tons of data about users' behaviour on misleading content. The first paper published, Collective Narratives in the Age of Misinformation studying the virality of content, went viral. A second study comparing how scientific information

and conspiracy information get consumed showed that users tend to acquire information adhering to their system of beliefs, substantially ignoring the information's truth value Science vs. Conspiracy: Collective Narratives in the Age of Misinformation. It was cited in major international newspapers as the scientists that trolled conspiracy theorists. Then, to prove another aspect: how users respond to information dissenting their system of beliefs, they studied how followers of alternative information sources react to debunking/fact-checking posts. It was the paper Debunking in a World of Tribes. They found evidence that users simply ignore opposing viewpoints. If someone tries to force them, the reaction is to backfire: they become more active in consuming alternative content after fact-checking. The paper was impressively viral, and the results heavily impacted the public debate about information and social media. The famous column "What was fake on the on the internet this week" of the Washington Post closed citing this work. At that point, there was all the information to provide a model for information spreading online. Users online can find the information they like the most, ignore dissenting information, and join groups of like-minded peers (echo chambers) in which we cooperate to frame a shared narrative. They published this in PNAS in 2016 in the paper The spreading of misinformation online. The paper nowadays is considered one of the pioneering studies on misinformation dynamics.

After that, they explored how users consume news through social media. They found the same dynamics of selective exposure dominating the system. The paper was published in the PNAS Anatomy of news consumption on Facebook. Misinformation proliferates when polarization is high. This led to a classification model to predict misinformation targets in the paper Fake News and Polarization: Early Warning of Potential Misinformation Targets. In this period, they are exploring the diverse dynamics in different platforms, especially during COVID-19. They are studying how the language adapted to the new information ecosystem and how those processes affect our society. These works made explicit that social media heavily changed how we process information and shape our opinions. Even Facebook admitted that in this blog post.

From this work, the important lesson is that there is a huge work to rebuild trust in Science. Keeping this in mind, it was set up as the Center of Data Science and Complexity for Society. The idea is to build a network to address important societal problems with an open and inclusive scientific approach. Science is for all of us. The Fermi Center will integrate this work and embed it in a broader framework of international collaborations. However, there are already several collaborations with international organizations and companies. Among the most important ones, we can mention Facebook, Google, the UK

Government, The University of Cambridge (Prof. Van Der Linden), Harvard University (Prof. Elena Savoia), City University (Prof. Andrea Baronchelli), London School of Disease and Tropical Medicine (Heidi Larson), Exeter University (Massimo Stella). Also, Sony CSL (coordinated by V. Loreto) has been active in information dynamics and now these different groups will converge in the joint project with the Fermi Center.
Here we give a brief account of the SONY CSL projects already active in this area.

The Dynamics of Information and the Social Dialogue.

During the COVID-19 crisis, we have seen yet another confirmation of how crucial information and information technologies (Internet, social media, etc.) are in the life of a country. Particularly in countries with high levels of democracy, where the political class is strongly linked to the opinions of the population, the information enjoyed by the population is the source from which many mass behaviors arise, as well as the selection of the political class itself. However, if information technologies have radically changed the dynamics according to which these mechanisms historically occurred, they have also opened this process to new influences and new phenomenologies.
It is quite evident that in the last century, the conflicts between states that previously took place mainly on the military level have been transferred mainly to the economic level. A recent and striking example of this is the trade war between the United States and China, which is actually part of a wider conflict for world economic hegemony. However, if the competition on the economic level is clear, another fundamental conflict level still in the shadows is that of information. Information technologies, which, in democratic countries, have reached very high levels of penetration, represent the new battlefields of world conflicts. However, the clashes are no longer between armies, but between narratives. There are many documented cases of attempts to influence democratic life during crucial and delicate moments, as in the case of Brexit or the US elections of 2016 and 2020.
However, it would be superficial to reduce the impact of social media on political discourse to attempts at external influences (which in fact have always existed since propaganda existed, but in other forms). The speed and interconnection capacity of new media, new technological tools for content creation, and new platforms have created a vast plethora of new phenomena, as well as changing the dynamics of historically known phenomena, even without the intervention of external influences. For example, the unprecedented interaction of confirmation bias with the gargantuan availability of content and resources made possible by the various platforms is one of the phenomena behind the rise of the so-called echo chamber. Another phenomenon of interest is the use of bots to “dop” the visibility of a profile or the dissemination of some news

for commercial purposes, or the explosion of hate speech and trolling phenomena linked to the crisis of trust on the part of social media users.
All this vast and heterogeneous phenomenology has three main ingredients in common:

- human cognitive and communicative abilities, with their peculiarities and their biases, which have always influenced social interactions, have now fallen into a new context with consequences that are only minimally understood;
- the new information technologies, which not only offer an unprecedented speed and capacity of use and dissemination of resources but which are also made up of algorithms and systems to manage the exploration of these resources that heavily affect the dynamics of exploration and fruition;
- the emergence of collective phenomena from individual behaviors mediated by new technologies, which occurs in a rapidly evolving manner but which the new availability of data and experimental possibilities, makes it possible to study from an absolutely unprecedented quantitative point of view.

It is the co-occurrence of these elements that makes the collaboration between the Fermi Center and the Sony CSL in Paris the ideal convergence to scientifically address the issues related to the new dynamics of information. The collaboration aims to address the problems set out on two different but parallel directives.

The Study of New Critical Information Phenomenologies.

The first directive consists of a tactical approach for the frontal study of critical phenomenologies such as:

- misinformation, and in particular the spread of fake news;
- the creation and dissolution of the echo chambers and more generally the phenomena of polarization of opinions;
- hate speech and trolling;
- the use of bots on social networks;
- the competition between conflicting narratives;
- information imbalances, i.e., the overabundance of information on some topics as opposed to the lack of information in others.

In recent years, these research topics have been attracting growing interest from both the scientific community and the institutions, which have understood their crucial importance for democratic stability and the health of public discourse. The study of these issues will be addressed thanks to the scientific advancement of the techniques of modelling the Dynamics of Opinion, Network Theory, Machine Learning and, in general, the technical armamentarium of Data Science. The purpose of this directive is first of all to offer a deep scientific understanding of these phenomenologies that increases the

transparency of the public debate. Secondly, this understanding will give rise to real-time monitoring and disclosure tools to verify and make visible, in a transversal and transparent manner, the state of health of the public debate both to the population and to policy-makers

Improving the Information Ecosystem.

