Economic Complexity

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Economic complexity, which links the productive structure of a country with its knowledge, labour, and sophistication, seems to raise new challenges for the environment's preservation and quality. The relationship between economic complexity and the environment is multi-faced and creates unimagined challenges for humanity in its path toward social and economic progress.

economic complexity environment

1. Introduction

Herein notice a growing interest in economic modelling that has emerged in several different approaches that include factors such as: limited rationality and heterogeneity of agents, multiple social interactions at various spatial and temporal scales, and learning processes, in the presence of adaptive evolutionary processes. Such evolutionary processes, observed in human socio-economic systems can lead to disequilibrium, non-linear relationships, path dependence, discontinuity, and irreversibility. Socio-economic systems are considered complex evolving systems, composed of multiple irrationals interacting and rapidly adapting agents and aggregate outcomes are seen as emerging properties of such systems.

The following features of the current and social global context suggest the need for a 'complexity' approach: (i) high interconnections between financial and economic systems (national/regional economies, markets); (ii) development of global value chains of production and consumption; (iii) turbulence of social and economic life (limited prediction, new capabilities, new objectives, and unstable and hostile environment); (iv) a new development paradigm: sustainable development—diffusion in society of the specific knowledge is critical for human survival; (v) a high level of connections between individuals and organisations (i.e., social networking); (vi) development of knowledge and informational society and digitalisation of economy and work (virtual markets, remote-work, e-work, e-learning, and e-reading); (vii) human capital has distinctive societal function comprising managerial, creative, entrepreneurial, and high-tech skills; (viii) emergence of new technologies, products, and materials; (ix) miniaturising and de-materialisation of products (nanotechnologies, virtual prototypes, and tools); (x) the pressure of automation of production processes and migration of labour force to creative industries; and (xi) global competition for resources, markets, and profit.

Complexity is an immanent attribute of the world in which we function and it is increasing with unprecedented speed.

2. Economic Complexity: Measures and Interconnections

In the structuralist literature, economic development and growth are connected to the changes in sectoral composition of production and the progress on production of complex goods. Inspired from the structuralist view, new literature emerged in the last years discussing the role of structural change to stimulate the long-run economic development and identifying linkages between GDP per capita and the structure of production, growth rates of exports, and productivity.

In this context, recent studies have revealed that economic development can be interpreted as a process of learning for a country on how to produce (and export) more sophisticated and complex products. Each country must find its own development path and focusing on its learning system may add capabilities to the ones it already possesses [1][2]. New literature has revealed the role of accumulating capabilities in the production of more complex goods, claiming that it is a premise for structural change. Such capabilities refer to non-tradable and intangible inputs (i.e., tacit knowledge). A large part of the literature on this approach was focused on identifying and measuring capabilities across industries or countries (e.g., [1][3]).

Following this line, Hidalgo et al. [4] and Hidalgo and Hausmann [5] developed and introduced a methodology meant to be used in the analysis of the economic development process. In their methodology, the level of complexity of a country's productive structure is expressed through two metrics: diversity (the number of goods a country produces with revealed comparative advantage (RCA)) and ubiquity (the number of countries capable of exporting goods with RCA). They used computational, network and complexity techniques to generate a model expressing a country's productive sophistication or *economic complexity*.

Economic complexity refers to the composition of a country's productive output and reflects its structures that hold and combine knowledge [6].

A new and recent literature emerged exploring the impact of economic complexity on economic outcomes. The study of economic complexity was mainly motivated by the development of endogenous growth theory, the revival of industrial policy, and the growth of artificial intelligence (AI) [7].

