

# Measuring the International Structural Competitiveness and the Hierarchy of National Economies: The Case of the European Union

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## Research

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## **Measuring the International Structural Competitiveness and the Hierarchy of National Economies: the case of the European Union**

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### **Abstract**

The determination of the level of competitiveness of national economies and the resulting hierarchy in the world economy is a central economic issue. Research on the subject has been mostly dominated by empirical, rather atheoretical, studies. In this paper, the determination of the international competitiveness level is achieved by using three criteria, which jointly define the level of international structural competitiveness: –the ratio of technologically advanced products in exports, the degree of economic diversification, and the level of the interconnectedness of the economy. The Technologically Advanced Domestic Valued Added in Exports condenses the above three criteria and it is proposed as a measure of international structural competitiveness. In addition, another measure of international structural competitiveness is being examined and tested: the Economic Complexity Index. The implementation of both measures in the European Union reveals similar results regarding the hierarchical position of the economies of the European Union member states, in terms of their international competitiveness.

**Keywords:** International Structural Competitiveness, Economic Diversification, Productive Linkages, Technological Level, Global Value Chains, Input-Output Analysis.

**JEL classification:** R15, C67, F15

## 1. Introduction

The aim of the paper is the identification of the criteria that determine the level of competitiveness of national economies and the resulting hierarchy in the world economy. Research on this central economic issue has been mostly dominated by empirical, rather atheoretical, studies.

The identification of the main criteria on the basis of which the hierarchical position of national economies, in terms of their international competitiveness, could be determined, is investigated assuming that there is a structural relationship between the competitiveness of a national economy and the level of its economic development. It is argued that, there are three criteria which jointly define the concept of international structural competitiveness: –the ratio of technologically advanced products in exports, the degree of economic diversification, and the level of the interconnectedness of the economy. The Technologically Advanced Domestic Valued Added in Exports (TADVX) – based on the Global Value Chains methodological framework and input-output analysis – condenses the above three criteria and is proposed in the paper as a measure of international structural competitiveness. TADVX is applied to the economies of the European Union (EU) in order to provide evidence of their hierarchical position in terms of international competitiveness.

The Economic Complexity Index (ECI), which is another well founded measure of international structural competitiveness that also gives evidence of national economies' hierarchical position in terms of international competitiveness is also being examined and tested in this paper. ECI is supposed to also condense the same three criteria as the TADVX, although in a different methodological framework.

The comparison of the hierarchical position of the economies of the EU member states, derived from the application of both measures, reveals a strong positive linear relation between them, along with a high degree of similarity concerning their hierarchical positions.

The paper is organized as follows: An analytical description of the concept of international structural competitiveness is given in the following section. The quantitative methods used in order to measure the international structural competitiveness are presented in the third section. The empirical results obtained from the empirical application will follow in the fourth section. In the final section the conclusions of the research are discussed.

## 2. Structural International Competitiveness: Theoretical Framework

A variety of competitiveness indices have been introduced in the literature in order to rank countries in the world economy. The most well-known competitiveness indices are: the *Global Competitiveness Index* (GCI) from the World Economic Forum and the *World Competitiveness*

*Ranking* (WCR) from the Institute for Management Development, which are based on complex benchmarking of economy-wide indicators (Žmuda 2017, p. 100). The *Global Competitiveness Index 4.0* comprises the use of 98 indicators organized into 12 main pillars (Schwab 2017) and the WCR divides the national environment into four main factors, and a total of 332 criteria (International Institute for Management Development 2019). Both indices combine economic, institutional, and policy determinants in an attempt to approach different aspects of international competitiveness. Still, the absence of a coherent theoretical and methodological framework capable of providing directions to the choice of the appropriate criteria, their weights, as well as the possible relationships among them, render the indices weak and misleading as measures of an economy's competitiveness level (Lall 2000; Berger and Bristow 2009).

### *2.1. Economic Development and International Competitiveness*

The competitiveness of a national economy “refers to the ability of a country to realize central economic policy goals, especially growth in income and employment, without running into balance-of-payments difficulties” (Fagerberg 1988, p. 355). According to the OECD (1992, p. 242), international competitiveness arises from the country's level of development and is defined as “the degree to which a nation can, under free trade and fair market conditions, produce goods and services which meet the test of international markets, while simultaneously maintaining and expanding the real income of its people over the long-term.” The above underline the structural connection of international competitiveness with economic development. Based on this connection, it could be supposed that the competitiveness of a national economy depends on the same structural factors on which its economic development also depends. Contrary to the rather atheoretical empirical measures of international competitiveness discussed above, the assumption that international competitiveness arises from a country's level of economic development, provides the theoretical basis for an appropriate structural competitiveness measure.

Accepting that international competitiveness arises from a country's level of economic development, a methodological approach to the concept of international competitiveness of a national economy should start from the position that international competitiveness is not predominantly dependent on “price” (or “cost”) factors, expressed by unit labor costs (“price” or “cost” competitiveness). Instead, international competitiveness is based on “structural” factors, such as technological opportunities, technical infrastructure and production capacities, which constitute the productive structure and the related “externalities” of a national economy and mirror its development level (“structural” competitiveness) (Amable and Verspagen 1995, p. 2; Nurbel 2007, p. 65; Ilzkovitz et al. 2009, p. 197). “Kaldor's paradox” confirms the validity

of the distinction between “price” or “cost” and “structural” competitiveness. According to “Kaldor’s paradox”, there is “a lack of empirical relationship between the growth in unit labor costs and output growth. ... Kaldor found, for the postwar period, that those countries that had experienced the greatest decline in their price competitiveness (i.e., highest increase in unit labor costs) also had the greatest increase in their market share” (Felipe and Kumar 2011, pp. 3–4).