From a more strategic point of view, the collaboration aims to improve public discourse through the study of the conditions in which this occurs and through the proposal of new tools to avoid vicious circles and enhance virtuous behavior. The study subjects will be, for example:

- the algorithms for selecting and filtering resources on social media (the so-called recommendation systems) and their impact on the dynamics of exploration and formation of opinions. Such systems have often been linked to the creation of echo chambers due to their drive towards the preferences expressed in the past by users. Therefore, the strategic objective will be to verify this effect and develop new systems that can help the user explore new content without making the experience less pleasant, thus playing on the border of the so-called comfort zone.
- reputation systems to improve the dynamics of trust in information sources. Paradoxically, we have information aggregated and organized into reviews and ratings on almost any type of content available on the net (movies, music, etc.) but not on the information sources themselves. The strategic objective consists of the study of these reputation systems and the experimental introduction of these systems, appropriately adapted, in the context of information sources. In fact, the aggregation systems of the evaluations will necessarily have to be adapted to compensate for the effects due to the echo chambers, avoiding that each “supporter” validates their own source of trust, by attributing a privileged weight to the transversality of the evaluations. These systems will be able to play a strategic role in building healthier and more transparent information dynamics.

These two directives, parallel but communicating, consist of pure research activities, as well as experimentations and case studies. This is also why the axis between the Fermi Center and Sony CSL in Paris is fundamental, as a collector of skills, experiences, and know-how that cover both the scientific and technological aspects. In addition, the Sony CSL in Paris boasts a historic collaboration with AGCOM (Italian Communications Authority), with several active projects on topics close to those explained. AGCOM is a partner of exceptional value because it has standing with both the community of information professionals, with the stakeholders, and with the policy-makers, whose strategic value,

both for theoretical and more experimental initiatives, has a very high impact.

4. Infrastructure for Photonic Computation@CREF

How do we make up for the losses of the brain drain?

When a young researcher leaves Italy, not only does a motivated talent be lost, but the investment that Italy has made in the new generations is burnt. It takes years, laboratories, and educators to train a talented person, like the many professors and scientists who work in our universities and research institutions. When some young people move abroad, they transfer this value for free to another nation. How can we fix it? Creating the conditions for the skills born in Italy, gained abroad, to return to Italy. This does not just mean ensuring the return of brains. But to create tools so that Italians who work outside, but also foreigners interested in collaborating with Italian scientists and scientists, can transfer their skills back to Italy.

The brain-rehabilitation and bilateral collaboration programs are always too limited and do not have the background to fuel an effective relocation of experienced staff who have been working abroad for years in more mature and more organized contexts for a specific activity.

The internationalization program we propose here is the creation of joint laboratories set up in collaboration with foreign scientists, interested in spending various periods in Italy or even remotely directing their collaborations with Italian researchers. This activity not only allows the recovery of skills (gained and integrated with years outside) but, if oriented towards the creation of industrial realities, such as start-ups, it can create jobs for young researchers and effectively stop the flight of researchers. The Fermi Center, with its facilities and location and the numerous university professors who collaborate with it, can both attract skills from outside and students for the technological growth of the country.

Distributed laboratory of computational nano-photonics @CREF (directed by C. Conti, also at Sapienza and director of ISC-CNR)

As an example of this initiative, it is proposed to create a laboratory at CREF for the development of classical and quantum photonic computing systems. This laboratory involves the University of St. Andrews in the UK, KAUST University, the CNRS, and other institutions through

collaborations with Italian and foreign professors interested in creating and transferring their skills to Italy.
A new laboratory will, therefore, be created with various spaces dedicated to fundamental and applied interdisciplinary research as described below. The laboratory will also include facilities for the fabrication and testing of devices. And it will be oriented towards technology transfer in order to stimulate the development of patents and spin-offs as well as start-up creations to create jobs for young researchers.

Note on proposed research

The major obstacle to the large-scale diffusion of modern computational systems is to be identified in electricity consumption and the related environmental impact. The latter emerges from the use of integrated silicon technologies and the refrigeration costs of the computational equipment. Various studies show how the cost of pollution in training a neural network for language recognition or for the translation of texts is comparable to that of an intercontinental flight. If you think of the thousands of times in which this training is repeated, or of other massive uses such as in cryptocurrency mining or security technologies, one quickly becomes convinced that the problem of the "carbon footprint" of artificial intelligence will be one of the main issues. in the short term.
Photonic technologies are now recognized and mature to represent the solution to this problem. The use of photons for the transport and processing of information is inherently less expensive than and devoid of consumption when compared with electrons, commonly used. The advantage is combined with higher speed, infinitely larger bandwidth, and compatibility with fiber optic backbones that already dominate world telecommunications. In the field of photonic computing, numerous scientific startups have recently emerged, and the first photonic processors are emerging on the market, which are already replacing conventional computational systems such as GPUs for large-scale data processing.
Computational photonic technologies are also one of the most compelling propositions for quantum computing, but they are not limited to this type of technology. Using photonic processors it is possible to create both classical algorithms (such as combinatorial optimization or products between large-scale matrices) and quantum algorithms. Furthermore, it is possible to realize intrinsically safe computer systems compatible with the usual already pervasive fiber optic transmission systems.

In the face of these considerable potentials, which are the basis of considerable investments by industrial companies in the US or in China,

there is no significant attention on the part of the major research bodies in Italy. For example, in the IIT photonic computation is practically absent, in the CNR and in the INFN they pursue more conventional technologies for quantum computing, such as ultra-cold atoms. These are relevant to basic physics but suffer from fundamental problems, such as the need for apparatuses that operate at low temperatures, or the reduced number of accessible qubits. It, therefore, appears natural to propose the first Italian photonic computing infrastructure at the Fermi center, to complement the ongoing initiatives on quantum technologies on a national scale, but greatly extend its field of action.

