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International trade and economic complexity

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Introduction

Although it is not easy to comprehend what the economy is and how it functions, there are certain methods we may employ that are more insightful than the most common ones in an effort to do so.

«What is the true difference between an apple that you buy in a supermarket, the apple that grows on a tree, and the Apple you buy in the Mac store and you use to check your email?» [1]

This is one question that MIT Prof. Cesar Hidalgo loves to ask when talking about Economic Complexity.

All the goods that are produced and of which we are surrounded daily, originally, have been manufactured with the use of machinery, raw materials, and labor force. These elements alone, however, would not be enough to justify their surprising variety and the exceptional genius of some of them. Equally important components, even if less evident, are the knowledge and the set of knowledge needed to design, develop, and implement new goods. Through the flow of products in the market, the knowledge of a few can reach many. At the corporate level, the more diverse the information is, and you can combine it with each other, use it and make it interact like a network, the more knowledge you can incorporate.

We can say that today's societies are more advanced than those of the past, not because individuals today are more intelligent individually, but because the level of knowledge accumulated and shared over time between all these subjects has greatly increased.

This thesis is focused on the analysis of Economic Complexity in all its components.

To explain the topic, an in-depth literature review was presented in Chapter 1, first analyzing the concepts of Product Space and Relatedness and the importance of sharing know-how within a society, and then highlighting the explanatory skills of Economic Complexity on the themes of economic growth, innovation, education, income growth, and sustainability.

[1] Hidalgo C. https://serious-science.org/understanding-economic-complexity-2898

Subsequently, two alternative methods for quantitative measurement of Economic Complexity are presented. In fact, the concept of Economic Complexity was first introduced within the MIT Media Lab and Harvard University's Kennedy School of Government, but another version was also developed by CFR[2] and CNR[3].

The ultimate objective of this research is to apply the analysis of Economic Complexity to the case of the Italian provinces and regions.

The phases of this study first required the preliminary preparation of certain conversion tables, which are extremely useful for this research. In fact, as wide described in Chapter 2, there is currently no official table of equivalence between NACE (or, in Italy, ATECO) and HS (Harmonized System) codes.

Since the data bases available connect the export data of the Italian provinces to the NACE codes and the Product Complexity Index to the HS codes, in order to perform a joint analysis, some correspondence has been made between the two systems.

In the third and final chapter, a dynamic analysis of the export situation and Italian Economic Complexity of the last decade has been carried out, testing through a new Complexity Index (calculated according to the Hidalgo and Hausmann method and the incidence of territorial exports on the Italian total export) that sectoral diversification within regions is crucial for recovery following external shocks.

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[2] Centro Ricerche Enrico Fermi

[3] Centro Nazionale di Ricerca

CHAPTER 1

Economic Complexity

1.1. Classical theory of economics versus new Economic Complexity

Economic Complexity is a new model within economic theory that represents the economy as a complex adaptive system, composed of several various agents that inter-operate through networks and that evolve overtime.

Economic complexity can be referred to as the productive composition of a country as it reflects the structures that emerge to hold and combine knowledge. [4]

In order to better understand in more practical terms what economic complexity is about, it is useful to name some categories of complex products: machinery, chemicals and metal products. They are complex as they require a wide range of know-how in production and in terms of highly qualified staff.

Focusing back up to the economic complexity of a country, following the definition given by the *Atlas of Economic Complexity* [5]*,* it is a measure of the knowledge in a society as expressed in the products it makes. Countries that are able to sustain a diverse range of productive know-how, including sophisticated, unique know-how, are found to be able to produce a wide diversity of goods, including complex products that few other countries can make.

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[4] Hausmann, R.; Hidalgo, C.A.; Bustos, S.; Coscia, M.; Simoes, A.; Yildirim, M.A. The Atlas of Economic Complexity: Mapping Paths to Prosperity; MIT Press: Cambridge, MA, USA, 2014; Available online: https://s3.amazonaws.com/academia.edu.documents/30678659/

[5] The *Atlas of Economic Complexity https://atlas.cid.harvard.edu is a tool that provides data on global trade and markets, tracking their dynamics over time. It is a project born at the Harvard Kennedy School of Government*.

The main exporters of the most complex products are developed countries. Producing complex products means that the countries have high export competitiveness and high development potential. [6]

Economic complexity is indeed about development: there is growth and there is development. Even though they are related they are not the same thing. Development involves the creation of structures and a consequently improvement in the quality of life and living standards, and this is something that includes growth but transcends it. Growth is linked to an increase in real national income and national output. Economies not only grow but they develop, change, and transform. [7] Economic complexity investigates this very topic in an insightful and new way.

It is one among the numerous alternative economic theories that have emerged over the past years, as a result of an augmenting consciousness of the limitations of the already existing economic theory.

Talking about the standard approaches to economic theory, the roots to modern economics date back to the 18th Century where it borrowed much from the natural sciences, in particular from physics with its classic mechanistic view of the world where everything has its cause and effect in a linear deterministic perspective.

In this model of classical economics individual human behavior is corresponding to the physical laws of motion, since it is predictable, regular, and deterministic and to which consequently mathematics rules can be applied. Within this paradigm the social sphere is a closed system made by isolated individuals that act in their long-term personal interests.

A central presumption of many economic models is that there are optimal states to which the system will naturally and rapidly evolve, driven by the market forces of supply and demand. This exposed idea is the concept of "invisible hand".

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[6] Economic Complexity and Export Competitiveness: The Case of Turkey**:** Birol Erkan,Elif Yildirimci**,** Procedia Social and Behavioral Sciences**;** 3 July 2015

[7] Hidalgo, C.A. Economic complexity theory and applications. *Nat Rev Phys* **3,** 92–113 (2021). https://doi.org/10.1038/s42254-020-00275-1

To conclude, standard economics acquired the reductionist view of classical physics in which the behavior of a society and its institutions is equal to the sum of its individual agents, meaning that the behavior of all agents together corresponds to that of an average individual.

Today the leading trends such as the quick development of our global economy, the acceleration of financial capitalism, the expansion of services, knowledge and information economy are all revealing the constraints and limitations in the classical economics theories and many new theories have arisen in order to provide a more realistic vision of how economies actually work.

First of all, the individual are now considered to be motivated by more than self-interests: their behavior is now guided by a broader set of cultural and social motives.

Complexity economics is part of these new theoretical framework and represents a new paradigm that finally sees the economy as a complex adaptive system, made by multiple agents with different motives, whose cooperation within networks result in the building of enterprises and markets.

Whereas in the past the economy was the product of isolated individuals making rational choices with perfect information resulting in efficiency markets, now complexity economics represents a new kind of individual: it has bounded rationality and limited information and their cultural and social networks affect its behavior. The results are irrational actions ensuing in suboptimal markets.

The focus is now on the non-equilibrium processes that alter the economy from within, thanks to repeated adaptation, the emergence of new institutions and technologies.

Complexity economics applies this concept of evolution in order to explain the dynamics of economic development, which is seen as a process of differentiation and continuous change.

Therefore, Economic Complexity extends the thinking of the classical economists.

There is a standard economics where everything is in order and equilibrium, there are well-defined problems, deductive rationality. Everything is pure, elegant but artificial.

On the contrary, the concept of Complexity means contingency, indeterminacy, openness to change.

Table 1. Different perceptions of the individual's characteristics between the two models.

STANDARD APPROACH	**COMPLEXITY APPROACH**
There are pre-assumptions about individuals' characteristics	Individuals follow simple rules
Individuals should satisfy economists' axioms of rationality	Individuals adapt to the environment
Individuals should optimize in isolation	Individuals' behavior emerges from the social interactions
Aggregate behavior is like that of a rational "representative agent"	Coordination not efficiency is the main problem

Source: Hidalgo, C.A. Economic complexity theory and applications. *Nat Rev Phys* **3,** 92–113 (2021).

As we will have the opportunity to argue more in deep in the following paragraphs, generally speaking, complex products have low ubiquity and made by well diversified countries.

Let's take the top five products by complexity and the bottom five ones to better understand.

Table 2. *Top 5 products by complexity in 2022*

PRODUCT	**COMPLEXITY INDEX**
Machines & appliances for specialized industries	2,27
Instruments and appliances for physical or chemical analysis	2,24
Appliances based on the use of x-rays or radiations	2,16
Lubricating petrol oils and other heavy petrol oils	2,10

Other machine tools for working metal or metal carbide	2,05

Source: The Atlas of Economic Complexity, 2022

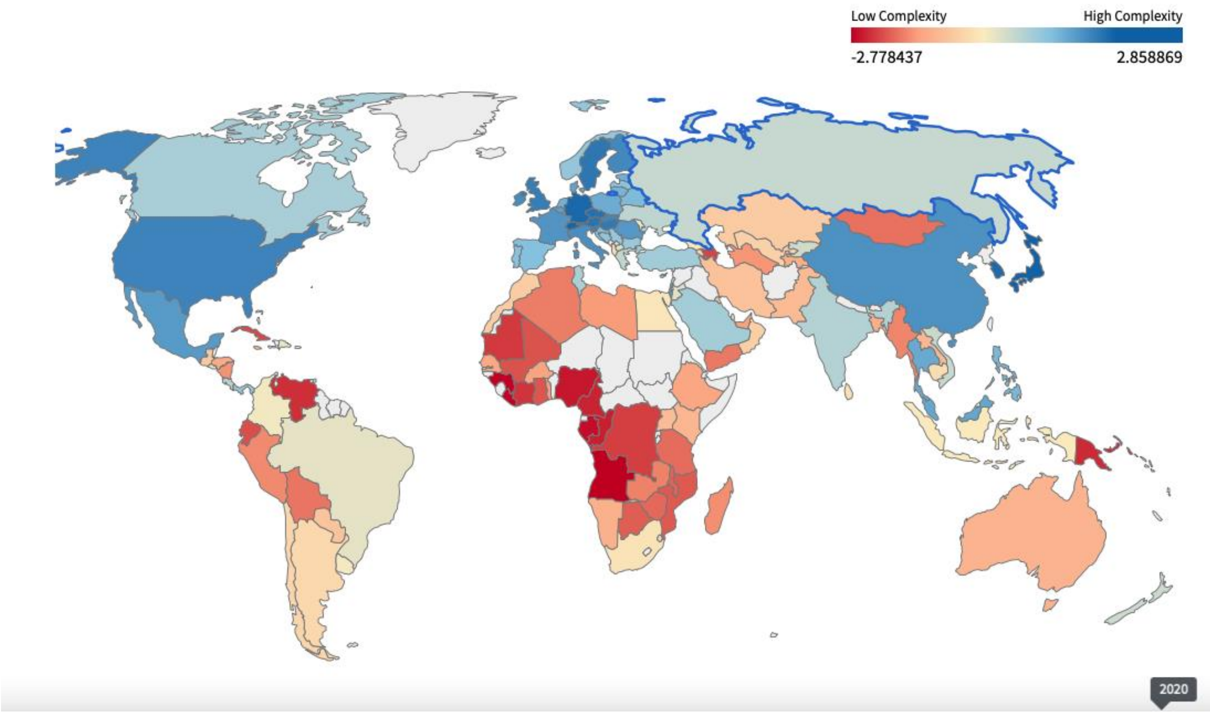
Table 3. *Bottom 5 products by complexity in 2022*

PRODUCT	COMPLEXITY INDEX
Crude oil	-3
Tin ores and concentrates	-2,63
Cotton	-2,63
Cocoa beans	-2,61
Season seeds	-2,58

Source: The Atlas of Economic Complexity, 2022

As we can see from the map in Figure 1, Western Europe (in particular France, Germany) is quite complex together with the United States of America and East Asia. Looking at the less complex areas, South Africa is the more complex country in the southern Africa.

Figure 1. *Countries Complexity ranking. Geomap*



Source: The Atlas of Economic Complexity, 2020

1.2. Society and know-how

How can we have a society that is able to make airplanes, antibiotics, movies?

What drives prosperity on an economy is the amount of societal know-how, given that what a society knows does not really look like what a person knows. We as individuals are highly limited. The way the society gets to know a lot is by having know-how spread into many different heads and get them to build a network in such a way as to work together.

Economists have built a measure of how much a society knows by creating matrices of products or industries each society holds, what products a society is able to export, and the concept is the more you know the more stuff you are able to do.

Moreover, maybe a country is diversified across very simple products or on the contrary it makes few very complex products.

How would we know the difference? If a product is simple everybody should be able to make it while if a product is complicated few others are going to be able to make it.
By moving to another level, it is important to know how many other countries are able to make a product. In that case, we must consider also that what some countries are able to make is affected by the fact that they might be making some products that are rare for some reason and not because they are complex (e.g. diamonds: they are rare but the countries that make them are not complex since they make very few other products).

Iterating this process (how many products you make, how many products are made by the countries that make the products that you make, how many countries can make the product that you make) a formula is derived for how much know-how a country has.

How countries accumulate know-how? [8] Or better said, why isn't everywhere prosperous?
The difference in know how between countries is what drives differences in income and in growth so it is important to know how to compare know-how across societies.

Cultural factors are critical to accumulate know-how in a society.
At first level such know-how can be grown by setting the education system as a basis for all the development in order to get a technically, well-educated, flexile labour force

Secondarily, as Adam Smith exposed, the main driver in know-how increase is specialization by individuals, which is limited by the extend of the market. But since products can be exported to the world, the space for specialization is broad and countries can acquire knowledge in things they do not produce yet by trading.
Not all capabilities can be acquired through trade though: some capabilities may come from a domestic political system that ensures security, or a legal system that protects

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[8] Economic Development and the Accumulation of Know-how, Hausmann, Ricardo, Welsh Economic Review, 2016

inventions and property rights through patents. It may come from having high grade infrastructures and good telecommunications, and lack of corruptions and good institutions.

Know-how is something that exists in brain and moving it around is complicated and the problem is not just that it's know how in brains, it is that it's know-how in teams of complementary people who know different things who must collaborate.

All this taken into consideration leads to understand how learning happens at a societal level. Economies acquire new knowledge by moving to nearby goods. Knowing the structure of the products space can lead to very insightful results in predicting how the know-how of a society grows.

As stated by economist Hausmann Ricardo, to increase collective know-how it is needed to solve a fundamental "chicken and egg problem": you don't know how to make the things you do not do but cannot make the things you don't know how to do. For example, you cannot make watch without watchmakers, but you cannot become a watchmaker in a place who do not make watches because you do no have anybody to learn from.

So, the growth of collective know-how has to solve this problem and the way society typically does it is to move to things they know how to do to things that are not too far away in know-how space so that the number of "chicken and egg problems" you need to address is somehow reduced.

In order to serve and express in a more visual way with a metaphor, let's think that our products are like trees and the collection of all possible products is a forest where every product is a forest.