The more developed countries mostly produce and export commodities of higher technological level and higher income elasticity of demand compared to those produced by the less developed countries (Prebisch 1959; Krugman 1989; Thirlwall 1999; Economakis et al. 2014, 2015, 2018). This means that there is a dissimilarity in the structure of production-trade between the more and the less developed countries, which is reflected in the different “relative” income elasticities of demand, that is income elasticities of demand for an economy’s exports against those for its imports (Krugman 1989; Thirlwall 1991; Trigg 2020). As a consequence, as income increases, the demand for products from the more developed countries is higher than that for products from the less developed countries (the so-called “Engel’s Law”). This, results, *ceteris paribus*, in faster growing prices for the products produced by the more developed countries, that is the terms of trade change against the less developed countries. Thus, economic growth for the less developed countries is accompanied by increasing import payments, in other words, trade deficits (see Singer 1950; Prebisch 1959; Love 1980; Ocampo 1986; Economakis et al. 2014, 2015, 2018).

## 2.2. *The Drivers of International Structural Competitiveness*

A substantive challenge for the understanding of the drivers of international structural competitiveness across different countries is the determination of the link between the international structural competitiveness and the aspects of a country’s economic performance – which depict its development level. A large and growing body of literature has investigated the specific features of competitiveness at the country level, highlighting that it is connected with (i) the ability to produce and export a wide range of technologically advanced industrial products (ii) the sectoral diversification of the production system and (iii) the level of the inter-connectedness of the production system.

The first driver of international structural competitiveness is the technological structure of exports, expressed by the share of technologically advanced products (that is, products of higher income elasticity) in the total exports. Cohen and Zysman (1988, p. 24) link the export performance of a country and the level of international competitiveness with the effective use and diffusion of technology among sectors. Lall (2000, pp. 337–338) argues that the structure of exports has important implications for growth and development, while, in addition, stresses

that industrialization remains an engine of development. He also highlights the importance of the technological structure of manufactured exports as an indicator of “quality”. A large share of technologically advanced manufacturing products in exports is a sign of an efficient development path, while the opposite would hold if a country mainly exports less advanced products. This view is supported by Petralia *et al.* (2017, p. 967) who point out the importance of technology in the determination of the level of development, and find that the more developed countries tend to specialize in the production of more diverse and more valuable products by the use of more complex and less concentrated technologies, in comparison to less developed countries.

The second driver is the sectoral diversification of the examined economy. From the theoretical model of Krugman (1989), it follows that the higher the income elasticity of demand that characterizes the exports of more developed countries, as opposed to those of the less developed countries, the greater the diversification of the domestic production of the former towards the production of the latter. As mentioned in Rodrik (2007, p. 9), “productive diversification is a key correlate of economic development”. Less developed countries are usually associated with the production and export of a narrow range of products and the concentration of their activities in low productivity services, while developed countries produce and export a diversified mix of manufacturing products and modern services, as they are engaged in a broad range of economic activities. Imbs and Wacziarg (2003) examine the patterns of sectoral diversification in a wide range of countries, and the changes of diversification within these countries. They conclude that diversification is a stylized fact of the development process. Furthermore, they show that the development process is not only expressed as a reallocation of resources from primary to industrial sectors, but also as a process of diversification and expansion of the range of activities within manufacturing. Finally, according to the findings of Hausmann and Klinger (2007), manufacturing sectors provide an economy with the capability of increasing product diversification to a greater degree, in comparison to the primary and services sectors.

Finally, the third driver of international structural competitiveness is the level of interconnectedness of the whole economic system. According to the European Commission (2009, p. 75), “competitiveness [...] is not the result of merely aggregating individual industries’ performances but is the result of a complex network of relationships between them”. Peres (2006, p. 68) supports the notion that the diversification of the productive structure of a national economy results in greater domestic sectoral productive linkages; the latter strengthens “the positive impact of economic growth on overall productivity”. In a similar direction, Rios-Morales and O’Donovan (2006, pp. 55–56, 64) maintain that domestic sectoral productive linkages are related to spillover effects, “in terms of technology transfer and absorption”. Furthermore, the development of manufacturing sectors, due to their inter-industry transactions,

would generate productive linkages, spillover effects, capital accumulation and technological externalities (see Hirschman 1958, pp. 109–110; Cimoli et al. 2006, p. 88; Pilat et al. 2006, p. 26). On the contrary, if a national economy is highly dependent on primary economic activities and services, this expresses a lower level of interconnection (Fotopoulos 1985, p. 178). Specifically, services are more independent from other sectors, in comparison to the manufacturing sector (Pilat and Wölfl 2005, pp. 3 and 36). Accordingly, the more diversified the production structure of a national economy, the greater are the domestic sectoral productive linkages, and consequently, its international competitiveness is higher (see Cimoli et al. 2006, p. 92). As a consequence, the more developed an economy is, the more complete and articulated is its economic structure (Leontief 1986, pp. 169–170). On the contrary, the most typical characteristic of economic underdevelopment is the relative absence of interdependencies and strong linkages (Hirschman 1958, p. 109).