There are numerous very recent results, which have appeared in the most important journals, regarding so-called neuromorphic algorithms, both classical and quantum, which open important horizons, which we want to explore at CREF, in a highly innovative approach compared to the most studied quantum technologies. on which it is difficult to compete given the unparalleled investment both in terms of people and funds that can be observed in China or the US.
The idea is to conceive a new infrastructure for photonic computing based on innovative computational models of artificial intelligence, still little explored but extremely promising. To get a concrete idea, it should be noted that at the time of writing the largest "traditional" quantum computer boasts 67 qubit. The photonic computer we are studying at CREF works at a classical 10^4 bit scale (extendable to 10^6) and is able to work also in a quantum regime. It is therefore of great interest to develop computational photonic technologies, and the Italian scientific situation seems to suggest this direction for an original and cutting-edge activity, which can quickly prove competitive even at an international level.

The problems considered are specifically oriented towards the applications in the transmission of quantum and classical photonic data and in novel algorithms of quantum computation for combinatorial optimization and neuromorphic computation. The researchers involved have published pioneering work of international resonance, like the largest optical Ising machine, the first experimental demonstration of neuromorphic computation, and the first systems of boson sampling which show the advantages of quantum computation.

The infrastructure on which this project is based will reinforce the national and international leadership in these areas and will pave the ground for further developments, like the models of Hybrid Quantum Computing (HQC) which mix quantum and classical information to achieve the maximum performance from the present technological platforms. The objective is to operate within the NISQ (Noisy,

Intermediate-Scale Quantum) era. The algorithms developed with these technologies are very promising in many areas like graph theory, NP-complete problems, bioinformatics and non-trivial optimization problems. This infrastructure will permit the implementation of quantum hybrid computations using advanced photonic machines to realize the first demonstrations of these applications and open the way also to possible industrial applications.

The CREF^2 is the final objective of the project and it is the acronym of "Calcolatore di Ricerca Elettronico Fotonico" (CREF) at CREF (Centro Ricerche Enrico Fermi). CREF^2 is inspired by the original proposal of Fermi for the first electronic calculator for research, with the difference that this computer will use hybrid photonic and electronic technology and will be based on conventional computational systems accelerated by devices based on classical and quantum photons. This infrastructure will be based in suitable laboratories at the Fermi Center. In terms of budget, the contribution of the present project will be important but partial, because the total cost will be much more and we plan to apply also to other funding sources specific to this infrastructure.

5. Fundamental Physics in Space: general Relativity and Inertial Dragging

This research group is coordinated by I. Ciufolini and it is dedicated to studying and testing General Relativity and theories of fundamental physics using dedicated satellites, among which LARES (launched in 2012) and LARES 2 (ready for launch in June 2022). The Fermi Center has the scientific leadership of this research with scientists from the University of Texas at Austin, University of Maryland, NASA, Helmholtz Centre Potsdam/GFZ Wessling, University of Oxford, Yerevan State University, University of Missouri and Sapienza University of Rome.

During the past century, Einstein's gravitational theory of General Relativity gave rise to an experimental and theoretical triumph [Charles W. Misner, Kip S. Thorne, John A. Wheeler, Gravitation (Freeman, San Francisco, 1973); Ignazio Ciufolini and John A. Wheeler. Gravitation and Inertia. (Princeton University Press, 1995)].
On the one hand, a number of key predictions of General Relativity have been experimentally confirmed with impressive accuracy. On the other hand, Einstein's gravitational theory is a fundamental component for the

understanding of a number of astrophysical and cosmological observations. Furthermore, General Relativity today has practical applications in space research, geodesy, astronomy and navigation in the
Solar System, from the global positioning satellite system (GNSS) to the techniques of very long baseline interferometry (VLBI) and satellite laser ranging (SLR). Today the evolution of the universe and the gravitational interaction are described by General Relativity which represents gravitation as spacetime curvature. Fundamental predictions of General Relativity include the expansion of the universe and black holes.

Nevertheless, despite its experimental and theoretical triumphs during the last hundred years, Einstein's theory has encountered some unexpected developments in observational cosmology. Indeed, the study of distant supernovae in 1998 led to a discovery that they accelerate away from us, this accelerated expansion of the universe can be explained by "dark energy" but its nature is today one of the biggest riddles in physics. Observational data currently support its interpretation as the cosmological constant introduced by Einstein. However, its current value needs to agree with the expectations of quantum field theory. Furthermore, General Relativity is a classical theory that does not encompass Quantum Mechanics, and no one has succeeded in a quantized version of Einstein's theory, though there are efforts, with both Loop Quantum Gravity and String Theory approaches. Combining General Relativity with quantum theory might reveal the nature of dark energy and hence resolve the mystery of its value, and whether it might be related to dark matter (that invisible form of matter inferred from its gravitational effects). Furthermore, Einstein's theory predicts the occurrence of spacetime singularities, events in which every known physical theory ceases to be valid, the spacetime curvature diverges and time ends. Modifications of Einstein's gravitational theory on cosmological scales, for instance, the so-called f(R) theories (with higher-order curvature terms in the action), have been proposed to explain the acceleration of the universe without dark energy.
"Fundamental Physics in Space" of the Fermi Center is studying and testing the predictions of General Relativity and theories of fundamental physics using dedicated satellites and dedicated space missions. Among the phenomena studied and tested by the team of Centro Fermi are the "dragging of inertial frames" or "frame-dragging" [I. CIUFOLINI, Dragging of inertial frames. Nature, 449:41–47, 2007] and the equivalence principle.
The origin of inertia has intrigued scientists and philosophers for centuries. Inertial frames of reference permeate our daily life. The inertial and centrifugal forces, such as the pull and push that we feel when our vehicle accelerates, brakes and turns, arise because of changes in

velocity relative to uniformly moving inertial frames. A classical interpretation ascribed these forces to acceleration relative to some absolute frame independent of the cosmological matter, whereas an opposite view related them to acceleration relative to all the masses and “fixed stars” in the Universe. An echo and partial realization of the latter idea can be found in General Relativity, which predicts that a spinning mass will “drag” the inertial frames along with it. However, what determines an inertial frame? And, in general, what is the origin of inertia? In the mechanics of Galileo Galilei and Isaac Newton, an inertial frame has an absolute existence, uninfluenced by the matter in the Universe. In Einstein’s gravitational theory, the inertial and centrifugal forces are due to our accelerations and rotations with respect to the so-called local inertial frames, which, in turn, are determined, influenced and dragged by the distribution and flow of mass energy in the Universe. In particular, they are dragged by the motion and rotation of nearby matter; this general relativistic phenomenon is called “frame-dragging” and represents in Einstein’s theory the remnant of the ideas of Ernst Mach (1838-1916) on the origin of inertia. Mach thought that centrifugal and inertial forces were due to rotations and accelerations with respect to all the masses in the Universe; this is known as “Mach’s principle” and inspired Einstein in his development of General Relativity.