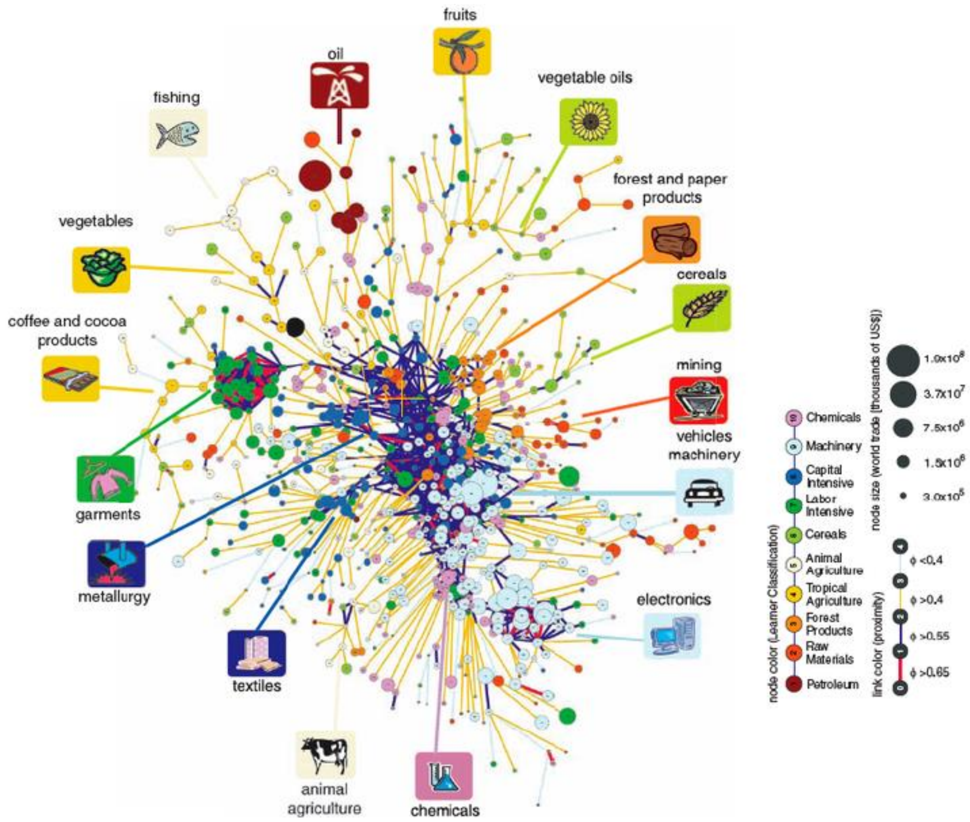
1.3. Product space

As stated in the previous paragraph, countries tend to move to the products that are nearby the ones they already know how to make.

That’s the concept of proximity and product space.

In order to serve and express in a more visual way with a metaphor, let’s think that our products are like trees and the collection of all possible products is a forest. Trees are close to each other in the forest if they share the same collective know-how. We are able to map this product space as a network representation. It is a very heterogeneous forest: there are near garments, shoes, constructions materials, machinery, trucks and chemicals and electronics. These are dense patches of the forest, and they are surrounded by other parts of the forest which are much less dense where products are much farther away one from the other.

Figure 2. *The tree map of product space*



Source: The Atlas of Economic Complexity, 2022

Inside this metaphor, countries are like monkeys that are living off some trees and they are in some part of the forest.

This metaphor allows us to visualize the concept of product space. It is necessary to check where a country have the necessary collective know how to be able to operate and then map the countries where they are in the product space and then watch them over time. Over time countries defuse the monkeys over the space and they become good at other things that they were not good at before. That's how collective knowledge grows: it grows preferentially by recombining the collective know how you already have with some additional one. This space however is very irregular: not all countries have it equally easy. If the country is in the dense space, it is very easy for these monkeys to be making progress by moving from tree to tree with very few spaces to go through. But for the countries that are more in the periphery of this space have the trees very far away so they may get stuck and that's why progress may slow down. That's the case of Thailand in 1965: it was in the very periphery of the product space making rice, sugar, jute, wood then suddenly started to get in the garment cluster; then a monkey started to jump into the electronics cluster to the point to take over the whole electronics cluster and now they are moving to the machinery cluster and now Thailand is the major exporter of cars and trucks.

In general, industrialized countries export products at the core, e.g., machinery, chemicals and metal products, and at the same time they occupy products at the periphery, e.g., textile, forest products, agriculture. East Asian countries have textile, garments, and electronics. Latin America has specialized in industry located in the periphery such as mining, agriculture, and garments. Sub Saharan Africa has advantage in product classes that occupy the periphery.

More technically speaking, Product Space is a visualization that links products based on their proximity to each other. When two products are in proximity it means that there is similarity in the know-how needed to produce them and that there is high probability of co-export of both two products. It has been created thanks to real world data about exports and imports and on the experience of countries' diversification over the past 50 years.

This visualization maps nearly 900 products, in color-coded sectors based on SITC classification of goods.

The concept of product space has significant applications in economic policy whereas the conventional economic development theory has not been capable of explaining why some countries grow faster and better than others.

Traditional theories argue that differences between countries production and economy lie in the differences in technology and productive factors but fail in capturing similarities between products, which as we have previously explained contribute to a country's pattern of growth.

The product Space theory uses a measure which is outcome-based and based around the concept that if products are connected because they require similar institutions, capital, infrastructure, technology, they are likely to be produced together. Dissimilar good in these terms, on the contrary, are less likely to be co-produced. This is called "a posteriori test" of similarity and it is called "proximity".

Through proximity it is possible to quantify the relatedness of products

1.4. Relatedness

Economic complexity starts with two key ideas: relatedness and complexity.

Relatedness measures the affinity or the "similarity" and "compatibility" between a location (or an economy) and an activity. For instance, it can be used to measure the existing link between a country and a product, or a country and an industry.

Some people may get confused and think that relatedness is a synonym for proximity. But relatedness is actually the affinity between a location (a country, city or region) and an activity (e.g. a product, industry, technology). It is often used to predict the probability that a location will enter or exit an activity.

The whole concept of relatedness has been introduced by Hidalgo in the paper *The Principle of Relatedness* (Hidalgo, C. A. et al. The Principle of Relatedness. in Unifying Themes in Complex Systems IX (eds. Morales, A. J., Gershenson, C., Braha, D., Minai, A. A. & Bar-Yam, Y.) 451–457 (Springer International Publishing, 2018).

The Principle of Relatedness presented by Hidalgo is a statistical law that provides the probability that a location enters an economic activity. This probability grows with the number of related activities present in a location.

The principle of relatedness has been shown to be true for countries entering new products, regions entering new industries, cities patenting in new technologies, and even universities publishing in new research areas.

First of all, relatedness is connected to the idea of recommender systems in computer science and to the idea of absorptive capacity and cognitive proximity in economics.

In computer science there is a concept called "recommender systems", that is algorithms suggesting related items to users. These systems were developed in the 90's as a mean to facilitate the social filtering of content and today they are very popular because in the 2000s and 2010s they rose together with e-commerce and streaming platforms: much of the content that we consume today actually comes from these recommendations.

Relatedness is not coming only from computer science; it comes also from the idea of cognitive proximity. During the 80s and 90s there was big literature focused on the role of geographic distance in the diffusion of knowledge and productive activities. We can go back to Romer endogenous growth theory (Romer, Paul M. 1994. "The Origins of Endogenous Growth." *Journal of Economic Perspectives*, 8 (1): 3-22.) and the idea of spillovers. By looking at the role of proximity and the role of physical distance in the transmission of knowledge, it has been figured out that there is more than physical distance, because you can have people that are physically close, but they cannot learn from each other because of the cognitive distance. Here it is possible to draw two maps, not just a map of the geography in space but also a map of the cognitive geography.

Basically, in the 2000s people realized that beyond physical distance, cognitive distance mattered.

Talking about the applications of the concept of relatedness, we can use it to understand what are the activities that a location is going to enter or exit in the future.

We can look at the map of product space. Each node represents a product. Products that are connected are likely to be co exported which is a measure of proximity and the painted products are the ones that Chile exports in 1979. The pattern of the specialization here is defined by the presence on some clusters. Looking at how this evolves over time we are able to see that the countries enter activities that are related to the ones that they did previously so relatedness can help us fast explain this process of diversification.

Recent development in the economic literature in the last decade have unpacked relatedness into multiple channels.

Cristian Jara-Figueroa in his paper "The role of industry, occupation, and location specific knowledge in the survival of new firms" [9]studies how labor flows work. Investigating people changing jobs, industries, occupations and locations allows to unpack relatedness into multiple channels: you can see the industries, the occupations and the location that a person has worked on, and this give us a history of different forms of relatedness.

In this paper there are various outcome: one of them is the growth and survival of pioneer firms. These are the first firms to operate in an industry that was not previously present in a location. Let's take an example: if you have a location that never had before a company on the video game sector we can figure out who is working on that company, where they're coming from, what education they have, what occupations they used to have, industries they used to work or location they used to work. We can then create matrices in which this idea of relatedness in not unidimensional but multidimensional and see people that work in the same industry and occupation, or different industry and occupation and so on.

Another interesting paper is the one by Dario Diodato "Why do industries conglomerate? How Marshallian externalities differ by industry and have evolved over time" in which relatedness and conglomeration are analyzed to explain why industries conglomerate over time. At the beginning of the twentieth century, industries tended to locate where their value chain partners are while in more recent decades the importance of this

[9] Papers in Evolutionary Economic Geography (PEEG)

channel has declined, and colocation seems to be driven by similarities in industries' skill requirements. However, firms take advantage from proximity to other firms with which they can exchange inputs, skilled labor, or know-how. Again, this can help in predictions of city-industry growth.

The concept of relatedness is linked also to diversification into upstream or downstream industries. That's what is analyzed in the work of..

Where, by putting in relation trade data together with industry data, it is shown that developing countries seem to be more successful at the point where they tend to diversify upstream of current exports rather than downstream processing.

1.5. Diversification and ubiquity

Diversification is one of the strategies of international trade and economic development pursued in order to continue the growth of countries. Therefore, it is important to understand the logic of this particular strategy and to locate it in the economic complexity analysis.

In this framework, we expand the meaning of diversification by looking at it by the point of view of diversification in exports.

Developing nations produce items and export them for the purposes to maintain themselves competitive and also create competitiveness in the world market.

However, one major problem for many developing countries comes from over specialization and consequently the over dependence on the exporting of a limited range of primary commodities, which are volatile because the prices of them are quite inelastic.

This means that developing countries need to have another strategy, as to say pushing towards the development of manufactured goods in order to provide protection from primary product fluctuations.

The idea is that by increasing technology and increasing the skills of its workers these countries will be able to compete more readily.

Studies have shown that there are optimal ways to diversify an economy.

First, we must consider that economies are more likely to enter related economic activities.

A country, region or a city is more likely to start producing products, industries and patents that are similar to the ones they've had produced in the past.

However, this doesn't mean that economies should focus their efforts only on things that are similar and on the contrary, they should try to break the pattern.

Namely, a recent paper published in Nature Communications, a team of scholar from MIT and Khalifa University studied this matter. [10]

These scholars looked at the total time that it would take an economy to diversify to all possible economic activities using different diversification strategies.

One strategy was to simply focus on the most related activities; another was focused on the most connected activities, as to say, the ones that can increase the chances to enter other activities.

What they found was that strategies focused only on related activities were suboptimal. This means that focusing only on highly related products is bad for economic development.

In fact, they found that the strategies that were most effective to diversify an economy were dynamic, meaning that they change at different stages of development: for economies with low levels of industrial diversity, it is profitable to focus on the most related activities. At that stage risky endeavors are likely to fail, and it is better to build capacity slowly but surely.

But at some point, economies enter a more diverse stage: this is the time when they need to switch strategy and focus on activities that are less related and more connected. These risky effects can slow down the diversification process momentarily but will provide the

[10] Alshamsi, A., Pinheiro, F.L. & Hidalgo, C.A. Optimal diversification strategies in the networks of related products and of related research areas. *Nat Commun* **9,** 1328 (2018).

basis for more rapid development in the future. In later stages, economies should focus again on related activities. This time because the most sophisticated activities are now also the activities that are also closely related. The scholars also compared their model with the empirical behavior of countries in the networks of related products and related research areas. They found that the behavior of countries was not too far from the optimal behavior of the model.

Yet, these findings are helping us understand how economies diversify their activities and how to think development strategies.

In the context of the product complexity, ubiquity is the basis together with diversity of this concept. It refers to the number of regions/countries/areas that produce and export a given good with comparative advantage. The more a product is complex, the less regions/countries/areas produce and export it since it requires more sophisticated manufacturing.

1.6. Economic Complexity Index

1.6.1. How to measure economic complexity

Given all the basic concepts explained in the previous chapter, it is now possible to describe in a crearly manner the concept of Economic Complexity and its index. We've learnt that economic prosperity cannot be reduced to a single component. In truth, the disparities between rich and poor nations are extensive and encompass a variety of extremely particular elements. As a result, we require methods to capture worldwide disparities in development outcomes that are not exclusively focused on a single component, but rather take into account all of the above. Economic complexity can help us understand how national and regional economies grow.

Economic Complexity, as an academic discipline, investigates the geography and dynamics of economic activity using methodologies influenced by ideas from complex systems, networks, and computer science.

The Economic Complexity Index, or ECI, is a measure of an economy's capacity derived from data linking places to the activities that take place in them. It has been found to predict key macroeconomic outcomes such as a country's income level, economic growth, income inequality, and greenhouse gas emissions. It is also calculated using a variety of data sources, including trade data, employment data, stock market data, and patent data. The difficulty of assessing economic complexity is the problem of estimating the complexity of both places (e.g., nations, cities, regions) and the activities that take place in them (e.g. products, industries, technologies). The main notion is that activities present, created, or exported from a place convey information about the area's complexity, whereas locations where an activity is present carry information about the complexity necessary to accomplish an activity. Cities such as San Francisco, Boston, and New York, for example, might be described as complex since they are home to complex activity. Similarly, it may classify an activity as complicated if it is mostly found in complex economies such as Boston and San Francisco. This circular reasoning may be turned into a broad set of equations that can be used to measure economic complexity. Technically, let the complexity K of a place c (for example, a nation or city) be Kc and the complexity K of an activity p (for example, a product or industry) be Kp. Let Mcp also be a matrix that summarizes the activities (p)) existent in location ((c).). Mcp is usually defined as Mcp=1 when a location's output in an activity exceeds what would be anticipated for a location of the same size and activity with the same overall output. This may be accomplished by employing a metric such as a location's Revealed Comparative Advantage (RCA) or Location Quotient (LQ).

That is, we can define

$M_{cp} = 1$ if $R_{cp} \geq 1$

Where:

$R_{cp} = (X_{cp}X)/(X_cX_p)$

And

$X_c = \sum_p X_{cp}$, $X_p=\sum_c X_{cp}$ and $X=\sum_{cp} X_{cp}$

Following this nomenclature, the general assumption made by economic complexity metrics is that the complexity of a location (Kc) is a function (f) of the complexity (Kp) of the activities present in it (Mcp) and that the complexity of an activity (Kp) is a function (g) of the complexity ((Kc)) of the places where that activity is present (Mcp).
This circular logic is equivalent to the following mathematical map:
$K_c=f(M_{cp},K_p)$,
$K_p=g(M_{cp},K_c)$,
Where f and g are functions to be determined.

These notations imply that measures of the complexity of economies, or of economic activities, are solutions to self-consistent equations of the form:

$K_c=f(M_{cp},g(M_{cp},K_c))$,
$K_p=g(M_{cp},f(M_{cp},K_p))$,

Which in many occasions can be reduced—or approximated by—a linear equation of the form:
$K_c=\tilde{M}_{cc'}K_c$,
$K_p=\tilde{M}_{pp'}K_p$,

These equations suggest that eigenvectors of matrices linking related nations (Mcc′) or related products (Mpp′) are eigenvectors of matrices connecting related countries (Mpp′) (e.g. the Product Space). We should remark that the first set of equations provides a more extensive family of functions that include functions that cannot be reduced to linear forms but can provide outcomes comparable to linear equations. These equations also remind us that complexity measurements are relative, because the complexity of a place or activity might vary due to changes in the entries for other locations or activities (other rows or columns in the Rcp or Mcp matrix).