Therefore, there is a structural interrelation between the degree of diversification of the productive structure of a national economy, the strength of its productive linkages, the level of its industrial and technological development (and the resultant externalities) and its international structural competitiveness.

Given the above, it is inferred that the level of international competitiveness of a national economy can be coded, in line with the three drivers (technological structure of exports, sectoral diversification and the level of interconnectedness) by the following criteria:

- the ratio of technologically advanced products in exports
- the degree of economic diversification
- the level of interconnectedness of the economic system

Compared with an internationally more developed and more competitive economy, a less developed and less competitive one is characterized by a relatively low level of industrial and technological development, strong specialization, and relatively weak productive linkages. As a result, less competitive economies exhibit unfavorable structural factors, expressed by relatively low-income elasticities of demand for their products, which is reflected in negative terms of trade and trade deficits.

The “drivers” (as well as the criteria) discussed previously are all important factors for the structural competitiveness of a national economy. However, the analysis would be incomplete without the determination of a reliable and valid single measure for the assessment of structural competitiveness at the country level. Such a measure allows the creation of a rank (economic hierarchy) of countries based on the notion of international structural competitiveness. Two distinct approaches, capable of specifically meeting the criteria for international structural competitiveness, are identified and compared in the following analysis: the *Technologically Advanced Domestic Valued Added in Exports* (TADVX), a measure

proposed in this research – which is based on the methodological framework of *Global Value Chains* and input-output analysis – and the *Economic Complexity Index* (ECI). The next section will provide a short description of these approaches.

### 3. Measures of International Structural Competitiveness

#### 3.1. *Technologically Advanced Domestic Valued Added in Exports as a Measure of International Structural Competitiveness*

In recent years, there has been an increasing research interest in the structural analysis of economic systems. Developments in this specific subject were reinforced after the introduction of the *Global Value Chains* (GVCs) methodological framework (Humphrey and Schmitz 2002). A widely used definition for a global value chain is that it “describes the full range of activities undertaken to bring a product or service from its conception to its end use and how these activities are distributed over geographic space and across international borders” (Amador and Di Mauro 2015, p. 14; adopted from the GVC Initiative at Duke University). The GVCs provide a detailed mapping of the global economic network that allows the determination of: the involvement of a country in different productive activities, its economic ability to produce new value through international trade and thus, its competitiveness position. Consequently, the position of a country in GVCs is linked to its international competitiveness and its technological features (Taglioni and Winkler 2016, p. 8).

Selected indicators, based on the GVCs’ approach, are widely used in the literature to determine the level of competitiveness of an economy (Cheng et al. 2015). In this study, firstly, the *Domestic Value Added in Exports* (DVX), which expresses the domestic value added, created to satisfy the demand for exports, will be examined as an indicator connected with the criteria of diversification and interconnectedness. According to the GVCs’ terminology, the “domestic value added in exports” or the “domestic content of exports” (DVX) is a measure suitable for expressing the level of participation in the GVCs (Johnson and Noguera 2012) and – as used in the present study – in the world trade in general. Secondly, the technologically advanced DVX (that is, the TADVX) is proposed in this paper as an indicator of the structural competitiveness of a country. The *Technologically Advanced Domestic Valued Added in Exports* will be investigated in this study as a suitable indicator of international structural competitiveness, expressing all three criteria of international structural competitiveness.

##### 3.1.1. Input-Output Analysis, DVX and TADVX

Input-output analysis provides, not only, the ability to distinguish the direction of a sector's production (the production to meet the final demand and the production to meet the intermediate demand), but also the ability to determine the source of a sector's intermediate inputs, that is domestically produced or imported from abroad. Furthermore, the impact of an economy's exporting activities to the domestic production (value added) can be estimated, capturing both the direct and the indirect effects (see below).

Input-output analysis was introduced by Leontief (1986) for analyzing the sectoral interdependencies of an economic system and for defining the level of interconnectedness of the economic system. In an economy divided into  $n$  sectors of economic activity, given  $x$  as a vector with dimensions  $n \times 1$ , with elements equal to the production by sector of economic activity,  $Z_d$  the matrix of intermediate transactions with dimensions  $n \times n$ ,  $f_d$  a vector with dimensions  $n \times 1$  with elements equal to the final demand by sector of economic activity and  $1_n$  a vector with dimensions  $n \times 1$ , with elements equal to one then:

$$x = Z_d \cdot 1_n + f_d \quad (1)$$

Given that intermediate transactions are a part of the production, a matrix  $A_d$  with dimensions  $n \times n$  is defined as follows:

$$A_d = Z_d \cdot \hat{X}^{-1} \quad (2)$$

where  $\hat{X}^{-1}$  is a diagonal matrix with dimensions  $n \times n$  and diagonal elements, the elements of vector  $x$ .

The matrix  $A_d$  is the technical coefficient matrix, with the typical element  $a_{ij}$  expressing the intermediate inputs of sector  $j$ , provided by sector  $i$ .