Frame-dragging may be usefully described by a formal analogy of General Relativity, in the weak gravitational field and slow-motion approximation, with electrodynamics. For this reason, frame-dragging phenomena, which are due to mass currents and mass rotation, have been called gravitomagnetism. In General Relativity, freely falling test-gyroscopes, i.e., sufficiently small and accurate spinning tops, determine the axes of the local, non-rotating, inertial frames, where the equivalence principle holds – i.e. where the gravitational field is locally "unobservable" and all the laws of physics are the laws of Special Relativity. Therefore, if we rotate with respect to these gyroscopes, we feel centrifugal forces, even though we may not rotate at all with respect to “distant stars”, contrary to our everyday intuition. Indeed, a gyroscope is dragged by spinning masses, i.e. its orientation changes with respect to “distant stars”. Whereas an electric charge generates an electric field and a current of electric charge generates a magnetic field, in Newtonian gravitational theory, the mass of a body generates a gravitational field but a current of mass, for example, the rotation of a body, would not generate any additional gravitational field. On the other hand, Einstein’s gravitational theory predicts that a current of mass would generate a gravitomagnetic field which would exert a force on surrounding bodies and would change the structure of spacetime by generating additional curvature. A gravitomagnetic field generates the frame-dragging of a gyroscope in a similar way to a magnetic field producing the change of

the orientation of a magnetic dipole (magnetic needle). Indeed, in General Relativity, a current of mass in a loop (i.e., a gyroscope) behaves in a formally similar way to that of a magnetic dipole, which is made of an electric current in a loop, in electrodynamics.
LARES (LAser RElativity Satellite) and LARES 2 are two laser-ranged satellites of the Italian Space Agency (ASI) to test General Relativity and fundamental physics. LARES was successfully launched on 13 February 2012 with the VEGA launcher of the European Space Agency (ESA), which was developed by ASI and AVIO SPACE. LARES has a semimajor axis of 7821 km, orbital eccentricity of 0.0008 and inclination of 69.5 degrees. Its mass is 386.8 kg, its diameter 36.4 cm and is covered with 92 retro-reflectors reflecting back the laser pulses to precisely determine the range between the satellite and the laser-ranging stations on Earth with an uncertainty, for the best SLR (Satellite Laser Ranging) stations, of less than 1 cm. It is well observed by the global network of laser stations of the International Laser Ranging Service (ILRS) and provided hundreds of international publications in General Relativity, fundamental physics, space geodesy and geophysics. Using LARES, the international team led by the Fermi Center published a number of tests of the intriguing phenomenon of “dragging of inertial frames”, predicted by General Relativity, reaching an accuracy of almost one per cent [4]. Some alternative gravitational theories, such as the Chern-Simons theory and some string theories, predict a different outcome than General Relativity for “frame-dragging”. LARES provided other tests of gravitational physics, among which a test of the equivalence principle with an accuracy of about one part in a billion, using materials never tested before and at unprecedented new ranges [[4] Ignazio Ciufolini, Antonio Paolozzi, Erricos C. Pavlis, Giampiero Sindoni, John Ries, Richard Matzner, Rolf Koenig, Claudio Paris and Roger Penrose, An improved test of the general relativistic effect of frame-dragging using the LARES and LAGEOS satellites. The European Physical Journal C, 79, 872 (2019)] and a number of measurements in space geodesy and geodynamics.
LARES 2, of ASI, is ready for launch in June 2022 using the new launching vehicle VEGA C of ESA, ASI and AVIO space. LARES will have a semimajor axis of about 12270 km and inclination of about 70 degrees. Its mass is 395 kg, its diameter 42 cm and is covered with 303 retro-reflectors. Due to both its special orbit and its special structure allowing a laser-ranging precision below one millimeter, LARES 2 will provide tests of dragging of inertial frames with an accuracy of almost one part in a thousand, other accurate tests of gravitational physics and measurements in space geodesy and geodynamics.

The Fermi Center has the international scientific leadership of both the LARES and LARES 2 space missions, with scientists from the University of Texas at Austin, University of Maryland, NASA, Helmholtz Centre

Potsdam/GFZ Wessling, University of Oxford, Yerevan State University, University of Missouri and Sapienza University of Rome.

6. The Fermi Hub Connections, Present and Future

An important element for the creation of the Fermi Hub is the fact that LP has been the leader of a generation of young scientists who are protagonists of the condensed matter theory, statistical physics and complexity science scene internationally. Many of these students are mature or young scientists who continued their scientific careers and occupy important scientific positions at the national and international levels in academic, research institutions and companies. The international Hub which is the objective of this project will have, as a natural core, this network of interactions and long-standing collaborations which will play a fundamental role in the project.
In this section, we illustrate in some detail the contacts and collaborations that the Fermi Center has already developed together with those that are being considered or planned. In order to have an international impact and to be considered as a Hub in various areas it is essential for an institution to be strongly representative in its own country. So we start with the collaborations that the Fermi Center has in Italy.

ITALIAN EPR:

- ### Institute of Complex Systems of CNR (ISC-CNR)

This institution was established in 2004 (and directed until 2014) by LP and in many ways, CREF is a natural evolution of ISC-CNR. The present director of ISC-CNR Claudio Conti is also the director of the Photonic Lab. of CREF. The methodology of Economic Fitness and Complexity was originally developed at Sapienza Univ. and ISC-CNR and the collaborations are broad and cover many projects. In many respects, the two institutions are fully integrated and perfectly collaborative.