Using the paradigm described above, we define a location's Economic Complexity Index, or ECI, as the average of the Product Complexity Index, or PCI, of the activities existing in it. Similarly, we define an activity's Product Complexity Index (PCI) as the average Economic Complexity Index (ECI) of the regions where that activity is present. That is, we define a location's complexity as the average complexity of its activities, and an activity's complexity as the average complexity of the places where that activity is present. The ECI formula is the formal solution to the system of equations:

$Kc=1Mc\sum pMcpKp$,

$Kp=1Mp\sum cMcpKc$,

Which is equivalent to diagonalizing the following matrix:

$Mcc'=\sum pMcpMc'pMcMp$

Here $Mc=\sum pMcp$ is the number of activities (or diversity) of a location and $Mp=\sum cMcp$ is the ubiquity of an activity (number of locations where it is present).

Since Economic Complexity is a relative metric, the results are usually normalized using a Z-transform. That is:

$$ECI = \frac{K_c - \tilde{K_c}}{\sigma(K_c)},$$

1.6.2. New metrics for economic complexity: the CREF-CNR approach

When people talk about development, it is quite common to talk about money. Problem is that money and finance are not the key for development. The key for development is engineering, industry, ideas and products and economics in a broad sense.

The focus here in therefore complementary things around development and growth in order to understand how effectively growth happens.

Forecasting in the era of big data seems easy.

Typically to analyze a country it takes a lot of indicators: the economy, pollution, the road network, education, finance and so on, collecting a vast set of data.

Actually, more data do not always lead to better forecasting. Indeed, whilst more data can give more information, unavoidably it also leads to more noise: large dimension of data is problematic. [11]

That’s why Luciano Pietronero’s group of work decided to consider and elaborate a new method for measuring economic complexity, different from the Harvard’s and MIT’s one.

The approach of the research centre Enrico Fermi differs from the one used by Hidalgo and Hausmann. Whilst the algorithm used by the latter assumes a linear relation between the ubiquity of a product and the competitiveness of its exporters at a given order of iteration, using an arithmetic average, the method used by Pietronero is non-linear and the export basket taked into account is characterized by vast diversity.

The most important and innovative aspect of this approach is the relationship put in place between the complexity of a country’s products and the fitness of it.

This methodology allows to focus more on the capabilities of an economy and leads to the conclusion that the more complex goods are the ones that are produced only by highly competitive countries, since if a product is made and exported by poorly developed countries this means that it requires a low level of sophistication.

[11] Poincaré problem in dynamical systems.

Thanks to this approach, it is possible to distinguish between countries with a high level of increase of development (such as Asian countries), and the countries whose wealth is based on the monopole of export of natural resources but which have not automatically a high level of industrial development and therefore fitness (e.g. Russia or Middle East)
The fitness of countries and the complexity of products are therefore put in relation in order to determine the strength of countries and products in the context of international exports.

The metrics used is able to measure a genuine feature of the country-product matrix and it is not dependent on the initial conditions of the country. In fact, the so calculated product complexity is non-monetary and non-income based.
The most important implication is that it can be used to interpret the potential for future growth of the countries when put in comparison with standard monetary and income-based indices (e.g. GDP of countries).

Formula

Starting from the 4 digits HS (Harmonized System 2007) classification, the research center has categorized a set of about 1200 products linked to 200 countries.
The first goal is to build a matrix, M_{cp}, that describes the bipartite network of countries and products. The elements of the matrix are 1 if the country *c* exports the product *p* and 0 otherwise.
In order to do so, it has been used the Revealed Comparative Adantage (RCA) to understand whether a country can be considered a producer of a particular good or not. RCA is the ratio between exports of the product *p* by country *c* and the global export of *p* done by all countries. This ratio itself is then divided by the fraction of the total export of *c* with respect to the whole world export.
If $RCA_{cp} \geq 1$ then it means that the given country produces that product and in order to buil the matrix *M*, we consider $M_{cp} = 1$ if $RCA_{cp} \geq 1$ and zero otherwise.

We take the Fitness of a country Fc, which is proportional to the sum of the products exported weighted by their complexity Qp.

Qp is inversely proportional to the number of countries which export it.

The idea is summarized in the iteration of the equations:

$$\begin{cases} \tilde{F}_c^{(n)} = \sum_p M_{cp} Q_p^{(n-1)} \\ \tilde{Q}_p^{(n)} = \dfrac{1}{\sum_c M_{cp} \dfrac{1}{F_c^{(n-1)}}} \end{cases} \rightarrow \begin{cases} F_c^{(n)} = \dfrac{\tilde{F}_c^{(n)}}{\left\langle \tilde{F}_c^{(n)} \right\rangle_c} \\ Q_p^{(n)} = \dfrac{\tilde{Q}_p^{(n)}}{\left\langle \tilde{Q}_p^{(n)} \right\rangle_p} \end{cases}$$

This formula allows to confirm from a mathematical point of view the fact that the fitness of a country, at each iteration, is defined as the diversification weighted by the complexity of products.

The more ubiquitous is a product, the less complex it is likely to be.

1.6.3. Economic Fitness

Economic fitness assesses a nation’s capacity to create complexe goods on a globally competitive basis as well as its level of diversification. The highest score of Economic Fitness means that a country is able to create a wide range of goods, upgrade into ever-more complicated goods, have more predictable long-term growth, and have a strong competitive position in comparison to other nations. Countries with low Economic Fitness frequently struggle with poverty, limited capacities, unpredictable growth, low value addition, and difficulties modernizing and diversifying more slowly than other nations.

The COMTRADE[12] list of goods exported by each nation serves as the initial set of information. This information establishes a bipartite network of nations and goods, or products and services. The Economic Fitness of all nations and the Complexity of all items are then obtained by applying an appropriate mathematical method to this network.

The new literature on economic fitness employs methods that, in contrast to conventional index construction approaches, explicitly capitalize on the heterogeneity of individual actors, activities, and interactions to extract pertinent parameters to characterize the system rather than attempting to average out its complexity. In this way, data on manufacturing capacities can be gleaned from the exchange of items. Future competitiveness and long-term growth are predicated on the interactions between the traded goods and the unique combinations. Being parameter free is a basic property of Economic Fitness. The traditional methods of analysis take into account numerous factors and provide a useful summary. The problem is, this sum of disparate elements leads to a major challenge of limiting noise while increasing signal. Here is where the Fitness approach starts to manage these issues since it takes into account a single dataset. Later, additional data can be incorporated in a regulated hierarchical architecture (e.g., services and technologies). The algorithm is based on transparent, easy-to-understand economic principles that have been extensively tested. The dynamics of each nation's evolution are characterized in the GDP-Fitness space, which exhibits significant variety. There are two zones: one with a more regular flow and one with a more chaotic one. Accordingly, growth projections should take this variation into account and go beyond simple regressions. Even though it uses significantly less data, this unique technique to analysis and long-term forecasting has been found to perform better than the conventional methods.

[12] The COMTRADE is an acronym for Common format Transient Data Exchange for power systems and it is a database of the United Nations with exports and imports statistics by countries and tariff codes.

Fitness of Countries

$$\tilde{F}_c^{(n)} = \sum_p M_{cp} Q_p^{(n-1)}$$

$$F_c^{(n)} = \frac{\tilde{F}_c^{(n)}}{\langle \tilde{F}_c^{(n)} \rangle_c}$$

F_c: diversification weighted by complexity

The Fitness methodology has been widely adopted by the IFC-World Bank, which has already examined over 50 countries and made numerous applications in the private sector.

Limitations and exceptions

Trade data are required to define a cohesive network for all countries and products. This may have some drawbacks for countries where exported goods are not a good proxy for industrial competitiveness. While most fitness analyses focus solely on manufacturing, Universal Fitness also includes services. However, because the corresponding database is less granular (i.e., more aggregated), the products database has also been aggregated, which can have a minor impact on algorithm outputs. The relative weight of products and services in the final, universal dataset reflects their respective importance in the international trade flow. The importance of diversification is a fundamental concept of the algorithm.

This is correct at the national level, but it becomes increasingly problematic as one moves to smaller scales such as regions, cities, and individual firms, where specialization becomes dominant. In these cases, appropriate modifications should be considered. The COMTRADE dataset is available at various levels of granularity and each level has advantages and disadvantages that must be weighed in relation to the problem at hand.

1.7. Product Complexity Index

The Product Complexity Index is founded on two fundamental ideas: diversity and ubiquity. The quantity of items that the region exports with a competitive advantage is referred to as diversity. The number of areas that export a certain product with a competitive advantage is referred to as ubiquity. The index is based on the premise that more complicated items are made and exported by a fewer number of locations while necessitating more productive expertise. As a result, more complicated products are those generated by a few places that produce a variety of items.

Intuitivelly, the way in which the Product Complexity Index is computed is by an algorithm similar to the one Google uses to rank the webpages.[13]

$$PCI = \frac{\vec{Q} - \langle \vec{Q} \rangle}{stdev(\vec{Q})}$$

Hausmann, Hwang, and Rodik (2007) suggested two simple empirical measures of product and economic complexity (or sophistication). The income level associated with a product represents the complexity of that product and is determined as a weighted average of the income per capita of the nations that export the given commodity. The weight is an indicator of apparent comparative advantage.

The Product Complexity Index includes income data (revenue per capita of nations exporting the product) as well as information about the network structure of countries and the items they export (the weights). Hidalgo and Hausmann(2009) refined them by isolating information on income from information on country network structure and

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[13] More precisely, the algorithm is more similar to the one used by J. Kleinberg for Ask.com. It is an eigenvector problem.

export items. In doing so, they addressed the argument that utilizing income data in the computation of the measures leads to the circular conclusion that "rich nations export rich-country products" (Hidalgo 2009).

Hausmann and Hidalgo use the *method of reflections.* It is called reflections because of the symmetry of the bipartite network and the fact that it produces a symmetric set of variables for the 2 types of nodes in the network (countries and products).

In the Method of Reflections, introduced in HH (Hausman and Hidalgo), sequences are built using a country-product matrix M with elements Mcp indexed by country c and product p. The matrix entries are equal to one if Balassa's(1965) index of revealed comparative advantage (RCA) is greater than or equal to one; in HH's words, nation c exports product p "with RCA." The beginning constituents of the series are represented by row and column sums of M in this matrix.

$$k_{c,0} = \sum_{p} M_{cp},$$

$$k_{p,0} = \sum_{c} M_{cp}.$$

The vector Kc,0 measures the number of items produced by a nation using RCA and is referred to as the country's "diversity." The vector Kp,0 counts the number of nations that make a certain product using RCA and is referred to as the product's "ubiquity." The The Method consists of iteratively calculating the average value of the previous-level properties of a node’s neighbors and is defined as the set of observables:

$$k_{c,N} = \frac{1}{k_{c,0}} \sum_{p} M_{cp} k_{p,N-1},$$

$$k_{p,N} = \frac{1}{k_{p,0}} \sum_{c} M_{cp} k_{c,N-1}.$$

Hence, we characterize each country through the vector k_c = ($k_{c,0}$, $k_{c,1}$, $k_{c,2}$ . . . $k_{c,N}$) and each product by the vector k_p = ($k_{p,0}$,$k_{p,1}$,$k_{p,2}$, . . . ,$k_{p,N}$). For countries, even variables ($k_{c,0}$,$k_{c,2}$,$k_{c,4}$, . . .) are generalized measures of diversification, whereas odd variables ($k_{c,1}$,$k_{c,3}$,$k_{c,5}$, . . .) are generalized measures of the ubiquity of their exports.

For products, even variables are related to their ubiquity and the ubiquity of other related products, while odd variables are related to the diversification of countries exporting those products.

n network terms, $k_{c,1}$ and $k_{p,1}$ are known as the average nearest neighbor degree (9,10). Higher order variables, however, (N □ 1) can be interpreted as a linear combination of the properties of all of the nodes in the network with coefficients given by the probability that a random walker that started at a given node ends up at another node after N steps.

Intuitivelly, this method of reflections lead to important concepts: firstly, there is a strong negative correlation between $k_{c,0}$ and $k_{c,1}$ (10, 11), meaning that diversified countries tend to export less ubiquitous products.

Formally, we can finally define PCI as the average diversity of countries that make a specific product, and the average ubiquity of the other products that the country makes:

$$\tilde{M}^{P}_{p,p'} \equiv \sum_{c} \frac{M_{cp}M_{cp'}}{k_{c,0}k_{p,0}}.$$

1.8. Revealed comparative advantage (RCA)

The revealed comparative advantage is an index used in international economics to calculate a country's relative advantage or disadvantage in a specific class of goods or services based on trade flows. It is based on the Ricardian concept of comparative advantage.

There are two major trade theories based on comparative advantage: the Ricardian theory and the Heckscher-Ohlin (H-O) theory. The Ricardian theory holds that comparative advantage arises from technological differences between countries, whereas the H-O theory holds that technologies are the same across countries. The H-O theory, on the other hand, attributes comparative advantage to cost differences caused by differences in factor prices across countries. In summary, orthodox (classical) trade theories predict based on the principle of comparative advantage, which derives from relative price determination, i.e. differences in pre-trade relative prices across countries, as highlighted by supply and demand factors. According to the H-O theory, a country's comparative advantage is determined by the scarcity of its relative factors (i.e. its factor endowment ratios, relative to the rest of the world or a set of countries). However, it is widely recognized that quantifying comparative advantage and verifying the Hecksher-Ohlin (H-O) theory are problematic (Balassa,1989:42-4), because comparable prices are not visible under autarky. Given this fact, Balassa (1965) suggests that including all elements influencing a country's comparative advantage may not be necessary. Instead, he contends that observed trade patterns "reveal" comparative advantage, and that the theory requires pre-trade relative pricing that are not visible. Inferring comparative advantage from seen data is hence referred to as "revealed" comparative advantage (RCA). In practice, this is a widely used method for analyzing trade data. Balassa(1965) develops an indicator (the Balassa Index) to assess a country's comparative advantage. Rather than determining the underlying sources of comparative advantage, the Balassa index attempts to establish if a country has a "revealed" comparative advantage.

The comprehensive measure of RCA presented by Balassa (1965) is expressed as follows:

$$RCA2 = (Xij / Xit)/(Xnj / Xnt) = (Xij / Xnj)/(Xit / Xnt)$$

Where X represents exports, *i* is a country, *j* is a commodity (or industry), *t* is a set of commodities (or industries) and *n* is a set of countries.

If RCA>1, a comparative advantage is "revealed." If the RCA is less than one, the country is said to be at a competitive disadvantage in the commodity or industry. The concept of revealed comparative advantage is similar to that of economic base theory, which is based on the same calculation but takes employment into account rather than exports.

RCA measures a country's exports of a commodity (or industry) relative to its total exports and to the corresponding exports of a set of countries, e.g. the EU.

A comparative advantage is "revealed", if RCA >1. If RCA is less than unity, the country is said to have a comparative disadvantage in the commodity / industry.

1.9. Relationship between Economic Complexity and economic growth

Several research over the last few decades have found links between economic complexity and key social and macroeconomic effects. The first wave of research concentrated on the relationship between economic complexity and economic growth. The research that originated the concept of economic complexity demonstrated that economies with higher economic complexity expanded faster per unit of GDP per capita. This finding was later validated and enhanced in a second book (The Atlas of Economic Complexity) and in several publications based on international and subnational data. Scholars have discovered that an increase in economic complexity of one standard deviation, at the same level of GDP per capita, is related with an increase in yearly growth of between 4% and 7%.

Also, people studying economic complexity have recently shifted their focus to other topics such as income inequality and environmental sustainability. In recent years, it has been found that countries with higher degrees of economic complexity tend to have lower levels of wealth inequality and produce fewer emissions.

Countries exporting complex products—as measured by the Economic Complexity Index—have lower levels of income inequality than countries exporting simpler products.