Based on Equation 2, the matrix  $Z_d$  can be defined as:

$$Z_d = A_d \cdot \hat{X} \quad (3)$$

Furthermore, taking into account Equation 3, Equation 1 can be transformed as follows:

$$x = A_d \cdot \hat{X} \cdot 1_n + f_d = A_d \cdot x + f_d \Rightarrow x = (I_n - A_d)^{-1} \cdot f_d \quad (4)$$

The matrix  $(1 - A)^{-1}$  is the Leontief inverse matrix, with a typical element  $l_{ij}$  expressing the input requirement in sector  $i$ , if the final demand of sector  $j$  is increased by one monetary unit. In other words, the element  $l_{ij}$  reflects the intersectoral linkage of sector  $j$  with the supplying sector  $i$  (Miller and Blair 2009). In Equation 4,  $I_n$  is the identity matrix with dimensions  $n \times n$ .

Based on Equation 4, the impact of a part of the final demand for the production can be defined, following Koopman *et al.* (2012).

Consider a diagonal matrix  $\widehat{D}_v$ , with dimensions  $n \times n$  is defined as:

$$\widehat{D}_v = \widehat{V}A \cdot \hat{X}^{-1} \quad (5)$$

where  $\widehat{VA}$  is a diagonal matrix with dimensions  $n \times n$  with diagonal elements equal to the value added by sector of economic activity. A typical diagonal element of  $\widehat{D}_v$  expresses the share of the value added on the gross output of a sector, or the direct value added coefficient.

Let  $EX$  be a vector with dimensions  $n \times 1$ , with elements expressing the distribution of the exports by sector of economic activity (note that the summation of  $EX$ 's elements equals one).

$$DVX = \widehat{V} \cdot (1 - A)^{-1} \cdot EX \quad (6)$$

where  $DVX$  is the vector with the dimension  $n \times 1$  expressing the value added generated by a unit change in exports. A typical element  $DVX_i$  of the vector  $DVX$  expresses the value added in sector  $i$ , generated by a unit change in exports, under the assumption that the distribution of exports between the sectors is stable (Johnson and Noguera 2012).

The summation of the  $DVX$ 's elements expresses the total value added created in the examined economy, due to the production of an extra unit of exports (Note that  $DVX$  is expressed in monetary units). It is important to note that the expression of  $DVX$  is a vector of sectoral value added, which provides the ability to estimate the impact of a unit increase in exports to a group of selected sectors, simply by finding the sum of the  $DVX$ 's corresponding elements (Fujii-Gambero and García-Ramos 2015).

In the following analysis, the link of the  $DVX$  with the notion of international structural competitiveness (as expressed by the three criteria) is discussed analytically.

***The level of interconnectedness of the economic system:*** Based on the expression of the Leontief inverse matrix as a convergent matrix power series, namely  $(1 - A)^{-1} = I + A + A^2 + A^3 + \dots + A^n$  (Miller and Blair, 2005, pp. 31-33), Eq. (6) can be transformed as follows:

$$DVX = V \cdot EX + V \cdot A \cdot EX + V \cdot A^2 \cdot EX + \dots + V \cdot A^n \cdot EX \quad (7)$$

Eq (7) highlights the most important advantage of employing an input-output analysis for the estimation of the domestic value added in exports, that is, the ability to estimate both the direct and the indirect effects by accounting for the level of interconnectedness of the production system (Chen et al. 2012; Koopman et al. 2012). In other words,  $DVX$  calculates both the direct and the indirect impact of exports in value added generation, managing to capture the value added creation from both the demand for exports and the intermediate demand for inputs used in the exports' production. When an extra unit of export is produced in the examined country, new value added is generated both directly and indirectly. The direct new value added is estimated by the first term of the power series, which also expresses the first round of the production process and demonstrates the new value added directly created by a unit of export. The first round will lead to further rounds of production due to the new intermediate demand, which results in the indirect generation of value added, expressed by the

summation of the 2<sup>nd</sup> to the n<sup>th</sup> term of Eq. (7). The summation of all the terms (or the total impact of all the rounds) expresses the total (direct and indirect) value added in exports.

***Degree of economic diversification:*** A country with a high degree of diversification is expected to produce and export a wide range of products, with strong productive linkages. On the contrary, a country with a low degree of diversification (or a specialized one), tends to concentrate both production and exports within a narrow range of products, and with limited productive linkages. Siegel *et al.* (1995) suggest that input-output analysis could be used as an integrating framework for the analysis of economic diversification. As discussed in Hirschman (1989), the level of diversification can be observed in the matrix of the technical coefficients. The production of a diverse range of goods and services is reflected in the matrix through the widening and deepening of intersectoral production linkages. Furthermore, as Szyrmer (1986) points out, in a specialized economy each sector is directly linked to a small number of suppliers and buyers and shows relatively low diversity of the direct flows. The degree of economic diversification is directly included in the estimation of the DVX, due to the distribution of exports by sector of economic activity and the matrix of technological coefficients: on the one hand, if the exports of the examined country are specialized (diverse), then the production process will activate a small (large) number of link sectors, with a relatively limited (expanded) impact on the generation of value added; on the other hand, if the production structure of the economy is specialized (diverse), then the technological coefficients will be relatively weak (strong) and the multiplying impact of the productive system will be less (more) significant.

Furthermore, it should be taken into account that the diversification of production is easier in larger countries (in this connection, see the European Commission 2009, pp. 9, 60). Hilferding (1981, p. 311) argues that “[t]he more extensive the territory, the more diversified is production and the more probable it is that the various branches of production will complement one another”.