A robust and stable relationship between a country's productive structure and economic growth is documented by several studies (i.e., [8][9][10][11][12]). Economic complexity is highly correlated with income and can explain differences in economic performance [13]. It also can predict future economic growth ([5][14][15][16]). Moreover, economic complexity of a country may limit its range of income inequality [17] and influences regional wage differentials in a nonlinear dynamic [18], meaning that increasing levels of complexity will first worsen and then will improve the income (in Brazilian states), and the effect is extended where urbanization and overall development is higher. When the economy experiences higher levels of products' complexity this induces lower levels of income inequality, meaning that economic complexity could be seen as a strong predictor of income inequality [19]. Human capital (i.e., education) is found as a factor that magnifies this reducing effect of economic complexity on income inequality [19]. When the level of human capital (i.e., education), trade openness, and government spending reach certain levels, they facilitate a beneficial effect of higher economic complexity, namely, to reduce income inequality [20]. The distributional effect of economic complexity depends on the country risk: economic complexity is associated with more equal income distribution in countries with low risk (i.e., economic, financial, and political risk) while an increase in economic complexity will generate more inequality when the country risk is high [21]. It is also revealed that the degree of economic complexity of regional production systems can be used to assess how it affects their pattern of growth and economic convergence. For example, a process of economic divergence between European regions is identified as a result of their increase in economic complexity [22]. Human development is also positively influenced by economic complexity ([17][23][24][25][26]) and an influence of economic complexity on the relationship between the real exchange rate and corporate investment is reported [27]. Economic complexity is also related to scientific production in basic sciences and engineering [28].

Drivers of economic complexity were identified as financial development and the number of patents [29]. Moreover, a higher diversity in the birth place of immigrants can boost economic complexity through an increasing diversification of the host country's export basket [30]. It has also been proved that economic complexity is associated with the fertility change across Italian provinces [31] and Internet usage [32]. Other driving forces of economic complexity are reported by several studies, such as: property rights [33], human capital accumulation [34] and foreign direct investment [35][36].

3. The Link between Economic Complexity and Environmental Degradation

3.1. Metrics Used in the Analysis

Environmental impact is seen as an understandable consequence of economic complexity. More sophisticated and complex products need an increased energy demand, mainly for industrial sectors, using energy from different sources, with different energy intensity and efficiency.

In order to provide a metrics for economic complexity, Hidalgo and Hausmann [5] introduced the measure called "economic complexity index" (ECI). It is defined as 'the composition of a country's productive output, reflecting the structures able to hold and combine knowledge'. The development of this index relies on the following assumption: when the exports of a country are more diverse and have fewer competitors, the economic complexity is higher (i.e., [6][14]).

In the energy–environment literature, environmental degradation is traditionally measured by the volume of carbon dioxide (CO_2) emissions (i.e., [37][38][39][40][41][42][43][44]) or Greenhouse Gas (GHG) emissions (i.e., [45][46]).

Lately, another proxy, the ecological footprint has emerged as a more comprehensive measure of environmental degradation (i.e., [47][48][49][50][51]). The ecological footprint was introduced by Wackernagel and Rees [52] as a more inclusive and comprehensive indicator of environmental degradation, encompassing built-up land, forest land, grazing land, crop land, carbon footprint, and ocean. It measures the total quantity of natural resources consumed by the population as well as the area of productive land and water needed to support human activities and sequester the waste they generate [53].

Another group of studies use an environmental performance index as metric of environmental performance. For example, Lapatinas et al. [54] and Boleti et al. [55] used the composite index of environmental quality that was developed by Yale University and Columbia University in collaboration with the World Economic Forum and the European Commission's Joint Research Centre. This index includes indicators of pollution and impact of pollution on human health as well as the effectiveness of environmental policies [56].

3.2. Analysing the Link between Economic Complexity and Environment

The analysis of the impact of economic complexity on environmental degradation has gained a noticeable research interest in the few last years.

A consistent number of studies use carbon emission as expression of air pollution. As an indicator of knowledge-based and sophisticated production in an economy, economic complexity is positively associated with CO_2 emissions. The study developed by Dogan et al., (2019) [57] examined the effect of economic complexity on CO2 emissions for 55 countries for the period of 1971–2014, using additional control variables (i.e., energy consumption, urbanization, and trade openness). Economic complexity has a significant and different impact on the environment depending on the stage of development. Economic complexity has generated the increase in CO_2 emissions in lower and higher middle-income countries, and has a limited environmental degradation in high-income economies. According to the results of Majeed et al., (2021) [58], in the OECD countries over the period 1971–2018, the long run impact of economic complexity is positive and significant on carbon emissions. Moreover, the impact is higher in the economies with a low level of CO_2 emissions.