Economic complexity's capacity to anticipate economic growth, inequality, and reduced emissions make it an appealing policy target for governments seeking to promote inclusive development. It is shown, using multivariate regression analysis, that economic complexity is a significant and negative predictor of income inequality, and that this link is strong when aggregate measures of income, institutions, export concentration, and human capital are controlled for. An economy is able to generate and distribute income given the product mix that it can produce and export. Using the multivariate regression, it is confirmed that the relationship between economic complexity index and income inequality is strong and robust to controlling for measures of income, education, and institutions; moreover, this relationship has remained strong for over the last fifty years. [14]

These findings do not imply that a country's degree of income inequality is primarily determined by its production systems.

A more likely explanation for the relationship between a country's productive structure and income inequality, on the other hand, is that productive structures are a high-resolution expression of a number of factors, from institutions to education, that co-evolve with a country's mix of exported products and the inclusiveness of its economy.

Moreover, it has been shown also that employees in high skilled occupations and industries experience lower gender wage gaps, and that the effect of knowledge intensity is stronger when the demand for skilled labor is high and the supply of skilled labor is low.[15]

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[14] 16.Hartmann, D., Guevara, M. R., Jara-Figueroa, C., Aristarán, M. & Hidalgo, C. A. Linking Economic Complexity, Institutions, and Income Inequality. World Development 93, 75–93 (2017).

[15] [15] BARZA, Radu and Jara-Figueroa, Cristian and Hidalgo, César A. and Viarengo, Martina, Knowledge Intensity and Gender Wage Gaps: Evidence from Linked Employer-Employee Data (2020). CESifo Working

In this chapter the intention is going further in investigating how economic complexity can explain economic development in broad terms, where development means not only increase in income, but also innovation, productivity, quality of the institutions, decrease of inequalities and so on.

1.9.1. Links between economic complexity and income

Recent studies (Hartmann D., Guevara M.R., Jara-Figueroa C., Aristarán M., Hidalgo C.A.

Linking economic complexity, institutions and income inequality, 2017), have shown through methods from econometrics, network science, and economic complexity, that countries exporting complex products—as measured by the Economic Complexity Index—have lower levels of income inequality than countries exporting simpler products.

There are several reasons why the productive structure of a country influences the level of its income.

First, the variety of goods produced by an economy affects the career options, educational possibilities, and bargaining strength of its workforce and labor unions. Notably, technical catch-up and industrialization have given workers new jobs and educational opportunities in several emerging economies, aiding in the emergence of a new middle class.

Economic complexity and the dynamics of the productive space allow us to identify structural relationships between economic growth and income inequality that aggregated variables like the average number of years of education or per capita income alone are unable to do. These empirical findings show that the relationship between the economic complexity index and income inequality is substantial and reliable. Researchers used multivariate regression to establish that this association has held over the past 50 years and is robust to adjusting for variables of income, education, and institutions.

Paper No. 8543, Available at

SSRN: https://ssrn.com/abstract=3689464 or http://dx.doi.org/10.2139/ssrn.3689464

Furthermore, authors demonstrated that declines in income disparity frequently coincide with rises in economic complexity.

Let's imagine a nation with an economy that primarily consists of low-value-added goods. Initially, economic activity produces substantial rewards for nations. However, the productive structure and employment in this form of economy rely mostly on low-skilled labor, which has low returns and is one of the key causes causing income gaps. Low-value products are also easy to use. They are typically developed in small groups and do not require advanced technology, skills, or product knowledge.

Small groups of people receive the economic advantages of these products, resulting in income discrepancies with the rest of the population. Because skilled labor is not required to produce low-value goods, job options are constrained in underdeveloped nations. A tall hierarchy within the professional structure will control most unskilled workers, leading to large disparities like the development of top earnings, low wage shares, and a limited middle class.

1.9.2. Links between Economic complexity, innovation, educational system and quality of institutions

In a complex environment, suppliers, regulators, and professional bodies frequently collaborate up front to negotiate new product designs, manufacturing processes, and post-delivery changes. Individuals regularly play a significant role in innovation.

Economic complexity and educational system affect each other in a reciprocal way. It is commonly assumed that in order to become more economically competitive, citizens must have the information, abilities, and attitudes required for success in both civic life and the knowledge-based economy.

Studies [16] have shown that new properties and behaviors, which are not always contained in the essence of the constituent elements or able to be predicted from an understanding of initial conditions, will emerge when a particular environment (or "dynamical system") reaches a significant level of complexity. These ideas of emerging phenomena from a critical mass, along with the concepts of lock-in, path dependency, and inertial momentum, propose that new phenomena, new features, and new behaviors develop from the dynamic interactions and adaptive orientation of a system.

Arguments are made that shifting educational and institutional practices has less to do with changing a single element or component and more to do with building momentum for change by paying attention to as many variables as feasible. To put it another way, complexity theory suggests that it may take massive and sustained intervention at every level, up until the phenomenon of learning excellence emerges from this new set of interactions among these new factors and sustains itself autocatalytically, in order to shift a school's inertial momentum from one of failure.

International trade is influenced by the quality of national institutions: Anderson and Marcouiller contend that defective institutions situated in the importer's nation discourage international trade because they allow economic scavengers to steal and extort rents at the importer's border. Daniel Berkowitz, Johannes Moenius, Katharina Pistor[17] completed this research by showing that good institutions located in the exporter’s country increase global trade, in particular trade in complex products. According to empirical evidence supporting these hypotheses, nations with strong institutions tend to export more complicated goods while importing a greater variety of straightforward goods.

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[16] Mark Mason (2008) What Is Complexity Theory and What Are Its Implications for Educational Change?, Educational Philosophy and Theory

[17] https://doi.org/10.1162/rest.88.2.363

1.9.3. Economic complexity, sustainability, and resource efficiency (RE)

The last years have seen a growth in empirical study of the ecological footprint, which is now a hot topic for academic study among environmentalists.

Long-term projections show that economic complexity, development, commerce, export quality, and urbanization all lead to larger ecological footprints. In fact, increased investments in the production and use of renewable energy as well as the effective use of human capital will increase economic complexity, export quality, and environmental protection in both developed and developing nations.

The top 10 economic complex countries have recently experienced impressive economic growth due to industrialization and urbanisation. Energy consumption in these countries has also multiplied as a result of this shift from complex industrial economies centered on agriculture. These economies are therefore regarded as making a significant contribution to GHG emissions, and the future of the global environment will depend on their ecological imprint.

The fact is that a more complex economy offers a platform for the development of knowledge-intensive production structures and protects the environment through the adoption of new knowledge and technology.

Economic complex nations go toward knowledge-intensive technologies like energy-efficient products and renewable energy generation through industrialization and product diversification to maintain a green economy. Also, A technical advance that protects the environment requires a high level of expertise.

Finally, a study conducted by Can, M., Gozgor, G. The impact of economic complexity on carbon emissions: evidence from France. *Environ Sci Pollut Res* shows that in the long run, greater economic complexity reduces CO_2 emissions.

Policymakers should therefore take note of the benefits of economic complexity and include product quality as one of the determining criteria when formulating environmental laws and policies.

More in deep, resource efficiency is one important objective of the Sustainable Development Goals (SDG).

The study conducted by Fengmei Maa, Heming Wang [18] demonstrates that the economic complexity index (ECI) and resource efficiency (RE) of nations have a significant exponential connection.

Therefore, to achieve sustainable development, it appears that policies that increase economic complexity and make investments in core products should be prioritized.

As known, ECI gauges how much information a society has amassed over time to enable the items it produces.

It is crucial to understand how a country's level of economic complexity affects its material usage and resource efficiency outcomes and links to environmental sustainability because human capital and knowledge are not only the foundation for producing commodities but also the foundation for how to produce efficiently from a sustainability point of view. The SDG call on nations to increase RE and develop sustainable patterns of consumption and production by "doing more with less."

Studies from the past have already previously shown that ECI can explain future economic growth. They have demonstrated that countries with stable institutions and a lack of reliance on the export of natural resources may experience greater future growth effects from ECI. The extent to which ECI predicts future RE for nations that are either net importers or net exporters of natural resources is examined in this study. The impact of institutional stability on the link between ECI and RE is another topic of interest for the study.

For what it concerns the evolution of economic complexity, the empirical investigations demonstrated that worldwide ECI gradually rose between 1995 and 2010 before declining after that year, primarily as a result of the global economic crisis of 2008–2009's effects on international trade. It is noteworthy that ECI was significantly greater for stable countries and net material importers than for unstable countries and net material

[18] https://doi.org/10.1016/j.resconrec.2022.106530

exporters, and the difference between these two sets of countries has progressively grown. The economic crisis had a smaller impact on the ECI of stable nations.

Between 1995 and 2005, global resource efficiency remained unchanged, but between 2005 and 2015, it increased by nearly 20%, largely due to the swift improvement in RE in resource-importing and stable countries.

The study finds a strong and statistically significant correlation between ECI and RE; this suggests that increasing economic complexity and increasing resource efficiency are closely related.

This suggests, for instance, that nations with high ECI but low RE, like China, have strong prospects for raising future resource efficiency.

In sum, the findings show that there was a significant relationship between economic complexity and resource efficiency during the study period, and that increasing economic complexity may be related to future gains in a nation's resource efficiency.

CHAPTER 2

Sector (ri)classifications

2.1. OEC, The Atlas of Economic Complexity

In order to analyse the research theme, it was necessary to draw on different sources. The main ones that deal and study the times of economic complexity are listed and described below.

The Observatory of Economic Complexity is a tool for analyzing the dynamics of economic development, the development of countries' production structures and trading partners created by MIT.
This tool enables a more in-depth analysis of massive amounts of data and improves the quality of information provided to decision makers. The Observatory's mission is to assist build a new bridge between economic growth development theory and statistics. Finally, the development of simple, yet accurate, representations of huge amounts of data will give new anchors for more disaggregate forms of development theory and aid decision making in an industrial policy framework.
Trade datas about

- Country (trade partner)
- Product (SITC4 code)
- Year
- Direction of trade flow (import or export)
- Amount (Value in $US).

are arranged in a relational database with the following three dimensions of variance:

1. Country
2. Product
3. Year

They also calculated each country's Revealed Comparative Advantage (RCA) on each product using the Balassa definition of RCA and the proximity between pairs of items. As a result, in addition to the three variables described above, other attributes such as export value, import value, RCA, and others are also saved.

The main apps that have been developed are:

1. TreeMaps

This tool is inspired by the TreeMap algorithm by Ben Shneiderman [19]. The algorithm used by the OEC generates a rectangle that when viewed as a whole, it reflects 100% of either the commerce of a certain nation in a given year or the traders of that product.

2. Product Space

In this kind of graph a product is represented by each node in the graph and links connect good that are often exported by the same nations. The opacity of the nodes reflects the items that a nation is exporting (full opacity signifies a product is exported with an RCA > 1). The product space is a forecasting instrument that may assist in directing industrial strategy since the items that a country will produce in the future may be predicted by where it is located in the Product Space.

3. Stacked Area Charts

The stacked area charts are used to display the same dataset with value changing over time. Data can be seen as nominal $US values or as shares of a total.

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[19] Ben Schneidermann in 1992 produced a compact visualization of directory tree structures.

This tool can be used to chart changes in a country's export diversification over time (which of their products have an RCA >1) or changes in the exporters of a particular product over time (which nations export a product with an RCA > 1).

Many of the insights that may be gained from looking at these representations alone would require hours spent combing over data spreadsheets.

The Atlas of Economic Complexity is originally a 2011 book by Ricardo Hausmann, Cesar Hidalgo, Sebastián Bustos, Michele Coscia, Sarah Chung, Juan Jimenez, Alexander Simoes and Muhammed A. Yıldırım written in order to investigate the productive knowledge that each country holds.

The book has been accompanied then by two websites: MIT's https://oec.world/en/ and Harvard's http://atlas.cid.harvard.edu/.

The Atlas was a collaboration between the Center for International Development at Harvard University and the Macro Connections group at the MIT Media Labs.

At first there was only the OEC, thanks to which the visualizations in The Atlas were created. It was only in 2013 that Harvard's Center for International Development released an independent version of the platform, entitled The Atlas of Economic Complexity.

The Atlas is offered for free for non-commercial usage thanks to a creative commons license.

Several factors have been considered to come up with the list of nations that are represented in the Atlas. To begin with, it is only considered the group of nations for which product-level trade data are present in UN COMTRADE and income data are available for 2008. Second, the usage of data is limited to nations with a population of at least 1,200,000. Third, nations are taken into account if, on average, exported at least $1 billion annually between 2006 and 2008. Finally, Iraq, Macau, and Chad are eliminated from this sample since they have serious data quality problems.

Using this procedure, 128 countries are considered.

The team is lead by Ricardo Hausmann and here are other 30 people among researchers and alumni working there.

In the Atlas of Economic Complexity by the Harvard Growth Lab, data visualizations are used to represent international trade, industrial potential, and economic dynamics.
This application enables users to investigate cross-market global trade flows, follow these dynamics through time, and identify fresh potential for national economic development.

2.2. Industry classification systems

Industry categorization systems both reflect and inform our economic understanding. Countries use industry classification systems to apply tariffs to products, track cross-border commerce, and for other intents.
But why there are so many classifications, who developed them, and for what purpose? Because they are the prism through which policymakers and economists observe industrial activity, these systems have a significant impact on our understanding of economic production, trade, and employment. Such systems also have an impact on management research and, presumably, manager behavior.

Classifications divide the universe of statistical observations into sets that are as homogenous as feasible in terms of the features of the statistical survey's object.
Statistical categories are distinguished by:

- comprehensive covering of the observable universe
- mutually exclusive categories: each element should be categorized in just one of the classification's categories.
- Methodological concepts that allow the elements to be consistently assigned to the classification's numerous categories.

In this chapter, a variety of industry categorization methods are examined in order to highlight distinguishing traits, how firms are awarded industry codes, how they are used by different user groups, and the coverage of industry codes in well-known business databases.

Although the categorization systems themselves do not give direct linkages to industry information, searching by these codes is possible in many online databases and print directories. The systems also give relevant descriptions of industries and sub-industries, as well as search term inspiration

Much of the information of industries and businesses is organized by three major industry classification systems: the North American Industry Classification System (NAICS), the Harmonized System (HS), and Standard International Trade Classification (SITC).

They are numerical classification techniques with a hierarchical structure. It should be noted that organizations that participate in a wide range of operations may have many industry categories, although one sector is typically deemed primary.

NAICS is a 6-digit categorization system focuses on business activities and manufacturing processes. The first two digits of the code represent the sector, which represents broad categories of economic activity; the third digit represents the sub-sector; the fourth digit represents the industry group; the fifth digit represents the NAICS industry; and the sixth digit represents the national industry.

Developed collaboratively by the United States, Canada, and Mexico to offer comparable business statistics across North America. There are correspondence tables for linking NAICS codes to other systems.

The Harmonized System is an international categorization system that is uniform across nations at the 6-digit level, with country-specific meanings at the 8-and 10-digit levels. It is used to categorize physical goods. In the United States, commodity categories are provided in two publications, one for exports and one for imports:

- Schedule B: initially, export statistics are collected and compiled in terms of approximately 8,000 commodity classifications in Schedule B, Statistical Classification of Domestic and Foreign Commodities Exported from the United States, a publication of the United States Census Bureau based on the Harmonized System. The United States Census Bureau manages Schedule B.

- The United States Harmonized Tariff Schedule (HTS) Annotated for Statistical Reporting Purposes - Import statistics are initially collected and compiled in terms of approximately 14,000 commodity classifications in the Harmonized Tariff Schedule of the United States Annotated for Statistical Reporting Purposes (HTSUSA), a U.S. International Trade Commission publication based on the Harmonized System. The HTS is overseen by the International Trade Administration Commission of the United States (USITC).