***Ratio of technologically advanced products in exports:*** In order to meet the criteria of international structural competitiveness, the technological level of exports should be measured. Therefore, the present study introduces the indicator of the Technologically Advanced DVX (TADVX), which contains the more advanced sectors of the economy. More precisely, for the calculation of the TADVX, the technologically advanced sectors are taken into account by summing the elements of the DVX, which refer to the corresponding sectors. Note that the TADVX counts both the direct and the indirect technologically advanced value added in exports. The direct component of the TADVX expresses the technologically advanced value added per monetary unit of exports, while the indirect component expresses the technological advance value added generated in the domestic economy for the production of a monetary unit

of exports. The technological advanced domestic content of exports is considered as an indicator of a country's structural competitiveness.

### 3.2. *Economic Complexity Index as a Measure of International Structural Competitiveness*

Although in a different theoretical context, the approach of “economic complexity” leads to conclusions close to ours, regarding the structural competitiveness of an economy.

According to the “economic complexity” approach,

*the complexity of an economy is related to the multiplicity of useful knowledge embedded in it. ... Economic complexity... is expressed in the composition of a country's productive output and reflects the structures that emerge to hold and combine knowledge. ... Complex economies are those that can weave vast quantities of relevant knowledge together, across large networks of people, to generate a diverse mix of knowledge-intensive products. Simpler economies, in contrast, have a narrow base of productive knowledge and produce fewer and simpler products, which require smaller webs of interaction. ... Increased economic complexity is necessary for a society to be able to hold and use a larger amount of productive knowledge, and we can measure it from the mix of products that countries are able to make (Hausmann et al. 2014, p. 18).*

Moreover, they introduce the notion of ubiquity:

*ubiquity is defined as the number of countries that make a product (...). Using this terminology, we can observe that complex products – those that contain many personbytes of knowledge – are less ubiquitous. The ubiquity of a product, therefore, reveals information about the volume of knowledge that is required for its production. Hence, the amount of knowledge that a country has is expressed in the diversity and ubiquity of the products that it makes (Hausmann et al. 2014, p. 20).*

Consequently:

The economic complexity of a country is calculated based on the *diversity* of exports a country produces and their *ubiquity*, or the number of the countries able to produce them (and those countries' complexity).

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 (Simoes and Hidalgo 2011).

ECI is constructed by Hausmann *et al.* (2014) to provide a measure of the relative economic complexity of national economies, taking into account the diversity and the ubiquity of the products included in their exports' basket. The construction of ECI is based on the concept of the *Revealed Comparative Advantage* ( $RCA_{cp}$ ), introduced by Balassa (1965).  $RCA_{cp}$  shows the share of product  $p$  in the exports of country  $c$ , compared to the share of product  $p$  in the international trade. When the  $RCA_{cp}$  is greater than 1, then the country  $c$  shows a larger share of exports of the product  $p$  than the share of  $p$  in the international trade, a result which is typically related to a comparative advantage in the production of  $p$ . Following the methodology and the mathematical notation of Hausmann *et al.* (2014), a matrix  $M$  is constructed with rows indicating different countries and columns indicating different products. The elements  $M_{cp}$  of the matrix  $M$  are defined as follows:

$$M_{cp} = \begin{cases} 1, & \text{if } RCA_{cp} \geq 1 \\ 0, & \text{if } RCA_{cp} < 1 \end{cases} \quad (8)$$

A first approach to the diversity can be expressed by summing the rows of  $M_{cp}$ , to create the vector  $k_{c,0}$ :

$$k_{c,0} = \sum_p M_{cp} \quad (9)$$

Moreover, a first approach to the ubiquity of a product can be expressed by summing the columns of  $M_{cp}$ , to create the vector  $k_{0,p}$ :

$$k_{0,p} = \sum_c M_{cp} \quad (10)$$

For a better approach to the concept of diversity and ubiquity, the results of Eq. (9) and Eq. (10) are improved with the calculation of the average ubiquity of products that a country exports and of the average diversity of the countries which produce these products (this is the method used by of reflection algorithm where the information of diversity is used to correct ubiquity and vice versa). The matrix  $\tilde{M}$  is constructed connecting country  $c$  to country  $c'$  according to the number of products they both export. The elements  $\widetilde{M}_{cc'}$  of  $\tilde{M}$  are weighted by the inverse of the ubiquity of the products ( $k_{0,p}$ ) and normalized by the diversity of the countries ( $k_{c,0}$ ), as follows:

$$\widetilde{M}_{cc'} = \sum_p \frac{M_{cp} \cdot M_{c'p}}{k_{c,0} \cdot k_{0,p}} \quad (11)$$

If  $\vec{K}$  is the normalized eigenvector associated with the second largest right eigenvalue of  $\tilde{M}$ , estimated as:

$$ECI = \frac{\vec{K} - \langle \vec{K} \rangle}{stdev(\vec{K})} \quad (12)$$

where  $\langle \vec{K} \rangle$  denotes the average value of the eigenvector's elements, and  $stdev(\vec{K})$  is their standard deviation.

Given the above, a higher ECI indicates an economy that produces a more diverse range of products, and products that are less ubiquitous in the world trade system. Thus, the countries of high “economic complexity” or the “complex economies” correspond with what this study has identified as the internationally more developed and more competitive economies, due to the following three criteria:

- a) larger “webs of interaction”, according to the “economic complexity” approach, which correspond to a strongly interconnected economic system;
- b) “diversity” of products and exports, according to the “economic complexity” approach, which corresponds to a greater diversification;
- c) “knowledge-intensive products”, “complex products that few other countries can make”, “sophisticated, unique know-how” products and exports, according to the “economic complexity” approach, which correspond to a relatively high ratio of technologically advanced products in exports.