· IRCRES-CNR

We organize meetings in the areas of Economics and Complexity Science and consider possible research collaborations, in particular with the team of Giovanni Cerulli.

· ISM-CNR Trieste

Collaborations with E. Cappelluti on the theory of High Tc Superconductivity, including a novel approach to materials research by Machine Learning to which Sapienza Univ. participates.

· INFN

CREF has signed an agreement of collaboration with INFN in relation to the project EEE (Extreme Energy Events). This is a project of outreach in which about 60 cosmic ray detectors have been located in high schools all over Italy. The collaboration with INFN consists of the technical maintenance of the detectors and the data analysis. There are also other collaborations in other interdisciplinary areas. In addition, many INFN meetings are currently hosted in the Fermi Center Auditorium.

· INAPP (Istituto Nazionale per l'Analisi delle Politiche Pubbliche)

There is a natural scientific complementarity between CREF and INAPP and we already had various meetings with the President D. Fadda and the DG Santo Darko Grillo. Recently LP gave a lecture at INAPP to present the methodology of Economic Fitness and Complexity which can be useful for a more quantitative approach to the INAPP analysis as already happens with the World Bank and the JRC-EU Commission.

· ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale)

We had many meetings and discussions with the President S. La Porta about the Green Economy and Sustainability. Also in this case we can add algorithmic methods to the standard analysis in these areas.

ITALIAN UNIVERSITIES:

· The Ph.D. Project

One of the very first initiatives we have implemented at CREF has been to support PhD positions in collaboration with all the universities in the Rome area, Sapienza, Tor Vergata and Rome 3. This initiative has two objectives. On one hand to have a constant flow of brilliant young scientists, and on the other hand, to develop strong interactions and collaborations in the area. This initiative brings into CREF about five new Ph.D. students every year and at the moment there are 12 PhD students operating at CREF with several projects in collaboration with the three universities. We also stimulate an international exchange of Ph.D. students with other institutions in Europe.

· Pisa Sant'Anna

This is a very prestigious institution in the area of economics and social sciences. It is a natural partner for our activities in the area of Economic Fitness and Complexity. We have various projects together (national and European) and we have already implemented an exchange of students and Post Docs. The leading figures of these collaborations are G.Dosi, M. Virgillito and A. Roventini. Recently there was a workshop at the Fermi Center in which scientists from the two institutions, plus some policymakers, discussed their research on Green Economy and Sustainability.

· Rome Universities: Sapienza, Tor Vergata and Rome 3

In addition to the PhD programs we have several further collaborations with these three universities in the Rome area. In particular, LP has been a professor at Sapienza for 34 years and V. Loreto, C. Conti, L. Boeri and W. Quattrociocchi are actually professors at Sapienza and are also responsible for research projects at CREF. This situation naturally implies very strong interactions and collaborations with many former students and colleagues. The collaboration with Sapienza is also well-developed for the Museum because Sapienza was historically the follower of the Fermi Center for the activities of the Fermi group. Sapienza has its own small museum (directed by S. Caprara) with which we collaborate to expose this material also in the CREF Museum.

· Milano Universities

We have close contacts and collaborations with Statale (S. Zapperi, professor of Physics and former student of LP); Politecnico (S.Savaresi,

Informatic Engineering) and Bocconi (F. Malerba, professor of Economics).

· Trieste Institutions

Long-standing collaborations with ICTP (M. Marsili, former student of LP) and SISSA (E. Tosatti)

We have also contacts and collaborations at various levels with other universities: Napoli Federico II (L. De Arcangelis, member of the scientific board of CREF and S. Esposito, collaborator of CREF for History of Physics); Florence (S. Ruffo and R. Livi); Ancona (M. Gallegati); Sicily: Palermo and Catania, CREF organizes a summer school in Lipari next July and various connections also with Turin, Venice, Bologna, Bari and L'Aquila.

MUSEUM, DIVULGATION AND OUTREACH IN HIGH SCHOOLS

· The CREF MUSEUM

The CREF Museum is already well-established with high-quality and interactive installations. We plan to improve it constantly and make a special effort to make it more popular in the city and beyond. In order to achieve this objective we will implement a number of initiatives. The first is to continuously improve the quality of the presentations and the possibility to raise interest at all levels, from the high school student to the professional scientist. The second is to implement new and up-to-date installations like for example a space for virtual reality which is being organized. The third is to make the museum well known to a broad public with a series of initiatives, from social media to the official group of Rome Museums. The fourth is to make access simpler and faster, considering that the Fermi Center is located within the area of the Ministry of Internal Affairs and that the security measures are rather strong. In summary, our objective is that, after the Pandemic, the number of visitors to the CREF Museum should rise exponentially and we consider this achievement as our specific responsibility.
Recently we made an effort to give an international dimension to the Museum. As a first step, we have contacted the association of the foreign Erasmus students in Roma and we invited them all to visit the

Museum. We intend to extend this type of initiative in various ways that are under consideration.

· EXTREME ENERGY EVENTS (EEE)

This is a project of outreach which involves about 60 high schools all over Italy. In each of these schools was located a cosmic ray detector for a vast joint program to get young students involved in a scientific project. We intend to support and develop these outreach activities in this and other fields and stimulate these students to visit the CREF museum periodically and have scientific interactions with CREF.

ELIS High Schools (ELIS: Educazione, lavoro, istruzione, Sport) and the Ecological and Digital Transition in High Schools.

A number of High Schools all over Italy have been organized by Pietro Papoff to include in a novel way the above concepts. We are organizing a collaboration with these high schools and recently Pietro Papoff has visited CREF for a concrete implementation. These students (more than 500) will be invited to visit CREF and its Museum and we will also organize scientific programs in relation to the science of the ecological transition.