Another group of studies reveal a mitigating effect of economic complexity on carbon emissions. For example, Dogan et al., (2021) [59] analysed the effect of economic complexity, economic progress, population growth, and renewable energy consumption over carbon emissions in a sample of 28 OECD countries for the period of 1990–2014. They reported that economic complexity has induced a decrease in carbon emissions. This decreasing effect on carbon emissions can be induced by the technologies used in the process of production, as reported by Romero and Gramkov (2021) [60]. Their study proved that production of complex goods is associated with reduced emission intensity and this effect is due to the types of technologies used in production process. Based on data for 67 countries between 1976 and 2012, it was found that an increase of 0.1 of ECI can generate a 2% decrease in kilotons of CO_2 per billion dollars of output as well as in CO_2 emissions per capita. They estimated an index of Product Emission Intensity to show that it has lower levels in the case of medium- and high-tech products while higher levels are assigned to primary products. The estimation of this index confirms that structural changes in the economy toward more complex and high-tech products can lead to a reduction in carbon emissions intensity.

Frequently, studies include also other relevant economic variables in the analysis of the relationship between economic complexity and environment. For example, the study of Abbasi et al., (2021) [44] analysed the association between the economic complexity index (ECI), gross domestic product per capita (GDP), tourism, and energy prices on CO_2 emissions within 18 top economic complexity countries from 1990 to 2019. There were identified long- and short-term associations among ECI, GDP, and CO_2 emissions. Tourism, GDP per capita and energy prices can decrease carbon emissions both in the long and short run. Moreover, any policy on economic complexity, tourism, energy prices, and economic growth has a notable influence on CO_2 emissions. Adedoyin et al., (2021) [61] concluded that an increase in the complexity of the economy or financial crises, together with international travel, do not accelerate environmental crisis in some EU regions over the period from 1995 to 2018.

Another expression of environmental degradation, greenhouse gas emissions (GHG) were used by Neagu and Teodoru (2019) [45] to explore the relationship between economic complexity, energy consumption structure, and pollution in the European Union (EU) countries. They found that economic complexity contributes to the level of GHG emissions and the impact is higher in the panel of less complex countries (i.e., values of Economic Complexity Index are lower than the EU average).

3.3. The Environmental Kuznets Curve (EKC) Model

There are very few studies investigating the economic complexity index (ECI) as an explanatory variable instead of income, in a non-linear relationship (using ECI squared) and testing the Environmental Kuznets Curve (EKC) model.

For example, Can and Gozgor (2017) [62] studied the linkage between economic complexity and environmental degradation in the case of France and found that a higher degree of economic complexity could curb the environmental depreciation, in other words, the environmental Kuznets curve can be validated. A similar result was reported by Neagu (2019) [42] in a panel of 25 European countries as well as in 6 European countries (Belgium France, Italy, Finland, the UK, and Sweden) when considering the influence of economic complexity on CO_2 emissions. Chu (2021) [63] also identified a nonlinear relationship between ECI and CO_2 emission in 118 countries, validating thus an inverted U-shaped curve.

In the case of USA, Pata (2021) [64] included in the analysis of pollution generated by economic complexity other explanatory variables such as: renewable energy, non-renewable energy, and globalization. The study validated the inverted U-shaped relationship between economic complexity and pollution expressed by CO_2 emissions and the ecological footprint. The production structure in the USA caused environmental degradation in the early stages, while the use of cleaner production techniques and advanced technologies induced a reduction effect of economic complexity on environmental pressure, after a certain level. A similar study was conducted by Chu and Le (2021) [65] for the G7 countries, by using as explanatory variables of environmental quality: economic complexity, energy intensity, and renewable energy. The environmental Kuznets curve of economic complexity and environmental quality (measured through CO_2 emissions and the ecological footprint) holds for these countries.

There are also studies finding no confirmation of environmental Kuznets curve. For example, in the case of Colombia, a developing country with relative low levels of production sophistication and pollution, Laverde-Rojas et al., (2021) [66] could not find any validation of the EKC hypothesis.

4. Concluding Remarks

Figure 1 displays the drivers and factors of economic complexity and its implications covering three dimensions: environment, economy, and society.