Correspondingly, “simpler economies” match what have been identified in this paper as less developed and less competitive economies, at least in relation to the same three interrelated issues:

- a) “smaller webs of interaction”, according to the “economic complexity” approach, which correspond to a weakly interconnected economic system;
- b) production of “fewer products”, according to the “economic complexity” approach, which corresponds to strong specialization;
- c) “narrow base of productive knowledge”, production of “simpler products”, according to the “economic complexity” approach, which corresponds to a relatively low ratio of technologically advanced products in exports.

#### **4. Empirical Investigation: International Competitiveness and Economic Hierarchy in the European Union**

The previous analysis focused on identifying the international structural competitiveness drivers and constructing a suitable measure to express the different levels of structural competitiveness among different national economies, that is the TADVX. In addition, ECI has been shown to be a measure of international structural competitiveness which theoretically seems to converge with TADVX. As argued, both measures *condense* the *structural interrelation* between the degree of diversification of the productive structure of a national economy, the level of its industrial and technological development and the strength of the domestic linkages between its sectors.

The assumption that both measures depict national economies' structural competitiveness in a similar way (that is both depict a similar economic hierarchy of national economies, in terms of their international competitiveness) can only be confirmed by empirical investigation.

The remaining part of this paper addresses the question of the correlation between TADVX and ECI, by comparing the hierarchical position of the European Union (EU28 in 2014) member state economies based on both measurements. The choice of EU28 countries is made in order to carry out an empirical analysis among national economies where the forces of economic competitiveness operate to a significant degree unhindered and uninterrupted (common market and single currency for the European Monetary Unit member states), revealing possible structural competitiveness issues and asymmetries in the process of European integration.

#### *4.1. Data Description*

The application of the methodology is based on the World Input-Output Database – WIOD (Timmer et al. 2015). The analysis is built on the most recent input-output table for the EU28 member countries, which is based on the year 2014. Given that the values in the WIOTs are expressed in millions of US dollars, the DVX and the TADVX count the domestic value and the technologically advanced domestic value, correspondingly, in US dollars, generated in the economy per unit in US dollars of the exports. The countries' abbreviations are listed in Table 1. The technological level of the manufacturing sectors follows the Eurostat's taxonomy (Eurostat 2014): high-technology (HT), medium-high-technology (MHT), medium-low-technology (MLT) and low-technology (LT). Following Miotti and Sachwald (2003), who characterized the HT and the MHT sectors as technological frontiers, the estimation of the TADVX is performed summing the HT and the MHT parts of the DVX. Data on the ECI for the year 2014 are extracted from the Economic Complexity Ranking of Countries (OEC) (Simoes and Hidalgo 2011). Luxemburg, Malta, Lithuania and Cyprus are not included in the OEC.

#### *4.2. Results and Discussion*

In this section, the economies of the EU28 member states are investigated in terms of their international structural competitiveness, based on TADVX and ECI. The hierarchy resulting from the applied methods is discussed in detail and some important findings are highlighted.

The TADVX is estimated by summing the elements of the DVX vector (Eq. 6), which are included in the technological intensity taxonomy as high-technology and medium-high

technology sectors of economic activity. Analytically, HT sectors include “Manufacture of basic pharmaceutical products and pharmaceutical preparations” and “Manufacture of computer, electronic and optical products”; MHT sectors include “Manufacture of chemicals and chemical products”, “Manufacture of electrical equipment”, “Manufacture of machinery and equipment”, “Manufacture of motor vehicles, trailers and semi-trailers” and “Manufacture of other transport equipment” (Eurostat 2014).

Table 1 provides the results obtained from the analysis of the international structural competitiveness provided by the TADVX and the ECI. The values are listed in descending rank-order with regards to the TADVX. The first objective of the research is to identify the hierarchical position of the economies of the EU28 member states based on their structural competitiveness, as is given by the TADVX. Cyprus, Luxembourg, Malta and Lithuania are excluded from the analysis given that they are not included in the ECI. Nevertheless, their results in respect of the TADVX are given in the note in Table 1. As shown in Table 1, the countries in the highest positions of the hierarchy are as follows: 1<sup>st</sup> - Germany, 2<sup>nd</sup> - Sweden, 3<sup>rd</sup> - Slovenia, 4<sup>th</sup> – the Czech Republic and 5<sup>th</sup> - Italy, while in the lowest positions of the hierarchy there are: 20<sup>th</sup> - Portugal, 21<sup>st</sup> - Bulgaria, 22<sup>nd</sup> - Estonia, 23<sup>rd</sup> - Latvia and 24<sup>th</sup> - Greece.

It should be noted that the findings support those of the European Commission (2009, p. 60) which argues that some of the EU28 countries “despite their relatively small size... exhibit a... balanced sectoral structure”. In this research Sweden, the Czech Republic, Austria, Finland and Slovenia exhibit high values for both measures, similar to that of larger countries, such as Italy, France and the United Kingdom, and also close to the values for Germany.