The Standard International Trade Categorization (SITC) is a statistical classification of commodities entering external trade that is intended to give commodity aggregates for economic research and to simplify international trade-by-commodity comparison.

Table 3. *Industry classification systems comparison*

ABBREVIATION	FULL NAME	SPONSOR	CRITERION	NODE COUNT BY LEVEL	ISSUED
NAICS	North American Industry Classification System	Government of the U.S.A., Canada, and Mexico	Production/ establishment	6 digits	1997, 2002, 2012, 2017, 2022
SIC	Standard Industrial Classification	Government of the U.S.A.	Production/ establishment	4 digits 1004 categories	1937-1987 (superseded by NAICS, but still used in some applications)

UKSIC	United Kingdom Standard Industrial Classification of Economic Activities	Government of the U.K.			1948- present (2007)
UNISPSC	United Nations Standard Products and Services Code	United Nations	Product	8 digits (optional 9th) (four levels)	1998- present
NACE	Statistical Classificationof Economic Activities in the European Community	European Union	Production/ establishment	6 digits	1970, 2990, 2006
HS	The Harmonized Commodity description and Coding System	Worldwide	Product/ component material	6 digits, 21 sections, 99 chapters, heading and subheadings	1988 - present

Source: https://www.naics.com ; https://www.trade.gov/harmonized-system-hs-codes ; https://nacev2.com/it

2.2.1. NACE

NACE is an abbreviation for the numerous statistical categories of economic activities created in the European Union since 1970. (EU). NACE provides a framework for collecting and presenting a wide range of statistical data based on economic activity in economic statistics (e.g., production, employment, national accounts) and other statistical areas. Statistics based on NACE are comparable at the European and, in general, global levels and the usage of NACE is required by the European statistics system.

NACE classifies the productive economic activities. But what does economic activities mean?
An economic activity occurs when resources such as capital goods, labor, manufacturing processes, or intermediary items are combined to generate specified commodities or services. Thus, an economic activity is defined by a resource input, a production process, and a product output (goods or services). An activity, as described below, may consist of a single straightforward process (for example, weaving), but it may also include a number of sub-processes, each of which is specified in a distinct category of the categorization (for example, the manufacturing of a car consists of specific activities such as casting, forging, welding, assembling, painting, etc.). If the manufacturing process is organized as an integrated succession of primary activities inside the same statistical unit, the entire combination is treated as a single activity.

NACE has a hierarchical structure [20], the introductory guidelines and the explanatory notes. The structure of NACE is described in the NACE Regulation as follows:

- Sections, a first level consisting of headings identified by an alphabetical code

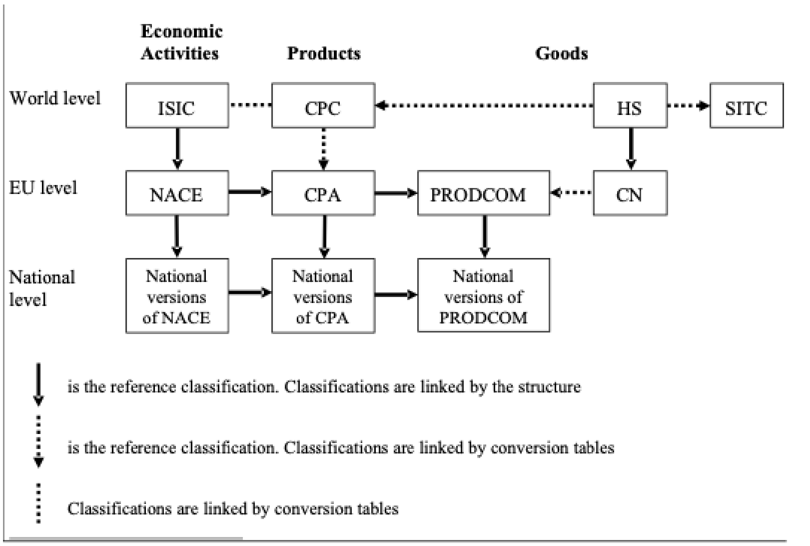
[20] The hierarchical structure is established in the Regulation (EC) No 1863/2006

- Divisions, a second level consisting of headings identified by a two-digit numerical code
- Groups, a third level consisting of headings identified by a three-digit numerical code
- Classes, a fourth level consisting of headings identified by a four-digital numerical code

The divisions are coded consecutively but there are some gaps left to allow the introduction of additional divisions.

NACE is derived from ISIC[21] nomenclature system, in fact ISIC and NACE have exactly the same items at the highest levels, while NACE is more detailed at lower levels.

Figure 3. *The international system of economic classifications.*



Source: Eurostat, 2022

[21] ISIC is the United Nations' International standard industrial classification of all economic activities

Where:

ISIC = the United Nations' International Standard Industrial Classification of all Economic Activities

CPC = the United Nations' Central Product Classification

HS = the Harmonized Commodity Description and Coding System, managed by the World Customs Organisation.

CPA = the European Classification of Products by Activity.

Prodcom = the classification of goods used for statistics on industrial production in the EU.

CN = the Combined Nomenclature, a European classification of goods used for foreign trade statistics.

An integrated system of this type enables for the comparison of statistics produced in many statistical fields. As a result, statistics on goods production (as reported in the EU by Prodcom surveys) may be compared with statistics on commerce (in the EU produced according to CN).

Each national statistical institute has issued a table through which to convert and translate NACE codes. In Italy, Istat translates NACE codes into ATECO codes. The list of ATECO codes is the national transposition of the European nomenclature NACE rev.2.

2.2.2. HS

When building the Harmonized System the issue designed to address was: how do you know what is crossing your border with over $15 trillion in goods moving around the world? The World Custom Organization (WCO) has built then a nomenclature that allows all physical goods crossing borders to be assigned to a class in a consistent manner around the world. It has versatile structure and multipurpose nature, a true “language of international trade”. It is adopted as the basis for Customs tariffs and for the compilation of international trade statistics by more than 200 economies and Customs or Economic Unions. The HS's identification and coding of merchandise is used by governments and businesses alike to facilitate international trade and regulation. As a result, the HS is an important tool not only for the WCO, but also for all public and private institutions involved in global trade.

While the HS has many applications, its primary purpose is to categorize goods so that governments can assign and collect import duties and taxes. The WCO has 183 Members (as of December2018), roughly three-quarters of which are developing or transitioning to market economies. A large proportion of these Members rely heavily on Customs duties for their national revenues.

The HS, on the other hand, is more than just a tool for developing tariffs for duty collection. It is used in many other areas of government regulation and business practices, such as rules of origin, controlled goods monitoring, internal taxes, freight tariffs, quota controls, and statistical reporting. Its statistical data is transformed into national and international trade information, which is used to inform trade policy, economic research and analysis, and corporate decisions.

The idea that an international tariff was a necessary prerequisite to any attempt at international statistical nomenclature was developed during the nine International Statistical Congresses held between 1853 and 1876.

In1889, the International Commercial Congress in Paris asked, "Would it not be in the interest of all nations to adopt comparable classifications and uniform vocabularies in their Customs tariffs and official statistics?"

Although the extreme difficulty of developing a uniform vocabulary for goods was acknowledged, the concept was firmly implanted, and there were successive national and international attempts to advance this goal.

The Harmonized System Convention, as amended, became effective on January1, 1988.

A Preamble, 20 Articles, and an Annex comprise the HS Convention. The 20 Articles include provisions for Contracting Parties' obligations, the role of the Council and the Harmonized System Committee, the resolution of disputes between Contracting Parties, and the amendment procedure. The Annex contains the Nomenclature for the actual commodity classification.

Contracting Parties must guarantee that their Customs tariffs and statistics nomenclatures for imports and exports are in accordance with the Harmonized System. They shall also make public their import and export trade statistics in accordance with the Harmonized System's six-digit codes, or on their own initiative, beyond that level.

Following its implementation, the use of the HS soon spread, with over 200 economies and Customs or Economic Unions now utilizing the System as the foundation for their national Customs tariffs. Its application, however, is not limited to Customs charges. It is also used for a variety of other uses. The following are some of the most important applications of the HS:

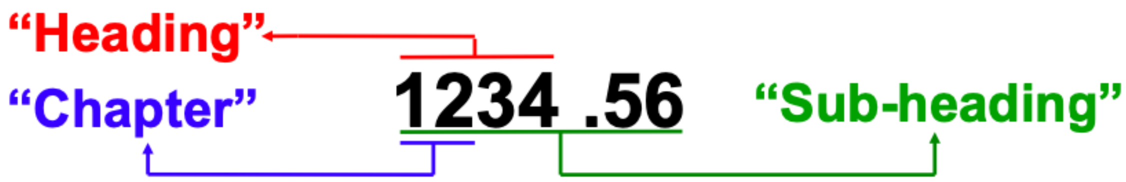
- Custom tariffs
- Statistics
- Rules of origin
- Collection of internal taxes
- As a basis for trade negotiation
- Monitoring of controlled good
- Etc

The headings (and their subheadings) of the Harmonized System are organized into 96 Chapters, which are further divided into 21 Sections.

In general, items are organized in the following order: raw materials, unworked products, semi-finished products, and final products. Live animals, for example, are classified as Chapter1, animal hides and skins as Chapter41, and leather footwear as Chapter 64.

The same progression may be found in the Chapters and headers.

Figure 4. *HS code organization*



Source: https://www.trade.gov/harmonized-system-hs-codes , 2022

The HS is comprised of the text of the HS convention, the "Nomenclature" (codes plus description); section, chapter, heading and subheading Notes (which contains definitions, inclusions, exclusions, methods); six "General Interpretation Rules" (GIRs); Classification Opinions and finally Explanatory Notes (HSEN).

The HS is periodically updated every 5 – 6 years. The last update was released on January 2022 (HS2022), following those of 2002, 2007, and 2012.

2.2.3. Building links between HS and NACE systems

The aim is to construct a comprehensive concordance between HS and NACE codes over time.

The difference between NACE and HS is that NACE refers to economic/industrial activities while HS refers to goods.

NACE are 4 digits codes divided into the different industrial and economic activities; among them, the most important are:

- Agriculture, silviculture, fishing
- Supply of energy
- Supply of water

- Constructions
- Wholesale and retail trade; repair of motor vehicles and motorcycles
- Transport and storage
- Accommodation and catering services
- Information and communication services
- Financial and insurance activities
- Real estate activities
- Professional, scientific and technical activities
- Administrative tasks and support services
- Public administration and defence; compulsory social insurance
- Education
- Health and social welfare
- Arts and entertainment
- Other service activities

HS categorizes goods with 6 to 10 digits codes. There is then a HS code for every kind of good.

This product classification is therefore more fine-grained with respect to the NACE, which, on the contrary, categorize the economic activities.

Although the HS basically includes goods, that is, products that have a physical dimension, it also includes electricity. The HS does not include the services, but includes the physical "manifestations" of the services themselves, (e.g.: the architects' projects, the discs containing software, the original works of art and the ancient and original pieces of more than a hundred years, etc.).

HS orders products according to the physical characteristics and intrinsic nature of the goods or according to the nature of the services rendered. This criterion includes, for example, the type of raw material used, the production process involved, the purpose for which the goods are created, etc. Although this criterion is often the same as that used for classifications of economic activities, NACE is not a product classification. For this reason, the HS coding system is independent of the NACE.

The criterion followed by HS is that of economic origin, according to which a product classification includes a category of goods or services that are the result of economic activities. Following this logic makes it possible for as many HS products as possible to be assigned to a category of NACE and ensuring the comparability of the data, that can be aggregated with an acceptable level of detail.

It was necessary for the purpose of the research to make a correspondence between HS codes, of which the relevant Product Complexity Index (PCI) is owned, and the NACE (or ATECO) codes, of which data on export value are available.

We have two separate databases, which for the purposes of research on the economic complexity of the Italian provinces must be concorded. The first database is the one containing for every good classified with the codes HS the relative product complexity index from year 1998 to 2019.

The second database contains information on import and export levels of all Italian provinces: for each province are listed the products of economic activities exported and imported according to the NACE (or ATECO) classification, the relative value in euro of exports and imports, the country from which it is exported or to which it is imported.

A correspondence between HS and NACE has therefore been constructed, carried out by keywords thanks to the descriptions present in both classification systems (which, as explained in the previous paragraphs, follow a similar logic albeit with different objects).

In order to achieve the complete creation of a new database in which each NACE code corresponds to a single Product Complexity Index, a further step has been taken.

Each HS has a NACE code. Due to the greater granularity of the HS classification, however, a single NACE code corresponds to several HS products and therefore several PCI: consequently, thanks to a job done with the pivot tables in Excel, averaging the different PCI values corresponding to a single NACE code, a list of NACE products corresponding to a single PCI has been obtained.

Thanks to this operation, it has been possible to create a new database in which each province corresponds to the relative product of the exported economic activities, the value in euro, together with the index of productive complexity (PCI) obtained as previously illustrated.

At this point, the database thus obtained shows for each province and for the products the same index of production complexity. To take account of the differences between the Italian provinces, the level of production diversification and export levels, a new index of production complexity was calculated.

This is an index of production complexity weighed by weight as a percentage of the export value in euro of the various provinces per product. To better explain, the total export value of all Italian provinces and all products has been calculated.

Based on this value, the percentage weight of each individual product was calculated on the total export. Using the total Italian value of exports as a denominator has allowed us not to create bias and make the situation more likely.

This weight thus calculated was then multiplied by the PCI calculated previously by the HS, thus obtaining a new index of production complexity of products exported from the Italian provinces. The new index provides a realistic picture, taking into account the importance of diversification of production.

In fact, the hypothesis is that not only greater production complexity corresponds to better performance, but also greater levels of diversification.

CHAPTER 3

Italian productive structure and complexity analysis

According to the Economic Complexity Index, Italy's economy ranked eighth in the world in terms of GDP (current US dollars), seventh in terms of total exports, tenth in terms of total imports, thirty-first in terms of GDP per capita (current US dollars), and among the top twenty countries in the world (19th as of 2021) in terms of economic complexity (ECI).[22]

In addition, Italian manufacturing continues to rank seventh globally in terms of value added, fourth in terms of production diversity, and second in terms of export competitiveness. It also has a greater investment rate than its primary rivals in Europe, such as Germany. The top five Italian exports are packaged medicines ($26.7 billion), automobiles ($14.8 billion), motor vehicles, parts, and accessories, refined petroleum ($8.26 billion), and vaccines, blood, antisera, toxins, and cultures ($7.75 billion). Unglazed ceramics ($4.21 billion), pasta ($3.55 billion), tanned equine and bovine hides ($2.34 billion), processed tomatoes ($2.14 billion), and processed tobacco ($1.78 billion) were Italy's top exports in 2020.[23]

However, it is commonly believed that Italy has long suffered from a fundamental lack of competitiveness, which has kept the nation from achieving the same growth trajectories as its major Western allies. This belief is not limited to Italy.

Many studies show the importance of the Italian industrial system's (low) competitiveness as one of the primary reasons for the country's economy's sluggish growth in recent years.

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[22] https://oec.world/en/profile/country/ita

[23] https://oec.world/en/profile/country/ita

The claims are based on the Italian economy's structural traits, particularly the high proportion of small businesses and the high proportion of the so-called "traditional sectors."

This theory contends that Italy faces competition particularly from emerging economies (East Europe and Asia), in industries where (low) labor costs are the key differentiator.

However, several contributions support the claim that Italy exhibits significant competitive advantages in industries like textiles, apparel, leather goods, footwear, furniture, etc. It is the supposedly famous "Made-in-Italy," which is a specialized model more akin to developing nations than wealthy ones.

As previously noted, there could be a number of effects from this feature.