PUBLIC RESEARCH AND PRIVATE SECTOR

One of the original objectives of the Fermi Center is to establish constructive and fruitful interactions
with the private sector. This is a particularly critical element in Italy because the small-medium enterprises, which are the backbone of the Italian industrial system, often cannot afford to have a research center. So, interaction with public research becomes extremely important. The fact that LP has worked for ten years in international industrial laboratories provides a sound basis for developing constructive interactions between public research and the private sector. This interaction is already active for a few years and we intend to develop it much more in the future.
Here we list the Italian companies in which we already have interactions at different levels. We have also collaborations with companies at the international level which will be mentioned later.

Assoknowledge (Confindustria)

We have long-standing interactions and collaborations with Laura Detìitinger, President of Assoknowledge, the branch of Confindustria for Innovation and Knowledge. In particular, LP has been invited to various meetings of Assoknowledge and we also had a meeting with Gianfelice Rocca when he was President of the Lombardy section of Confindustria. These interactions have created a network of contacts with various Italian industries which we will involve in the CREF initiatives. As an example last year, we organized a meeting at CREF about the links between scientific research and digital industries.
The program:
https://cref.it/il-cref-organizza-un-workshop-sul-rapporto-tra-scienza-ed-impresa-digitale/
All the videos of the lectures can be found here: https://cref.it/scienza-e-impresa-digitale/

Translated.com and PI CAMPUS

Automatic translations represent one of the most challenging applications and test grounds for Artificial Intelligence. Translated.com is a remarkable company based on the application of Artificial Intelligence to the problem of translation. It is an international leader in this highly competitive field and most of its clients and collaborations are in Silicon Valley but also the European Commission. It was established in Rome about twenty years ago by Marco Trombetti and his wife Isabelle Andrieu and today it represents a fantastic example in this field not only in Italy but at the top international level. The approach started with human translations and gradually added the automatic part which, since the beginning, has been constantly growing. This shows how AI combined with human action can be extremely successful and it is a very interesting example of the optimal collaboration of humans with AI. The resources gained from this company are mostly reinvested in the more scientific branch of PI CAMPUS (https://picampus.it/) which supports about fifty Start-Ups in the most diverse areas of AI.
For a few years, we have had a broad and intense collaboration with both institutions ranging from supporting PhD positions to organizing conferences and lectures together as well as developing joint research projects. The last project on which we are collaborating has the name T-index. The idea is to define the value of a language, from the perspective of the possible translation of the company information and data, considering its products, location and competitiveness. For this project, we have used extensively our results from the area of Economic Fitness and Complexity.

We plan to increase the interactions with PI CAMPUS because, considering the extremely international nature of this institution, this will be a very strong point for the internationalization plan of the Fermi Center in the private sector and industrial areas.

Last Minute and Vola Gratis

This is another company based on data science and AI. It was established about 20 years ago by Marco Corradino and it is a European leader in the online selling of air tickets. Before COVID it had more than 1200 employees all over Europe. We have already collaborated in various ways. First, we helped them to establish a group for data science and Machine Learning. Then we considered the so-called “attribution problem” which consists of identifying the optimal website on which to place an advertisement. In practice, this consists of an algorithmic problem that we have studied with the method of the Hidden Markov Model. We are now considering together other problems in various areas including the Block Chain and Cryptocurrencies.

ENEL

We had various contacts with ENEL in the past and some time ago LP was invited to a strategic meeting with the top management and the President of ENEL. This was followed by various other meetings but no concrete collaboration was established. Recently one of our former students was hired by the ENEL Data Science group and he proposed a collaboration in the area of Economic Fitness which is under consideration.

ENI

We had various scientific meetings with ENI scientists but up to now no collaboration has been established. We will work on this possibility with various initiatives because we believe we can contribute to their international strategies for country development and the energy transition. On the same ground, we had some collaboration with Shell for the strategic analysis of country growth and development and we are confident that also ENI should be interested in these subjects.

Generali

Generali is probably the largest financial corporation in Italy with broad international coverage. LP was recently invited to deliver a lecture in a strategic meeting with the President and the top management. We are considering possible collaborations in the area of Economic Fitness and Complexity.

Fincantieri

LP was recently invited to a meeting with G. Bono (President) and F. Gallia (DG) of Fincantieri to discuss the possible use of Economic Fitness for the diversification plans of Fincantieri and consider possible collaborations.

Space Italy

We have long-standing contacts with this scientific area and in particular with Rodolfo Guzzi and we are planning a specific study of the Space Economy with our methodology of the Economic Fitness and Complexity.

MEGARIDE

This is a young Start-Up which applies Artificial Intelligence to various problems in the area of Automotive. We had many discussions with them, they participate in our meetings and a collaboration is certainly possible.

Media Companies

In the last few years media companies at the international level have been using more and more technologies based on AI to collect and process information, while in Italy the situation is still rather traditional. This trend is producing a radical change in the whole area of media companies. We are organizing a research group (Lab4News) in this field to stimulate this evolution also in Italy.

INTERNATIONAL CONTACTS AND COLLABORATIONS:

EUROPE AND MIDDLE EAST

Joint Research Center of the European Union (JRC-EU)

Since a few years we have had a very close collaboration with JRC-EU and three former students of LP have been hired by JRC-EU to implement the Economic Fitness methodology for the analysis and development of all the EU countries. In particular, as discussed in detail earlier in this document, this methodology will be officially used to evaluate the PNRR recovery fund projects.

United Kingdom

Tiziana Di Matteo is a Professor at the King's College of London and she is also a member of the Board of the Fermi Center. For this reason, we have a very close interactions and collaborations with this institution and we are also considering the possibility of a joint PhD program. We also had effective collaborations with Michael Batty (UCL, London) on the application of the Fitness methodology for the internal structure of Cities.

Recently an important collaboration has been established with Pasquale Scaramozzino (SOAS Financial Institute, London) to develop a bridge between our algorithmic methods interpreted within a more standard economic analysis. This bridge is culturally important to develop a mutual understanding between Complexity Science and Economics.

In addition, we have various other contacts with other UK institutions like the Imperial College of London (LP was on the Steering Committee some time ago), Exeter Unversity (Riccardo Di Clemente is a professor and he is a former student of LP), and collaboration with Massimo Stella on Information Dynamics.

