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Economic Complexity to monitor and forecast countries' economic and environmental performances

By

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What drives the economic growth of countries? Why do countries export some products rather than others? The Economic Complexity (EC) aims to address these questions. In this framework, a country exports a given product if it has the capabilities (i.e., the know-how and technological knowledge) required to produce and export the considered product. Therefore, the EC studies the export basket composition of countries (encoded in the country-products network) to derive the complexity of an economy and the sophistication of the products through a data-driven approach. Due to its interdisciplinary framework at the intersection of complex networks, data science, and economics, Economic Complexity theory captured the attention of many scholars, leading to the development of many approaches and novel indices. Among these methodologies figure, for the countries' complexity, the Economic Complexity Index, the Fitness, and the GENeralized Economic comPlexitY (GENEPY) index –the latter combining in a unique indicator the former two cited EC metrics. All the Economic Complexity metrics provide complementary information with respect to the Gross Domestic Product (the favorite economic indicator of economic development), which can be used to map and predict economic growth. Moreover, the metrics agree that countries' economic growth is boosted by including novel complex products within their export baskets. To this aim, it is well known that investments in innovation and technological progress play a crucial role in countries' development. Yet, the nexus between Research and Development investments and complexity in economics has not been sufficiently explored, and the existing literature lacks a framework for exploring it. Beyond the economic status of a country, EC metrics have been tested for understanding economic effects over other sectors of development. In particular, considering the relationships between economic activities and environmental impacts (often addressed in terms of CO_2 emissions), Economic Complexity indices were applied to study the economic-environment nexus. For example, the Economic Complexity Index is commonly included in the Environmental Kuznets Curve (i.e., the main scheme to couple environmental impacts and economic activities of an economy), finding a significative correspondence.

Against this background, this thesis extends the study of the Economic Complexity framework in several directions. Firstly, we studied the country-products network (i.e., the starting point of the EC metrics) from a Research and Development (R&D) perspective. R&D is the systematic creative approach to promote new products and procedures; thus, it is the common denominator of innovation and technological development driving economic growth. We developed two novel indices that measure the R&D content in countries' trade baskets, called RDE and RDI for the export and import baskets, respectively. We showed the potential of these indices in tracing countries' development trajectories, where different dynamics appear that can be reasoned considering the availability of natural resources. Eventually, we identified two insightful applications of the indices to investigate countries' environmental performances further as related to their role in international trade.

Secondly, we investigated whether the Economic Complexity metrics contribute to forecasting CO_2 emissions of countries worldwide. To this aim, we focused on two predictive models (i.e., multivariate regression and a Random Forest Regressor) to identify which explanatory variables suitably address carbon emissions in the near future (from 1 to 15 years). Our results show that the Random Forest Regressor (i.e., a machine learning technique) provides better and more precise CO_2 forecasting than multivariate regression. Moreover, non-trivial explanatory variables rooted in the Economic Complexity framework relevantly contribute to the predictions of both modeling approaches.

Moving back to the root of the Economic Complexity, i.e., network theory approaches, we investigated the role of the GENEPY index to be used as a centrality measure of any network system. Centrality measures rank the elements of a network according to specific criteria. For example, the degree centrality ranks the elements of a system according to the number of connections. The use of the GENEPY index, an Economic Complexity measure, as a centrality measure is not out of the matter. In fact, all Economic Complexity metrics are defined as centrality metrics, where the importance of the nodes is determined by the structure of the country-product network. Different centrality metrics present high node ranking correlation with the degree despite the rationale underlying each measure changes. Generally, this correlation is due to the spectral gap of the network at hand (i.e., the difference between the two largest eigenvalues of the matrix representing the system): the correlation among centrality metrics increases as the spectral gap rises. Thus, for high spectral gap networks, sophisticated and time-consuming centrality measures do not add significant information concerning the degree centrality, the most straightforward centrality measure. On this ground stems the idea of using the GENEPY index to detect new structural features of the network, since it ranks the modes according to the similarities in their connectivity pattern. We show that the GENEPY's rationale is less related to the spectral gap than the criteria underlying commonly used centrality measures.

In a nutshell, this thesis places at the core of interdisciplinary research orbiting around complex networks, economics, and sustainable development. The present work uses and extends the Economic Complexity framework to monitor countries' economic output, forecast CO_2 emissions, and gain new knowledge from interacting systems.