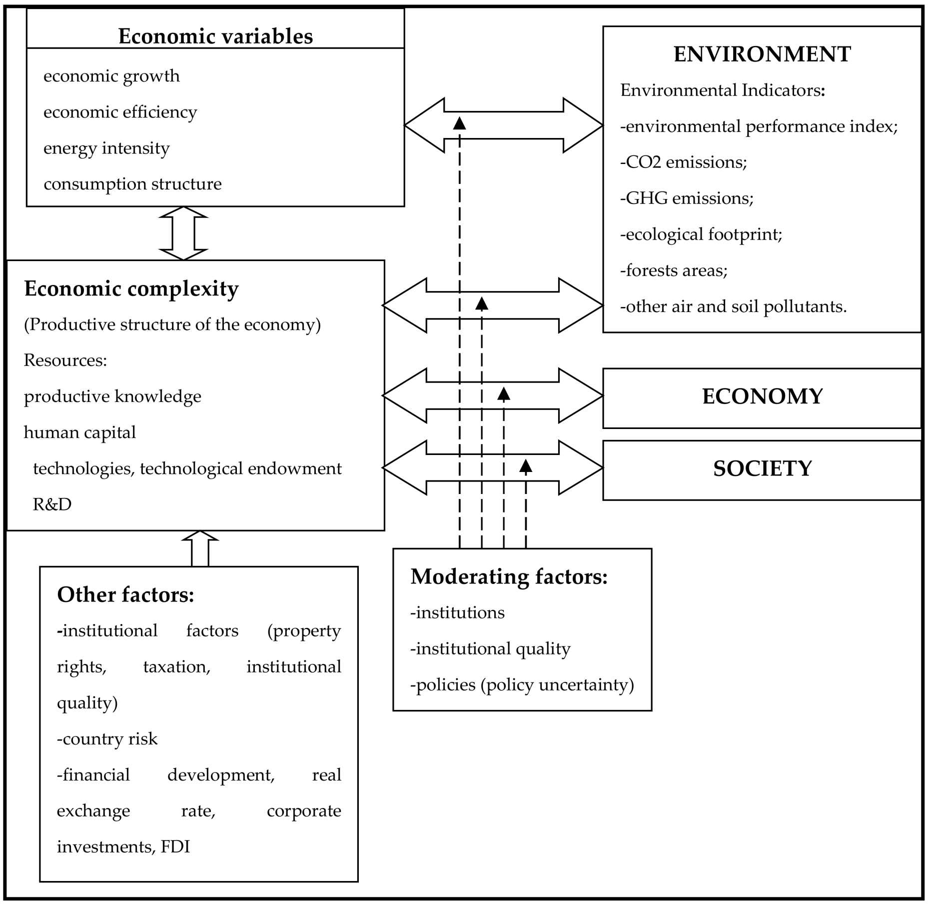

Figure 1. Linkages between economic complexity and environment, economy, and society, including moderating factors.

Economic complexity is the expression of a country's structure based on several resources: productive knowledge embedded in people and technology, technological endowment, and R&D activities.

Economic complexity is also based on the economic level of a country, its development stage being a critical driver of the production systems and structure. Rich and higher income countries have the capabilities to enhance the level of sophistication of the products they export, whereas developing or lower-income countries must attract the resources they need in order to experience a higher level of economic complexity. The studies above summarized reveal that economic structure, energy intensity, and the energy consumption mix can shape the level of economic complexity.

Several national and international factors affect the level of economic complexity: institutional factors (taxation, and institutional quality), financial (financial development, real exchange rate, and foreign direct investment), country risk (i.e., financial, economic, and political), globalisation, tourism, urbanisation, Internet usage, and demographic factors (fertility, and birthplace diversity).

Economic complexity impacts the economy, environment, and society. Economic complexity is an accurate of economic growth and of income inequality. Economic complexity generates a new pressure on environmental quality. It increases the air pollution and extends the ecological footprint. Some studies report a beneficial influence of economic complexity on environmental performance. It is worthy mentioning in this context that studies focused on validating the Environmental Kuznets Curve (EKC) model, with the Economic Complexity Index (ECI) as an explanatory variable bring the brightest side of the link between economic complexity and environmental degradation. Pollution increases with the complexity growth, but a certain level of complexity can curb the evolution of environmental degradation and the pollution pressure will decrease. This supports the existence of a threshold of economic complexity, meaning that the productive structure of the economy is based on the use of cleaner technologies and appropriate environmental rules that induce the reduction effect of pollution. Based on previous studies (i.e., [42][62]), in the case of complex economies, this threshold means a value of ECI higher than one. For example, the estimation of EKC model for 1995–2017 for some European countries (**Figure 2**) shows for France a threshold value of 1.6 for ECI, while for Italy this is 1.45. In Finland, the carbon emissions start to decrease when ECI reaches values higher than 1.9 and in Belgium when ECI attained 1.4.