Oxford INET Center (participant in the GROWTHCOM EU project, coordinated by LP, 2012-2017) and also various groups in Cambridge. Also at Cambridge, there is a collaboration with Prof. Van Der Linden on Information Dynamics. Collaborations on Information Dynamics with City University (Prof. Andrea Baronchelli) and London School of Disease and Tropical Medicine (Heidi Larson),

Austria

The Vienna Complexity Science Hub (https://www.csh.ac.at/) directed by Stefan Thurner has various similarities with the Fermi Complexity Hub we intend to implement at the Fermi Center. We have very close interactions and collaborations with this institution and both LP and V. Loreto are members of the External Faculty and participate in most of

the activities. We have already implemented an exchange of PdD students for periods of a few months which is in action at the moment. The next plan is to organize joint conferences in both places and to develop joint research projects.

Belgium

We have contacts with various scientists but no close collaboration at the moment. We will consider possible points of contact.

The Netherlands

Before coming back to Italy LP was a full professor at the University of Groningen (NL) and there are close contacts and collaborations with various NL institutions. Recently in Groningen it was established the Center for Social Complexity Studies has similarities with some of the Fermi Center activities. We plan to invite them to our meeting and to consider possible collaborations.
Pier Siebesma (a former student of LP) is a Professor at Delft University of Technology and director at the Dutch Royal Institute of Meteorology
Cars Hommes (Univ. of Amsterdam) is an influential economist with whom we had meetings and considered possible projects.
We are participating in an EU Horizon Project SYNERGIES coordinated by the UN University of Maastricht (PI: Tania Trebich) with a total of 12 teams on Sustainable Growth, Inclusion and New Indicators. We are also considering the possibility of establishing a joint PhD program on these topics.

France

We have collaborations with V. Colizza (a former student of LP, Epidemiology, INSERM director, Paris), M.Mezard (Director of Ecole Normale Superieure, Paris) on Artificial Intelligence and D. Challet (Paris Saclay) on Economic Complexity.
M. Joyce, former Post Doc of LP (Paris VI) on Complexity in Cosmology.

Germany

Max Planck Institute for the Physics of Complex Systems (MPI-PKS) Dresden. We have many contacts with this institution and LP has been on the Steering Committee a few years ago. It is the German Institute for Complexity and it will be easy to have it as part of our project.
Center for Interdisciplinary Research Bielefeld. We have been invited to various conferences at this institution.
MPI Stuttgart, long standing collaboration and joint PhD students in the area of Condensed Matter Theory and Superconductivity.

Switzerland

Y.C. Zhang, Univ. Friburg. Intense and active collaboration in the area of Economic Complexity including the participation in joint EU projects and projects in China.
Univ. Geneva R. Durrer, Collaboration in the field of Complex Structures in Cosmology.
ETH-ZRH, various collaborations in the areas of Condensed Matte Theory and Complexity.
Uni. Zurich, C. Tessone, present and active collaboration in Economic Complexity.
EPFL-Lausanne, various collaborations in the past.

Denmark

M. Jensen, Niels Bohr Institute, University of Copenhagen and former President and Secretary General of the Royal Danish Academy of Science and Letters and K. Sneppen.
Long standing cooperation and joint participation to EU projects.

Sweden

Together with the Boston Consulting Group we made a first analysis of the Swedish industrial competitiveness with the methodology of Economic Complexity for the Ministry of Economics. We also have contacts with various universities in other fields.

Norway

We had extensive discussions with the Norwegian Wealth Fund (one of the largest and most scientific) in Oslo and London to make use of our Economic Complexity approach for their investment strategies. Up to now, no specific collaboration has been defined but we work for a positive development of the situation in the near future.
We also collaborated and participated in EU projects with the Univ. of Oslo

Spain

The JRC-EU Research Center for Economics is located in Sevilla. As we mentioned three former students of LP have been hired to introduce the methodology of the Economic Fitness in their analysis. The collaboration with this institution is very active and effective.
In addition, JRC-EU supports the activities of the Fermi Center with various specific projects.
Univ. of Granada, M. Munoz (a former student of LP). Application of the Economic Complexity algorithms to real ecosystems. Pilitec. of Valencia, Collaboration with D. Consoli on the Green Fitness.

Israel

I. Procaccia is a Professor at the Weizmann Institute and a member of the Evaluation Committee of the Fermi Center. We have intense collaborations on various subjects with this and other Israeli scientific institutions.

Armenia

Two years ago the Open Foundation organized an essential meeting in Yerevan with the top politicians and scientists to study the possible optimal development of Armenia. LP was invited to that event and since then there has been an exchange of information that could lead to a concrete collaboration.

Turkey

Past collaborations with the Istanbul Technical University to be reconsidered.

Russia

In the past we had many collaborations with Russian institutions, especially the Landau Institute in Moskow and the Dubna Research Center. At the moment these collaborations are problematic given the critical international situation. We hope that in the near future, the situation may improve and become again normal.

USA

International Finance Corporation of the World Bank (IFC-WB), Washington.

IFC-World Bank was the first mainstream economic institution to test, support and adopt the methodology of Economic Fitness and Complexity since 2016. Since then we had a continuous and very intense collaboration. Recently the method of Economic Fitness has grown in relevance in IFC-WB and now is the official method to evaluate the projects of country development and to identify the possible development of new markets. As described in detail before we have signed an MoU with IFC-WB to establish a joint lab in the Fermi Center (FermiKnet) to extend these methodologies and develop them also for the analysis of individual companies. In 2017 there was an official presentation of our method in Washington chaired by the Chief Economist of the WB Paul Romer (Nobel 2018).

Network Science Institute Boston

This institution is directed by A. Vespignani (a former student of LP) and it is a reference center in the US and abroad for the studies of Complex Networks, in particular epidemiology. Given the scientific affinity with various projects of the Fermi Center, the interaction and collaboration is very natural and it will be easy to reinforce it within the Fermi Complexity Hub project.

Santa Fe Institute of Complex Systems

This is the first institute of Complex Systems that was established around 1986. LP has been involved in various of its activities since the beginning, especially with the contacts with P.W. Anderson (Nobel). It was also a source of inspiration for LP to propose the foundation of the Institute of Complex Systems of CNR. At the moment the collaborations are mostly with S. Kaufmann who was also one of the founders.