First off, traditional industries may have low demand elasticity; as a result, if a nation concentrates a significant portion of its resources in these industries, the (relatively) slow rise of global demand will decide the country's overall pace of growth.

Second, given that these goods may be susceptible to price competition, a developed nation whose economy is characterized by labor-intensive industries will be adversely affected by fierce rivalry from emerging economies (with much lower labor costs).

In addition to those factors, we should note that firms in those industries tend to be tiny, which has the effect of making market power smaller as well. Moreover, those kinds of industries are not typical of RD and technology advancement, a crucial driver of economic growth (and firm sizes).

This has been supported by numerous studies. For instance, Brasili et al.(2000) emphasize that while it is true that the Italian sectoral structure appears more rigid when compared to other industrialized nations, it is also true that all advanced nations have more rigid structures than developing economies, the Italian structure is convergent with high-income country structures, and all economies appear to be moving toward a more symmetric structure.

However, the Italian share of global exports has been increasing for a while, and given this expanding penetration of Italian exports into global markets, it is (and has always been) challenging to interpret the strength or weakness of the Italian position in the global division of labor in a clear-cut manner.

It should be noted also that the skill endowment, performance, and developmental stage of Italian regions differ greatly. It is intriguing to explore the connection between entropy and economic complexity at this level since they exhibit a notable geographical variability in terms of specialties, revealed comparative advantages, and density of commodities in the product space.

It's common to think of regional growth as coming from economies that specialize rather than diversify.

In specialization, the concentration of a certain industry in a given area would promote knowledge specialization and increased productivity by facilitating knowledge exchange between related businesses.

On the contrary, regional economic performance in countries with diversification would result from local interaction between businesses from various industries, which fosters idea-sharing and innovation, particularly in highly urbanized areas.

Here we can think of an approach in which industry specialization and diversification are developed together.

Because there are more odds of recombining various knowledge sources, it may be that greater product or industry diversification encourages areas to specialize in high-quality goods and industries. The level of regional economic complexity also rises as a result of this higher specialization, which is ultimately related to the development in overall productivity.

Moreover, the idea that is popular also among scholars is that economic complexity and wealth are correlated; nations with more income per capita tend to produce a more diverse range of highly complicated but less common products. This is the starting point of the research and analysis of the productive structure of Italy and its provinces and regions.

3.1. Data analysis on export of Italian provinces

When a country exports products, it is not only transferring physical objects, but also all the knowledge and skills that are needed to design, design and finally build it.
All these features that go beyond the simple product, increase its value and therefore the price that end consumers will be available to pay. Following this logic, countries that produce and trade sophisticated goods are likely to have higher GDP per capita.

Thanks to Coeweb databases, export values of Italian provinces are available.
The evolution of territorial exports in our country has been obviously influenced by the pandemic shock in 2020, with different effects for the various sectors. The considerable diversity in local productions has enabled supply chains to respond in particular ways, showcasing the extraordinary adaptability of Made in Italy. The hypothesis is that productive complexity and geographical diversification are strategies that increase the resilience of companies to exogenous shocks, as in the case of the Covid-19 pandemic.

Territorial exports fell by 12.5% in the first nine months of 2020 compared to the same period in 2019. The loss suffered by agri-food businesses in southern Italy was less substantial than the national average. The reduction in the sales of machinery and appliances from Lombardy, Emilia-Romagna, Veneto and Piedmont and of base metals and metal products from Lombardy contributes to the trend decrease in domestic exports by 3.5 percentage points.
On the other hand, there was an increase of 1.5% in sales of basic metals and metal products from Tuscany and of pharmaceutical, chemical-medicinal and botanical articles from Lombardy, Veneto, Tuscany, Marche and Emilia-Romagna, which contrasted the decline in exports.

In this research the period from 2011 to 2021 has been analyzed, where data are available.

The choice fell on this particular year because it is a period immediately after the financial crisis of 2007 that inexorably infected the real economies of the major Western countries. And since in the global economy one country's imports constitute the exports of many other countries, the crisis of consumption in the richest countries spread like wildfire in the rest of the world. By the end of 2010, the consequences of this crisis were now being resolved and almost all the real economies involved had started to grow again.

However, another financial crisis occurred that affected the public budgets of countries with very high public debt and poor or absent economic growth: the 2011 sovereign debt crisis. It was not a global crisis but a succession of national financial crises - probably triggered by a general increase in the financial needs of European states also as a result of the bank bailouts following the 2007 crisis - which also involved Italy.

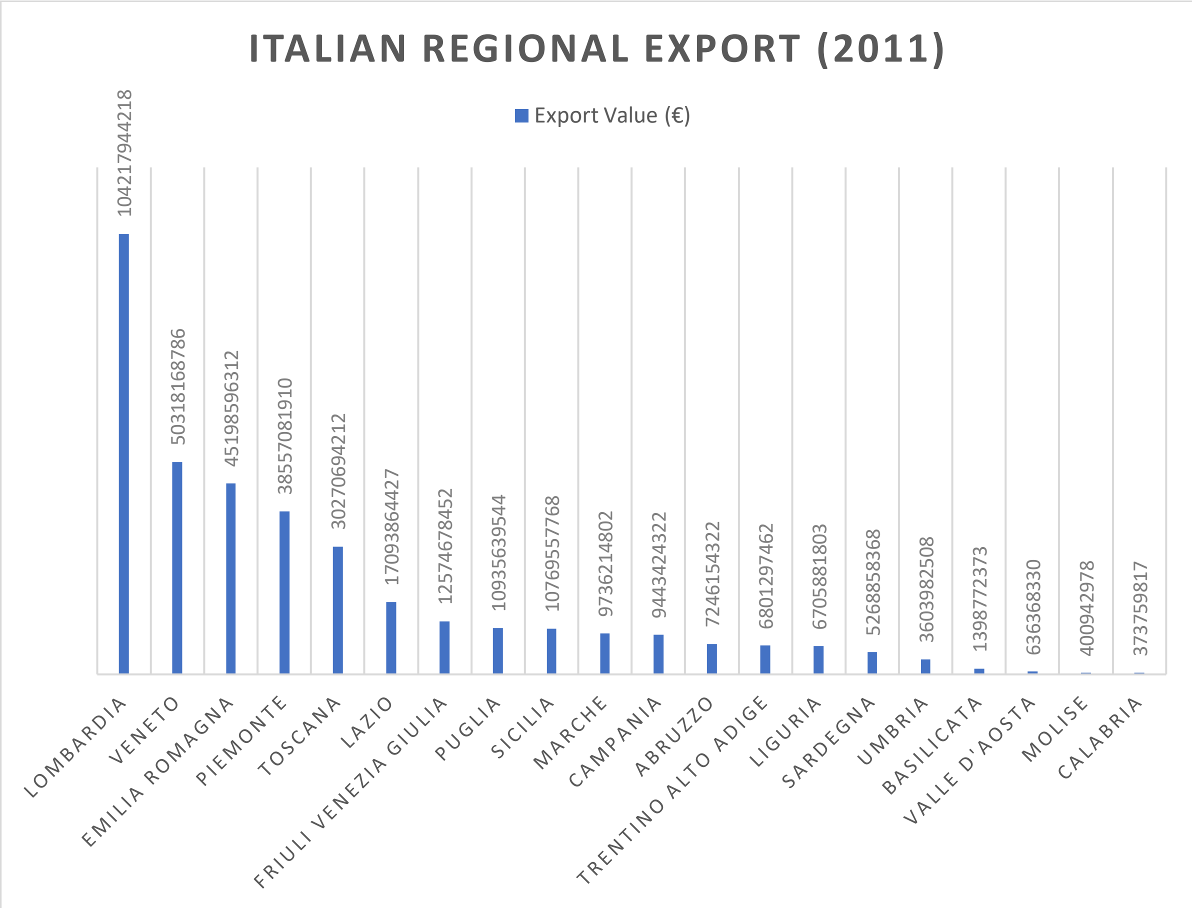
The Italian manufacturing sector, which grew according to a development model based on exports, underwent a heavy backlash due to the decrease in the demand for goods from abroad. The drop in exports led to negative GDP growth in 2008 (-1.2%) and one of the worst performances in 2009 (-5.5%).

While the other countries affected by the repercussions of the financial crisis started to grow again, Italy continued to sink burdened by the structural problems of its economy.

In fact, the Italian manufacturing industry, which, thanks to the recovery in foreign demand in 2010, had recovered, albeit with difficulty, market shares eroded by the crisis and international competition, In the following years it was slackened by a new crisis of demand, this time due to the decrease in Italian household consumption and investment. To aggravate the situation of Italian companies there was also the credit crunch caused by the repercussions of the sovereign debt crisis of 2011.

In 2011 the province that exports the most is Milan. Rome is at the tenth place. These export values were obtained by adding all the sectors by province, therefore without disaggregating the export by sectors.

__Figure 5.__ Italian regional export in 2011



Source: personal processing of Coeweb data, 2011

Export is, in short, driven by Northern Italy as it is visible in the table: Lombardy outperforms the other regions and has an export value which is nearly the double of the second ranking region, Veneto.

However, if we consider not the total sum of the exports, the province being at the top of the list is Siracusa (SR) with NACE sector 192 "Products derived from oil refining".

__Table 4.__ Ranking of exports by province and industrial sector in 2011

RANKING	PROVINCES	GROUP DESCRIPTION	EXPORT VALUE (€)

1	SR	Manufacture of other general-purpose machinery	6732444336
2	AR	Manufacture of basic precious and other non-ferrous metals	4356263556
3	CA	Manufacture of refined petroleum products	4339742545
4	TO	Manufacture of parts and accessories for motor vehicles	3561587117
5	CH	Manufacture of motor vehicles	2537816602
6	MI	Manufacture of other general-purpose machinery	2280148905
7	MI	Manufacture of general-purpose machinery	2170172035
8	TO	Manufacture of other general-purpose machinery	2167213736
9	MI	Manufacture of other special-purpose machinery	2123269123
10	MI	Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms	2083034778

Source: personal processing of Coeweb data, 2011

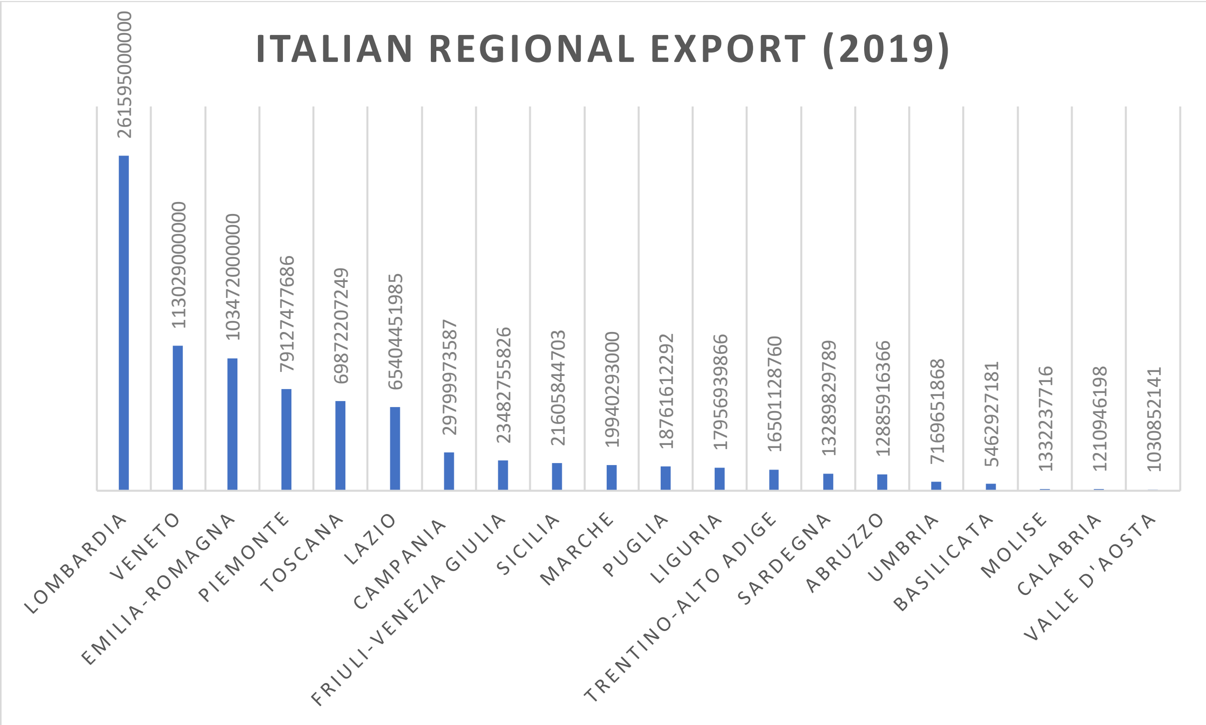
If we consider a wider time range (10 years), we can carry out a comparison analysis between the Italian export reality between 2008 and 2018

In a situation of domestic weakness caused by the collapse of domestic demand caused by the 2008 crisis, the main engine to the development of the industry were exports.

Over the 10 years between 2008-2018, these have increased by more than 25% albeit in a non-homogeneous way.

In these ten years, some territories have been able to exploit foreign markets to get out of the crisis completely; others instead have obtained benefits are marginal from exports; still others, finally, have not been fully able to compensate for falling domestic demand with increased sales abroad.

Figure 6. *Italian regional export in 2019*



Source: personal processing of Coeweb data, 2019

The southern regions are at the bottom of the results obtained on foreign markets. Among the regions that have achieved the most results, the performance of Basilicata stands out, which has more than doubled the results of 2008.

If Basilicata is almost an "anomaly", no less important is the growth of Lazio: this region has increased its exports abroad by 4.5% on average every year, ranking second as the best growth for exports. The most representative sector for Lazio's exports is pharmaceuticals, especially with the provinces of Frosinone and Latina.

The regions far below the average are mainly located in the south. Molise and Sardinia are, in fact, the only two regions that are still lagging compared to 2008. For these two regions, the crisis has brought out the strong difficulties that already characterized them, further penalizing the companies that were already weak on foreign markets.

The situation changes from the one in 2011 for the year 2019 in which Latina, in the NACE group "Medicines and pharmaceutical preparations", is at the top of the ranking. Moreover, it makes 1,23% of the total Italian export.