The hierarchy obtained from the ECI has in the first five positions: 1<sup>st</sup> - Germany, 2<sup>nd</sup> - Sweden, 3<sup>rd</sup> - Austria, 4<sup>th</sup> - the United Kingdom and 5<sup>th</sup> - the Czech Republic, while in the last five positions are: 20<sup>th</sup> - Croatia, 21<sup>st</sup> - Latvia, 22<sup>nd</sup> - Portugal, 23<sup>rd</sup> - Bulgaria and 24<sup>th</sup> - Greece.

The results from the TADVX are then compared with those from the ECI. For the determination of the relationship between TADVX and ECI, the Pearson’s Correlation Coefficient and the Spearman Rank Correlation Coefficient are employed, while the data are also represented in figure 1. Pearson's Correlation Coefficient measures the linear relationship between the two variables. The Spearman Rank Correlation Coefficient is used to measure the ordinal association between the rankings of the two variables (Newbold et al. 2013). In this research, the Pearson’s Correlation Coefficient equals 0.867 ( $p < 0.01$ ) and the Spearman’s Rank Coefficient equals 0.903 ( $p < 0.01$ ). The results indicate a strong positive linear relation between the two measures of international structural competitiveness and high degrees of similarity of the hierarchical positions of the EU28 economies derived by each measure.

Table 1: Technological Advanced Domestic Value Added in Exports (TADVX)\* and Economic Complexity Index (ECI), EU28, 2014.

<b>Abbreviations</b>	<b>Name</b>	<b>TADVX</b>	<b>ECI</b>	<b>Hierarchy based on TADVX</b>	<b>Hierarchy based on ECI</b>
DEU	Germany	0.21	1.956	1	1
SWE	Sweden	0.154	1.755	2	2
SVN	Slovenia	0.143	1.447	3	7
CZE	Czech Republic	0.14	1.577	4	5
ITA	Italy	0.14	1.214	5	14
FIN	Finland	0.133	1.555	6	6
AUT	Austria	0.131	1.612	7	3
HUN	Hungary	0.125	1.3	8	10
FRA	France	0.124	1.35	9	9
GBR	United Kingdom of Great Britain and Northern Ireland	0.116	1.593	10	4
DNK	Denmark	0.111	1.236	11	12
ESP	Spain	0.102	0.841	12	19
ROU	Romania	0.094	0.871	13	18
IRL	Ireland	0.089	1.444	14	8
SVK	Slovakia	0.087	1.284	15	11
POL	Poland	0.086	1.147	16	15
BEL	Belgium	0.074	1.219	17	13
NLD	Netherlands	0.063	1.107	18	16
HRV	Croatia	0.061	0.831	19	20
PRT	Portugal	0.055	0.555	20	22
BGR	Bulgaria	0.05	0.536	21	23
EST	Estonia	0.05	1.029	22	17
LVA	Latvia	0.042	0.65	23	21
GRC	Greece	0.022	0.222	24	24

Note: TADVX is based on WIOD (Timmer *et al* 2015) and data on ECI are extracted from the Economic Complexity Ranking of Countries (OEC) (Simoes and Hidalgo 2011).

\*\* TADVX for Cyprus (CY), Luxembourg (LUX), Malta (MLT) and Lithuania (LTU), which are not included in OEC are 0.018, 0.006, 0.014 and 0.052, respectively.

The findings confirm the association between the TADVX and the ECI for the economies of the EU28 member states. As discussed in the theoretical and methodological framework, the TADVX and the ECI are both measures of the structural competitiveness of an economy and can be used to determine the economic hierarchy of national economies, in terms of their international competitiveness.

The relation between the TADVX and the ECI has to be carefully interpreted. Differences between the hierarchical positions of the economies of the European Union member states, in terms of their international competitiveness, given by the two measures, as shown in Fig. 1, mainly reflect differences in the “nature” of these measures. It is important to note that the ECI is calculated using gross trade data, while for the estimation of the TADVX, only the value added generation is counted. Analytically, the value of exports in the ECI is measured in gross terms by trade statistics, meaning that the value of both intermediate and final products is included. This leads to the “double count” of the value of intermediate inputs that participate in the international trade (Koopman et al. 2012). The GVCs’ approach provides the methods to determine the different origins (domestic or foreign) of the value added generation, which is included in gross exports. Significant differences between the TADVX and the ECI are to be expected when a country participates in the last stages of a production process, which involve activities of relatively low value added (such as assembly or packaging), when producing complex products. In this case, low value added is accompanied by high economic complexity.

Figure 1: Comparison of Technologically Advanced Domestic Value Added in Exports and Economic Complexity Index, EU28, 2014.

*[insert figure 1]*

Note: The horizontal axis measures the Technologically Advanced Domestic Value Added in Exports (TADVX) and the vertical axis measures the Economic Complexity Index (ECI).

Although the theoretical and empirical connection between the DVX (or TADVX) and ECI is not yet investigated in the literature, previous quantitative studies tried to link the Foreign Content of Exports, defined as the share of imported inputs in the overall exports of a country (OECD 2019), with ECI. Baltar *et al.* (2005, pp. 12–13) pointed out a positive, though not strong, correlation between the Foreign Content of Exports and a country’s ECI. Ahmad and Primi (2017) found (i) a positive correlation between the change in the ECI ranking and the change in the Foreign Content of Exports, when countries show more than a five per cent

change in the foreign content of exports; (ii) a negative correlation between a change in the ECI ranking and a change in the foreign content of exports for the rest of the countries.

In the present study, the TADVX – which is based on the methodological framework of GVCs – is shown to be strongly associated with economic complexity – as expressed by the ECI – on the basis of the concept of international structural competitiveness.