Harvard Univ. Boston

R. Hausmann is a professor at the Kennedy School of International Economics. He also proposed an algorithm for Economic Complexity which is in direct competition with our Economic Fitness. We follow each other work very carefully but it is more in the spirit of competition rather than collaboration, at least at the moment. However, both the World Bank and the EU Commission have tested extensively both methods and decided to use ours.
L. Summers was the Treasure Secretary in the US and later the president of Harvard Univ. We had several discussions, especially about the economic growth of China.
Collaboration also with Prof. Elena Savoia on Information Dynamics

Boston Consulting Group

Since the beginning (2013) there has been an interest from BCG in our methods. For them, we made a first analysis of the industrial competitiveness of Sweden and had a continuous interaction with m. Reeves, director of the Henderson Strategic Institute.
Recently LP was interviewed by the BCG Chief Economist in a Podcast:

https://bcghendersoninstitute.com/economic-complexity-and-growth-forecasts-a-conversation-with-luciano-pietronero-b9be1e1c0d0c

CHINA ·

Xijing University

Xijing University is a private university approved by the Ministry of Education of China and is one of the top 2 private universities in China, located in Xi'an, the ancient capital of the Six Dynasties of China. Xijing University has gathered a group of high-level researchers in complexity science and its applications, with one of its missions to study economic growth mechanisms in China, and has emerged in the field of digital economy. Xijing University actively carries out international cooperation and exchanges and has established cooperation and exchange relations with well-known universities in more than 10 countries and regions.

Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences

The main mission of Chongqing Institute of Green and Intelligent Technology (CIGIT) is to provide intellectual support for the social and economic development of the Yangtze River Economic Belt, especially the upper reaches of the Yangtze River, featuring "green" and "intelligent". The face recognition technology with applications of CIGIT represents the world's highest level of artificial intelligence, and the proposed dual-carbon verification method has been adopted by the Intergovernmental Panel on Climate Change (IPCC).

Institute of New Structural Economics

This prestigious institution of Peking University is directed by Justin Lin, who was Chief Economist of the World Bank some time ago and at the moment is one of the most influential economists for the government of China. There is a natural complementarity between the New Structural Economics and the concept of Economic Fitness and Complexity discussed in more detail before. This is an extremely interesting situation to link a more traditional economic analysis with the new approach of complexity science and is leading to very important results. We have already written various papers together and we expect to develop this collaboration as one of the pillars of the present project.

Hangzhou University and Alibaba

The University of Hangzhou and the Alibaba research center (Jack Ma) were one of the teams of the EU GROWTHCOM project coordinated by LP. This has already led to various collaborations in the analysis of the recommending algorithms in social networks which will be further developed.

Hainan Scientific Institute

There is an essential project at the national level to establish an international science institute in the island of Hainan. The basic idea is a strong internationalization and the Fermi Center has been already contacted to be among the founding institutions.

India

International Labor Organization of UN (ILO).

Project on the labour skills from the online advertisement data.

JAPAN AND SINGAPORE

Sony Lab, Tokyo

This is the headquarters of the Sony CSL Lab with whom we have already established a joint lab at the Fermi Center (discussed extensively before). We have many collaborations with its President and some leading scientists, for example, H. Takayasu.

Tokyo Tech

M. Takayasu is Professor at Tokyo Tech and we organized several meetings together in the past. It will be a natural partner in our project.

Singapore Ministry and Nanyang Univ.

We have been invited several times to Singapore for scientific meetings but also for technical discussions and consulting at the Ministry of Economics. This could possibly lead to a collaboration with the Fermi Center.

LATIN AMERICA

Brasil

F. Operti (San Paolo Economics). We have made a collaboration for an analysis of Brasil's industrial economy with Economic Complexity.

In the past, we also participated in many conferences in various other universities and we maintain several contacts that will be involved in the future activities of the Fermi Center.

Argentina

Some collaborations in the past are to be reconsidered for the future activities.

Mexico

Gonzalo Castaneda (Economics , Mexico City Univ.) spent a sabbatical with us in Roma last year to work on the applications of the Economic Fitness to the resilience of countries and the recovery after a shock. We have already published a paper together and more work is in progress.

Bolivia

F. Zaratti (Univ. of la Paz); a possible collaboration of the use of Economic Complexity for the economy of Bolivia.

AFRICA AND GULF COUNTRIES

IFC-WB plan for Sub-Saharian countries

The IFC-WB has adopted the Economic Fitness to plan the industrial development of Sub-Saharan countries and this has led to a detailed joint paper (discussed before). Among the subsequent initiatives, it is possible that LP will be invited to deliver various lectures in some African countries and to discuss the IFC-WB plan together. This consists of a major concrete application of our methodology for the optimal development of poor countries.

·Gulf Countries

We have been contacted by various Gulf countries and have visited some of them (Oman, Saudia and The Emirates) to consider the application of Economic Fitness for the industrialization of these countries beyond the pure Oil Economy.

AUSTRALIA

Several invitations to conferences in the past but not much collaboration recently. We will consider how to improve the situation.

BUDGET AND FINANCIAL STRUCTURE OF THE PROJECT

Budget requested (K euro)	First Year	Second Year	Third Year
Economic Fitness and FermiKnet Collaboration with IFC-World Bank			
Infrastructure	300	200	100
Personnel	150	200	300
SGD Objectives, Sustainability, Green, Inequality and Information Dynamics Collaboration with SONY CSL joint Lab			
Infrastructure	100	100	100
Personnel	200	250	300
Photonics Lab. @ CREF			
Infrastructure	200	200	200
Personnel	150	150	200
LARES 2 Gravity Probe project	100	100	100
Exchange of Ph D students and Post Docs	150	150	150
Invitation of foreign scientists for extended periods	200	200	200
Travel and extended visits of CREF scientists	100	150	200
Conferences at CREF (large and small)	100	150	200
Museum update (apart from specific separate projects)	50	100	150
Summary Infrastructure	650	600	550
Summary personnel	1150	1350	1650
Total	1800	1950	2150