Table 5. *Ranking of exports by province and industrial sector in 2019*

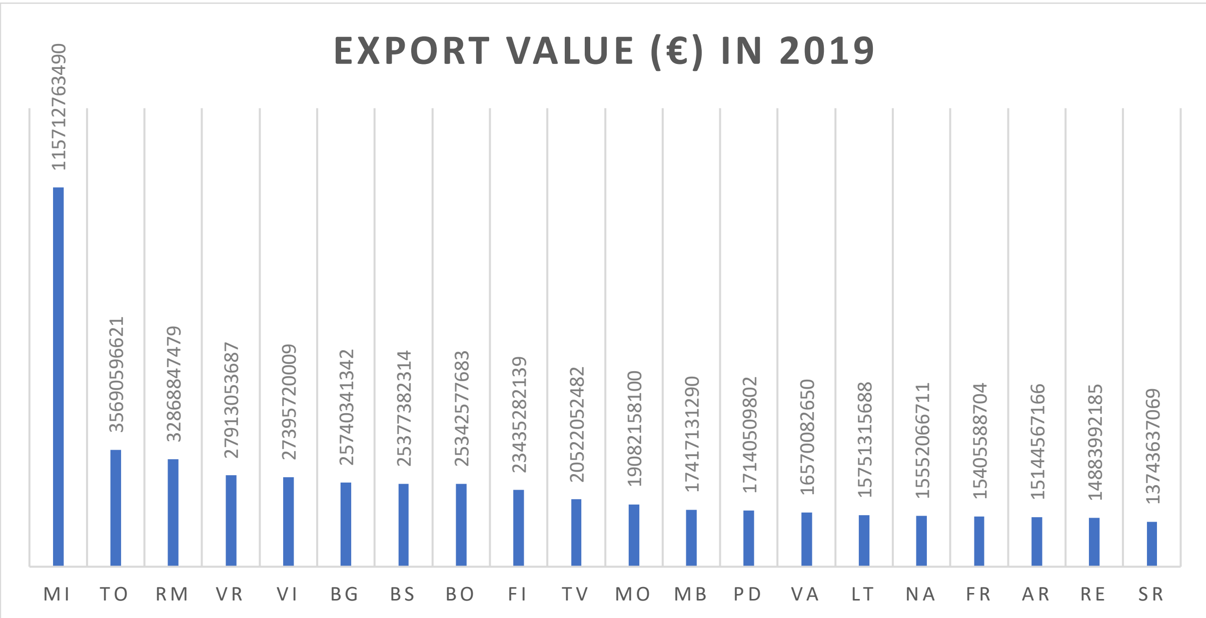
RANKING	PROVINCES	NACE GROUP	EXPORT VALUE (€)
1	LT	Manufacture of pharmaceutical preparations	10.800.073.768
2	MI	Manufacture of pharmaceutical preparations	10.236.055.498
3	FR	Manufacture of pharmaceutical preparations	9.570.671.670
4	MI	Manufacture of motor vehicles	7.545.462.040
5	AR	Manufacture of basic precious and other non-ferrous metals	7.478.977.579
6	MI	Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms	7.017.432.479
7	SR	Extraction of crude petroleum	6.893.461.061
8	VR	Manufacture of motor vehicles	6.418.883.412
9	MI	Manufacture of wearing apparel, except fur apparel	5.833.370.457

10	TO	Manufacture of motor vehicles	5.814.902.548

Source: personal processing of Coeweb data, 2019

At the aggregate level, however, without distinction of sectors, the province that exports more is Milan again; in second place we find Turin, then Rome, Verona, Vicenza.

Figure 7. *Export Value ranking by province in 2019*



Source: personal processing of Coeweb data, 2019

Another point of view is provided by some studies conducted by Stafforte et al. (2012), using two measures:

- PRODY, that summarizes the per capita income associated with each exported product.
- EXPY, which expresses the sophistication of goods exported from a country. It is simply the weighted sum of the PRODY values of each product k which the country j exports.

analytically defined by Hausmann et al. (2005) in the following way:

$$PRODY_k = \sum_j \frac{x_{jk}/X_j}{\sum_j (x_{jk}/X_j)} Y_j$$

$$EXPY_j = \sum_k \frac{x_{jk}}{X_j} PRODY_k$$

At this point these measures can be used to assess export performance and

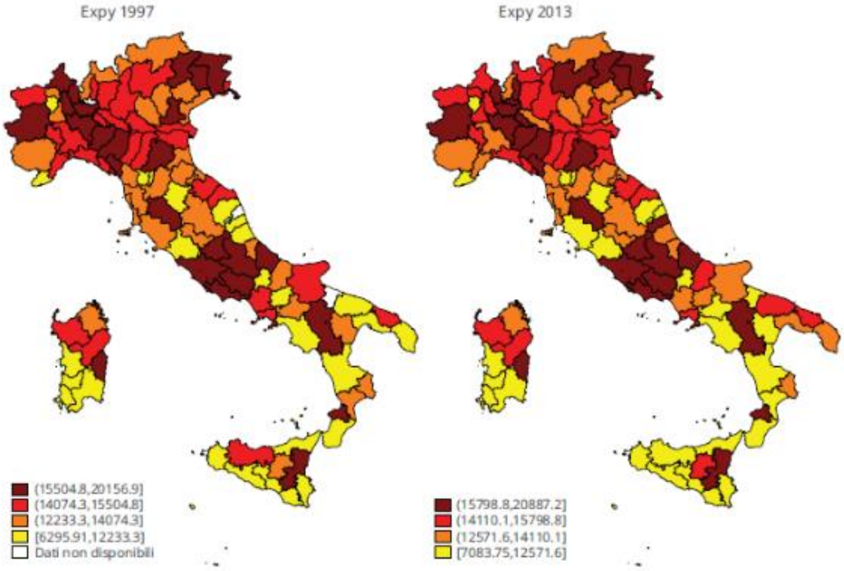
production complexity following an external shock: the economic crisis of 2008-2009 in Italy.

The crisis culminated on 15 September 2008 with the bankruptcy of the US investment bank Lehman Brothers and it soon spread to the real economy, earning the nickname "Great Recession" and causing the exponential increase in the price of oil, raw materials, and in production costs in various sectors. There was a sharp contraction in exports, which dragged down the values for that period of GDP.

In order to understand some of the effects of the recent crisis on Italian exports and on the prospects of economic development of the country, it is necessary to focus the survey on the sectoral changes of Italian exports at the provincial level.

The figure below depicts the distribution of the complexity index of exports of the various provinces, at two different times.

***FIgure**. Values of the complexity index of exports of the Italian provinces. Different colors indicate the belonging to different quartiles of the distribution.*



Source: Coniglio et al. (2012) p. 210

Three zones stand out, highlighted with darker colors, which export particularly complex goods. The regions involved are: Lazio and Abruzzo, Piedmont, Lombardy and Emilia Romagna and finally Trentino, Veneto and Friuli.

Coniglio et al. (2017) studied the provincial EXPY dynamically between 1997 and 2013. They noted that from 1997 to 2008, the index developed steadily. Since that year, coinciding with the period of recession and international crisis, it has decreased and has resumed growing only since 2013.

3.2. Data analysis on Italian product complexity

PCI, we recall, measures the knowledge intensity of a product by considering the knowledge intensity of its exporters.

The product complexity of the italian regions and provences is described in detail for 2019, which is the most recent year in our sample. However, a dynamic analysis since 2011 is also conducted.

First of all, why do some regions have a higher level of economic complexity than others? What factors influence the increase or decrease in product complexity?

Italy is distinguished by a fundamental dualism between the more sophisticated Centre-North areas and the country's south (the Mezzogiorno), and the financial crisis has impacted the country's south particularly hard. Southern regions have seen an absolute loss in population size since the turn of the century, owing in part to large outmigration of young educated workers to the Centre-North and beyond (De Angelis et al., 2017; Ballatore and Mariani, 2019). One possible explanation for this continuous difference is a slowing of the process of accumulation of capabilities.

The product complexity index is in here calculated according to the methodologies set out in Chapter 2.

The highest score in PCI in 2019 goes to NACE group 284, "Manufacture of metal forming machinery and machine tools" with PCI equal to 2,18. Afterwards, "Manufacture of general-purpose machinery" nace group 281 with PCI 1,7.

In line with the product complexity of other countries, we find in fifth place "optical instruments and photographic equipment" with a PCI of 1,62.

In the purpose to check the level of penetration of the sectors in the various Italian provinces, the analysis shows that in 2019 the Nace 282 group, the one with the highest product complexity, is exported from all Italian provinces, as well as all the first five sectors for product complexity.

This attests that sectors with high product complexity are penetrating all along the Italian peninsula.

In 2011 the PCI ranking was different: at the top of the ranking there is group Nace 292 "Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers" with PCI 1,29, almost a point of difference with the most complex product of 2019. "Manufacture of general-purpose machinery" nace group 281 is only at fifth place with a lower PCI of 1,07.

The most complex product in 2011 is exported by 103 out of 110 provinces, as well as the "Manufacture of general-purpose machinery" which is exported by 108 out of 110 provinces.

3.3. Building a New Product Complexity Index based on weighted export levels of Italian provinces

In order to achieve the complete creation of a new database in which each NACE code corresponds to a single Product Complexity Index, a further step has been taken.

Each HS has a NACE code. Due to the greater granularity of the HS classification, however, a single NACE code corresponds to several HS products and therefore several PCI: consequently, thanks to a job done with the pivot tables in Excel, averaging the different PCI values corresponding to a single NACE code, a list of NACE products corresponding to a single PCI has been obtained.

Thanks to this operation, it has been possible to create a new database in which each province corresponds to the relative product of the exported economic activities, the value in euro, together with the index of productive complexity (PCI) obtained as previously illustrated.

At this point, the database thus obtained shows for each province and for the products the same index of production complexity. To take account of the differences between the Italian provinces, the level of production diversification and export levels, a new index of production complexity was calculated.
This is an index of production complexity weighed by weight as a percentage of the export value in euro of the various provinces per product.
To better explain, the total export value of all Italian provinces and all products has been calculated. Based on this value, the percentage weight of each individual product was calculated on the total export. Using the total Italian value of exports as a denominator has allowed us not to create bias and make the situation more likely.
This weight thus calculated was then multiplied by the PCI calculated previously by the HS, thus obtaining a new index of production complexity of products exported from the Italian provinces. The new index provides a realistic picture, taking into account the importance of diversification of production.

Focusing on the result thus obtained, we can analyze the situation first in 2011 and then in 2019 in order to make a dynamic comparison.

To recap, the index in this research is calculated as follows: PCI [24] * percentage incidence of the sector per province over total Italian exports.
It is a new "mixed" index and we call it *weighted PCI*, because it takes into account both the sheer complexity of the sector, but also how much it weighs that sector in that particular province.

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[24] PCI data from The Atlas of Economic Complexity

As it is visible from the table below, in 2019 it is the province of MI (Milan) to have the highest weighted PCI: 0,877 in the “Manufacture of general-purpose machinery” sector, followed by the province of Turin in the same sector.

In third place we still find Milano, sector “Manufacture of motor vehicles” with PCI 0,73.

Arrived at the fifth place in the ranking, there is a city of Center Italy, Latina, with a weighted PCI of 0,62 in the “Manufacture of pharmaceutical preparations” sector.

Table 6. *Weighted PCI ranking in 2019*

PROVINCE	NACE GROUP	GROUP DESCRIPTION	WEIGHTED PCI
MILANO	281	Manufacture of general-purpose machinery	0,87
TORINO	281	Manufacture of general-purpose machinery	0,84
MILANO	291	Manufacture of motor vehicles	0,73
VERONA	291	Manufacture of motor vehicles	0,63
LATINA	212	Manufacture of pharmaceutical preparations	0,62

Source: The Atlas Of Economic Complexity, 2019

The sectors just exposed are at the top of the ranking because it means that in addition to having a high degree of productive complexity, they are also highly exported in terms of value.

Aggregating the data, it is possible to make a wider analysis also at the level of regions: the regions of northern Italy dominate the top places of the ranking, being Lombardy, Piedmont and Veneto respectively in first, third and fourth place. Excellent results are also obtained from the regions of the center, being the Emilia-Romagna and Lazio in the second and fifth place in terms of poduct complexity.

The sectors that most affect the achievement of a high weighted PCI score are for Lazio the pharmaceutical sector and for Emilia the automotive, having important production plants.

3.4. Income analysis of Italian provinces

Data on average Italian income come from Istat sources. Income is alayzed following the subdivision of Italy into North-east, North-west, Center, South, Islands. The most recent data made available by the Istat website date back to the year 2018, the analysis will therefore be carried out over the period 2011-2018.

The benchmark is the average annual net income of households.

The survey carried out by Istat each year highlights the substantial differences between the average annual incomes of Italian households in the north and south.

In 2018, it is estimated that households living in southern Italy received an average annual net income of €26393, which means €2199 per month. Compared to 2011, in 2018 average family incomes grew more in the Islands (8%) and in the North-East (6%) compared to the South (4%) and the Centre (3%).

Despite the growth recorded in 2018, the overall decline in incomes compared to 2007, the year preceding the first symptoms of the economic crisis, remains remarkable, with a loss in real terms of 8.8% on average for family income.

Table 7. *Ranking of italian net income in 2011 and 2018*

AREA	2011 SURVEY	2018 SURVEY	% increase

NORTH-EAST	33.317	35.165	6%
NORTH-WEST	33.120	34.642	5%
CENTER	31.910	32.988	3%
SOUTH	25.451	26.393	4%
ISLANDS	23.167	24.934	8%

Source: Istat, 2022

As the income distribution is asymmetric, the majority of households received an income below the average amount. Calculating the median value, that is the level of income that separates the number of families in two equal halves, it is observed that 50% of households resident in Italy have an income not exceeding 25,426 euros (2,120 euros per month).

Families in the North-East have the highest median income (29,785 euros), followed by those in the North-West, Central and Southern Italy.
By analyzing the correlation between the income of the territories and the level of complexity, it is understood that higher levels of income also correspond to higher levels of average PCI, leading to a decrease in income inequality and wealth of the population.

Table 8. *Comparison between net income and PCI of Italian areas in 2011*

AREA	**2011 AVERAGE NET INCOME**	**Average PCI**
NORTH-EAST	33.317	13,69
NORTH-WEST	33.120	8,23
CENTER	31.910	2,67
SOUTH	25.451	1,21
ISLANDS	23.167	-1,86

Source: Istat and The Atlas of Economic Complexity, 2011

Table 9. *Comparison between net income and PCI of Italian areas in 2018*

AREA	2018 AVERAGE NET INCOME	Average PCI
NORTH-EAST	35.165	7,96
NORTH-WEST	34.642	12,25
CENTER	32.988	2,58
SOUTH	26.393	1,45
ISLANDS	24.934	-1,5

Source: Source: Istat and The Atlas of Economic Complexity, 2011

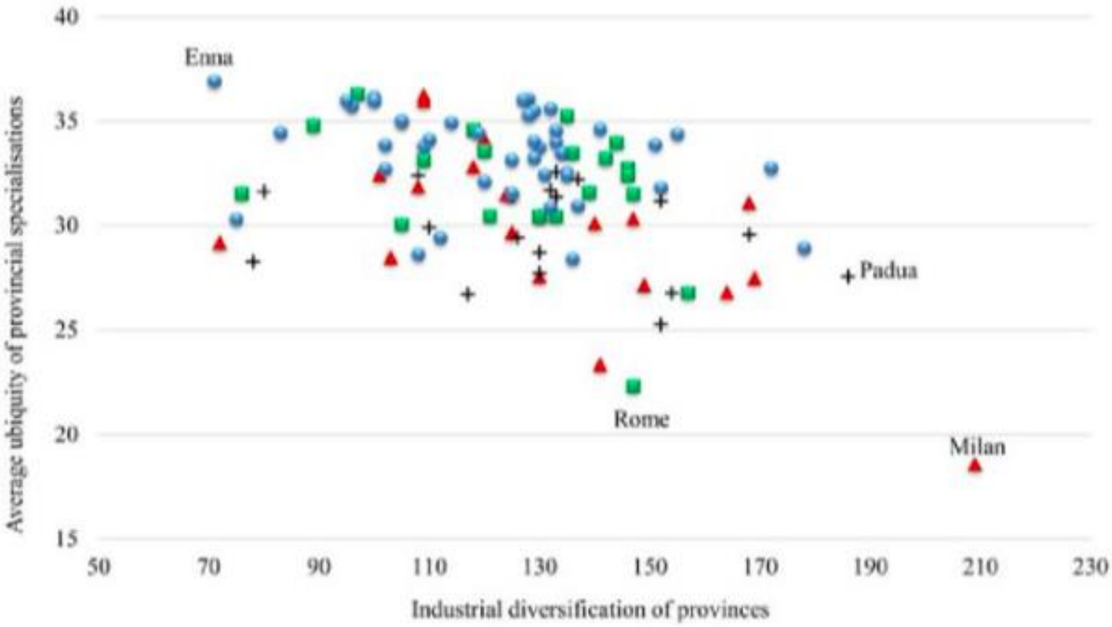
Between 2011 and 2019 the PCI decreased in all territories, except for the South where it slightly improved (from 1,215 to 1,459).