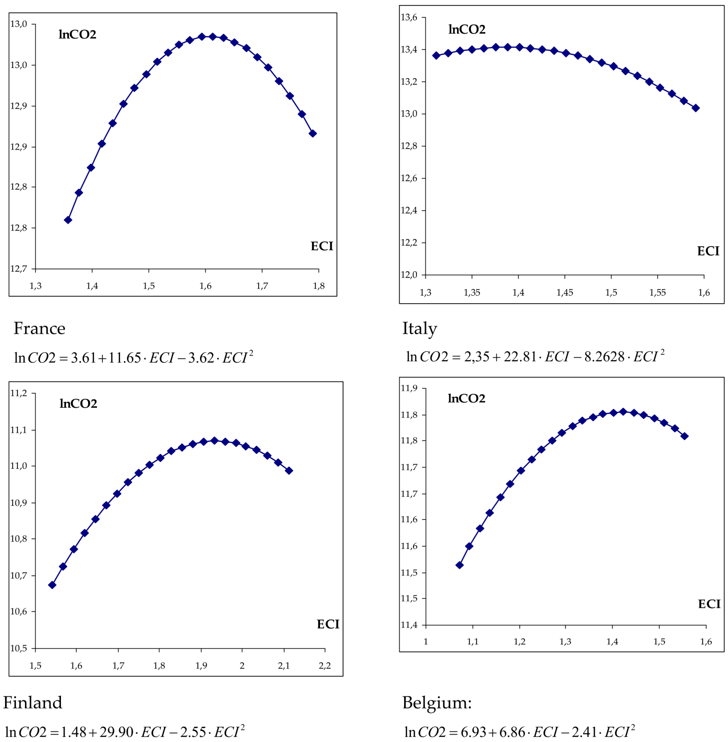

Figure 2. The estimated EKC model in some European countries using ECI as explanatory variable (1995–2017). Reprinted with permission from Ref. [42]. Copyright: © 2021 by the author. Licensee MDPI, Basel, Switzerland.

The recent literature suggests also that institutional factors, such as institutional quality and policy uncertainty have a moderating effect in the linkage between economic complexity and environment.

As the economic complexity can be seen as dynamic outcome of aggregate national innovation and entrepreneurship process that creates economic diversity through new sophisticated exported products and an increased economic complexity is a significant determinant of the efficiency gain in different production technologies and processes [67], we can conclude that this effect of economic complexity may stimulate further beneficial changes in the economy, meant to unveil or reduce detrimental effects (environmental degradation).

More complex and sophisticated products incorporate industrial technologies that may be harmful for the environment generating pollution. As a consequence, companies, industrial units, and policymakers should integrate energy considerations within the early design stage of their products, along with promoting investments in environmentally friendly technologies when they decide to include more complex products in their export baskets (i.e., [45]), and if the products' complexity generates pollution, imports could be an alternative.

Moreover, as Can and Gozgor (2017) [62] stated, an analysis of the level and the extension of environmental degradation generated by each industry, could be beneficial for designing adequate measures for pollution mitigation.

Economic complexity is a threat to the environment. There are some comments to be made to this assertion: (1) Economic complexity is an accurate predictor of economic growth. Countries with high income and economic growth can experience higher levels of sophistication of the products they export, and even if the pollution increase with the economic complexity level, at a certain threshold, the economic complexity can suppress the pollution. This is a result reported in several studies investigating the validity of Environmental Kuznets Curve taking into consideration the economic complexity as explanatory variable of environmental degradation; (2) A higher complexity is based on quality human capital, on large investments in R&D activities meant to introduce environmental friendly technologies, and on clean and decarbonised technology methods; (3) Economic complexity must be taken into consideration within the national commitments regarding carbon emissions reduction (the exports structure has to be adapted in order to generate less pollution) and a realistic plan for carbon emissions abatement is needed to monitor the energy intensity by using regulatory and financial measures as well as implementing effective industrial low-carbon strategies.

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