## 5. Conclusions

The aim of this paper was to identify the criteria that determine the level of competitiveness of national economies and their resulting hierarchy in the world economy. Assuming that there is a structural relationship between the competitiveness of a national economy and the level of its economic development, the determination of the structural factors that operate as the drivers of a country's level of competitiveness was attempted. Three crucial criteria were used in order to define the concept of international structural competitiveness. These were: the ratio of technologically advanced products in exports, the degree of economic diversification and the level of the interconnectedness of the economy. The Technologically Advanced Domestic Valued Added in Exports (TAVX), which condenses the above three criteria – based on Global Value Chains methodological framework and input-output analysis – was proposed as a measure of international structural competitiveness.

In addition, the Economic Complexity Index (ECI) – another known measure of international structural competitiveness – was found to converge with the TADVX. Although in a different methodological framework, ECI is supposed to also condense the same three criteria as the TADVX. The similar hierarchy determined among the economies of the European Union (28) member states, in terms of their international competitiveness, based on both measures, reveals a high degree of similarity between the two measures, while the correlation of their values is also strong. The compatibility of the empirical results, verifies that both measures are suitable to express the structural competitiveness of a national economy. Moreover, according to the empirical findings of the study, the size of a country cannot alone be used to determine that country's position in terms of its competitiveness. Finally, the combination of the findings provides some support for the conceptual premise that international competitiveness is structurally-driven and not cost-driven. Nevertheless, additional studies to understand more completely the key tenets of structural competitiveness are required.

The significant positive correlation between the TADVX and the ECI for the EU28 countries suggests that economic complexity should be further investigated in connection with the content of structural competitiveness. Further research is needed for the better understanding of the structural character of competitiveness. A natural progression of this work

would be the application of the proposed measures to a larger group of countries in order to confirm their ability to capture structural competitiveness of nations with more diverse socioeconomic features.

### **Declarations**

#### **Availability of data and materials**

All data generated or analyzed during this study are available from the corresponding author on reasonable request.

#### **Competing interests**

The authors declare that they have no competing interests.

#### **Funding**

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#### **Authors' contributions**

MM and GE have equally contributed to conceptualizing of the research, the design of the methodology the process of data collection and analysis and contribute their part to write the manuscript. Both authors read and approved the final manuscript.

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# Figures

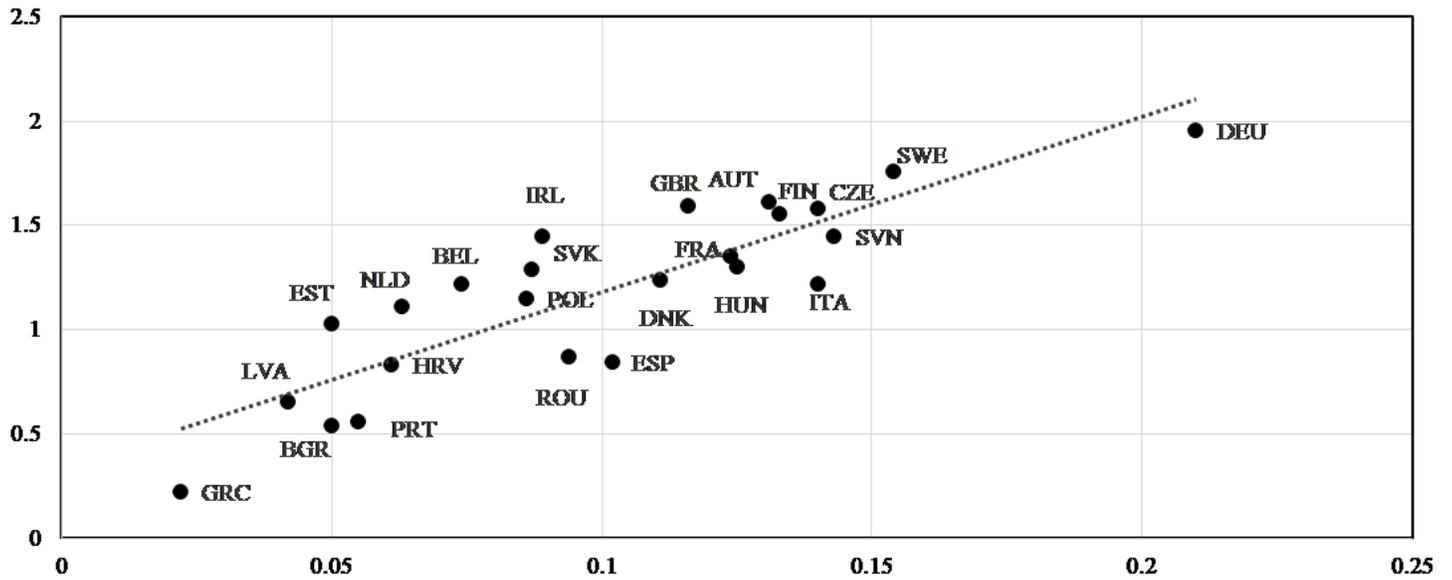


Figure 1

Comparison of Technologically Advanced Domestic Value Added in Exports and Economic Complexity Index, EU28, 2014. Note: The horizontal axis measures the Technologically Advanced Domestic Value Added in Exports (TADVX) and the vertical axis measures the Economic Complexity Index (ECI).