As already amply described in previous chapters, the increase in economic complexity significantly reduces income inequality, since development is a process of transforming a country's economic structure towards the production and export of more complex products.

Considering also that the major exporters of the more complex products are the high-income countries, while the major exporters of the less complex products are the low-income countries and export shares of the more complex products increase with income, while export shares of the less complex products decrease with income.

3.5. Sectorial diversification of Italian provinces

Figure 8. *Diversification and average ubiquity of Italian provinces in 2011*



Source: Economic complexity and fertility: insights from a low fertility country, N. Innocenti, D. VIgnoli, L. Lazzaretti, 2021

In the above figure diversification of provinces and average ubiquity of industries in 2011 is represented. Different symbols refer to Italian macro-regions: triangles the north-west, crosses the north-east, squares the centre and circles the south.

Italian exports are diversified at the territorial level. Each province has specific production characteristics, and it is precisely this level of specialization that makes Made in Italy unique in the world.

The evolution of the export of the Italian regions reflects both the different endowment and efficiency of the material and intangible factors underlying the competitive capacity of the individual territories, both the presence of a different model of regional specialization to the export at the level of products, markets, but also of organization of the enterprises.

It is clear that regions such as Sardinia and Basilicata, which have a concentrated sectoral structure, and a reduced base of operators active in a few target countries, are more vulnerable to global crises.

Regions with a greater differentiation of both markets and product structure appear to be better able to react to global crises through a more complex and diversified export structure.

Analysis

In the purpose of this research, when we talk about diversification it is meant the number of sectors in which the province in question operates in exports.

In the comparison between 2011 and 2019 the diversification of sectors in the Italian municipalities has increased. In all the provinces, in fact, there are increases in sectors and never a decrease. It should be noted that in 2011 there were 110 provinces. In 2019 they were removed 4 and added 1, resulting therefore in 107 provinces in 2019.

The most diversified cities, are, in 2011:

1. Milan
2. Rome
3. Bologna
4. Brescia
5. Bergamo

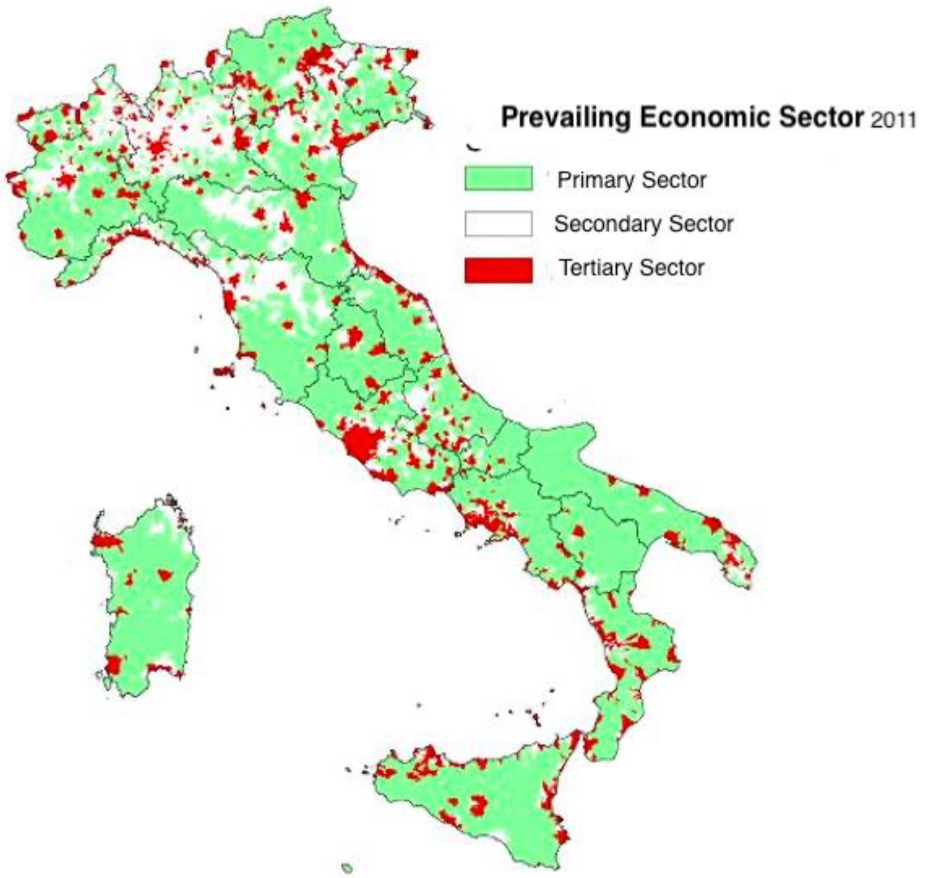
The cities in this ranking all belong to central-northern Italy.

In 2019 the ranking turns into:

1. Milan
2. Bologna

3. Rome
4. Genova
5. Pavia

Figure 9. *Economic specialization of Italian provinces in 2011*



Source: Centro Documentazione e Studi Anci-Ifel su dati Infocamere, 2012

The analysis is carried out for the three economic sectors: primary (or agricultural), secondary (or industrial) and tertiary (services). The Italian municipalities, overall, show in 2011 an entrepreneurial agricultural vocation: the realities in which this specialization prevails are 4.753, 58.7% of the total. It follows the industrial sector that prevails in 2.540 local realities and that of services in 799 municipalities (respectively 31.4% and 9.9% of the total).

In small municipalities (up to 5,000 inhabitants) the prevailing specialization is agricultural. Considering only the very small municipalities (with less than 2,000 residents) emerges as just under three municipalities out of four have their own economic specialization in the primary sector (2,584, 73.4% of the total).

As the population size class increases, the proportion of municipalities specializing in agriculture decreases. The ratio between demographic size and economic specialization in the tertiary sector is, instead, directly proportional: if in fact only 4.4% of the realities with less than 2 thousand inhabitants is specialized in this sector, the percentage increases in the following size classes, up to reach 66.3% in municipalities with a population between 60 and 250 thousand inhabitants and even 100% in 12 large municipalities.

The municipalities of average population size have, instead, an industrial specialization: particularly high is in municipalities with a population between 10 thousand and 20 thousand inhabitants where 47.4% is specialized in industry. They follow the local realities of class 5-10 thousand inhabitants, among which the industrial economic specialization is equal to 45.3%.

The trend towards the tertiarization of the economy of large centers and the decentralization of industrial and agricultural activities in small and medium-sized local areas is evident. The municipalities of medium size are now, in fact, the places of industrial production, while the small local realities are confirmed in their agricultural vocation.

The province that most increased its diversification is Vibo Valentia (VV), with 51 sectors of difference in addition between 2011 and 2019.

In 2011, in fact, Vibo Valentia (located in Calabria, South of Italy) exported products only from 41 NACE sectors over 118 and from sectors at low product complexity index.

Also, Oristano (OR), Agrigento (AG), Enna (EN), Catanzaro (CZ) are among the leatest diversified cities in 2011, exporting products only from few sectors. At present, the situation has improved significantly for the southern provinces, in fact increasing the resilience in case of external shocks as a result of increased diversification.

3.6 Final remarks

In 2011, the Italian province that exports the most is Siracusa (SR), with NACE sector 192 “Manufacture of refined petroleum products”, which has a PCI of -0,595.

In 2011 the average of PCI of the first ten NACE sectors in export order is 0,433.

In 2019 the situation is different, being NACE sector “Manufacture of pharmaceutical preparations” the most exported from the province of Latina, which has a PCI of 0,51.

In 2019 the average of the first ten NACE sector in export order is 0,120.

We can notice that the average of PCI has fallen over time. It should be noted that we are referring to PCI not influenced by the incidence of export: this means that over the years Italy exports products with a lower Product Complexity.

From 2011 to 2019, PCI has worsened (therefore, complexity has decreased) in fourty-one sectors out of the total. Sixty-four sectors have improved (complexity has increased). But by how much?

In order to understand better the reasons behind this change we have divided the analysis into two groups: the sectors in which PCI has improved and the other group with the sectors in which PCI has worsened.

Even if the number of sectors in which PCI has increased is greater than those in which it has decreased, the hypothesis is that, however, when the PCI increased, it did not increase enough to compensate for the decrease in the other fourty-one sectors, in which it worsened (more broadly).

In fact, this is confirmed by some simple calculus: the average of PCI in 2019 is, for those who are improved, 0,429. The average in 2011 is -0,069. The difference between these two values is +0,498.

For the group of worsened sectors, the average PCI in 2019 is -0,487, while in 2011 it was 0,037. The difference in this case is -0,524: this means that from 2011 to 2019, PCI has worsened by -0,524 which is in absolute values, much more than they have improved.

Since the purpose is to evaluate the impact of the worsened and improved sectors on exports, we proceed as follows: the percentage of incidence of improved and worsened sectors has been calculated. The sectors in which the PCI is worsened, affect with the export of 41,62% The improved sectors affect by 52,17%.

Empty cells (which are those in which it was not possible to make a comparison because in 2011 sector was missing due to the increase in sectoral diversification) account for 5.659%.

Therefore, the sectors in which PCI has improved have a greater impact on exports.

In the end, the situation of the production structure is as follows: diversification has increased, in the sense that some sectors that figure among the export items of the various provinces in 2019 were not there in 2011.

Export values have increased by 134,88% from 2011 to 2019.

The decrease in weighted PCI (formed by PCI and percentage of export incidence) seems to be the decrease in the complexity of products combined with a higher percentage incidence of exports. So, better to say: exports of products with low PCI has increased. In conclusion, although exports have increased, the increase has not been so high to cover the effect of the diminishing product complexity.

Conclusion

The ambition to get to know the causes of economic development is witnessed by centuries of study.

Without any doubt a powerful tool such as the Product space lends itself well to suggest ways for the prosperity of countries, also thanks to its easy intelligibility and understanding.

Tools such as the Economic Complexity index also allow us not only to explain future economic growth, but also to predict it with extreme precision.

This tool has been designed by the authors, as an aid for Governments, Authorities, investors, companies that want to orient themselves in the economic environment, so complex and deceptive, but also so rich in opportunities, so that they can take full advantage of them.

We've shown that economic complexity positively correlates with economic development and that broadening a region's knowledge portfolio is one of the most essential methods to generate innovation, new specialization, and wealth.

We discovered, as expected, that the positive association between expanding variety and rising complexity exists notably in locations with initially low levels of variety and complexity. In fact, while this might be less significant in mature and complex regional systems, it is critical in less developed areas, such as Southern Italian regions, where there is more space for both variety and complexity to expand.

Basing the idea of economic development on the progressive increase in complexity paves the way for numerous economic policy reflections: what are the most urgent actions to be implemented to foster the birth of new capabilities? How to support the path of growth traced by those already present in society, and how incentives can be strategically distributed to companies to invest in research and development and specialize in the production of goods in order to diversify the production?

Bibliography and sitography

ARTHUR, W. B., 1989, "Complexity and the Economy", *Science*,

BECATTINI G., 1979, "Dal "settore" al "distretto" industriale. Alcune considerazioni sull'unità di indagine nell'economia industriale", *Rivista di Economia e Politica Industriale*, n.1.

BOSCHMA, R., MINONDO, A., NAVARRO, M., 2011. *The Emergence of New Industries at the Regional Level in Spain: A Proximity Approach Based on Product Relatedness*. JEL-codes: R11, N94, O14.

BRESCHI, S. and F. LISSONI, 2001, "Knowledge Spillovers and Local Innovation Systems: A Critical Survey", *Industrial and Corporate Change*, Vol. 10, No. 4, Oxford University Press

CICERONE, G., MCCANN, P., VENHORST, V.A., 2017. *Promoting regional growth and innovation: relatedness, revealed comparative advantage and the product space.* Utrecht University. Working Paper No. 17.14.

CONIGLIO, N.D., LAGRAVINESE, R., VURCHIO, D., ARMENISE, M., 2017. *The Pattern of Structural Change: testing the Product Space Framework.* Working Paper No. 01/2017.

DOMAR, E., 1946. Capital expansion, rate of growth, and employment. *Econometrica*, 14(2), 137–147.

FREEMAN, A., 2004, "Measuring and Comparing World Cities", GLA-Economics, working paper

HARROD, R., 1939. An essay in dynamic theory. *The Economic Journal*, 49(193), 14–33.

HAUSMANN, R., HIDALGO, C.A., BUSTOS, S., COSCIA, M., CHUNG, S., JIMENEZ, J., SIMOES, A., YILDIRIM, M.A., 2011. *The Atlas of Economic Complexity*. New Hampshire: Puritan Press.

HAUSMANN, R., HWANG, J., RODRIK, D., 2005. *What You Export Matters*. NBER Working Paper No. 11905.

HIDALGO, C.A., KLINGER, B., BARABÁSI, A.-L., HAUSMANN, R., 2007. The Product Space Conditions the Development of Nations. *Science*, 317, 482-487.

HIDALGO, C.A.,*Linking Economic Complexity, Institutions, and Income Inequality.* World Development Vol. 93

HAUSMANN R., KLINGER B., 2007, *The Structure of the Product Space and the Evolution of Comparative Advantage* Center for International Development and Kennedy School of Government Harvard University

HIDALGO, C., and HAUSMANN, R., 2009 *The building blocks of economic complexity.* PNAS.

HIRSCHMAN, A. O., 1959, *The Strategy of Economic Development*, Yale University Press, New Haven, CT.

KRUGMAN, P., 1991, *Geography and Trade*, MIT Press.

KRUGMAN, P and A. J. Venables, 1995, *The Seamless World: A Spatial Model of International Specialization*, 1230, C.E.P.R. Discussion Papers.

KRUGMAN, P. R., A. J. Venables and M. Fujita, 1999, *The Spatial Economy*, The MIT Press, Cambridge, MA.

NEFFKE, F., HENNING, M., BOSCHMA, R., 2009. *How Do Regions Diversify over Time? Industry Relatedness and the Development of New Growth Paths in Regions.* Utrecht University. Working Paper No. 09.16.

PORTER, M., 1990. *The Competitive advantage of nations*. The Free Press, New York.

SACHS, J.D., WERNER, A.M., 1995. *Natural resource abundance and economic growth*. Cambridge, MA: National Bureau of Economic Research. Working Paper No. 5398.

SIMOES, A.J.G., HIDALGO, C.A., 2011. *The Economic Complexity Observatory: An Analytical Tool for Understanding the Dynamics of Economic Development.* Workshops at the Twenty-Fifth AAAI Conference on Artificial Intelligence.

SMITH, A., 1776. *The Wealth of Nations*.

SOLOW, R.M., 1956. A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics*

STAFFORTE, S., TAMBERI, M., 2012. Italy in the Space (of Products). *Economia Marche Journal of Applied Economics*, Vol. 31

TACCHELLA A., CRISTELLI, M., CALDARELLI G., GABRIELLI A., PIETRONERO L.; 2012, A New Metrics for Countries' Fitness and Products' Complexity, Scientific Reports 2, Article number: 723 doi:10.1038/srep00723

TACCHELLA A., CRISTELLI M, PIETRONERO L.; 2015, The Heterogeneous Dynamics of Economic Com- plexity, PLoS ONE 10(2): e0117174. doi:10.1371/journal.pone.0117174

ZACCARIA A., CRISTELLI M., TACCHELLA A., PIETRONERO L.; 2014, How the Taxonomy of Products Drives the Economic Development of Countries

The Atlas of Economic Complexity, (2022) < http://atlas.media.mit.edu/en/ >

The Observatory of Economic Complexity, (2022) < https://oec.world/en/ >

The World Bank Data Catalog, (2022) < https://datacatalog.worldbank.org/ >