THE BLACK BOX OF ECONOMIC INTERDEPENDENCE IN THE PROCESS OF STRUCTURAL CHANGE. EU AND EA ON THE STAGE

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Abstract. The search of a hierarchy in economic systems, using triangulation method, has a long tradition in economics. This study, after revisiting Authors' optimization algorithm, based on "path restricted unimodularity", tries to cast new light into the black box of the rules governing the transformation of the economic structure in growth process. Inter-temporal, cross-sectional and simulated comparisons have been made on European Community, Union and Euro Area input-output tables (1965-2007) aiming at verifying above all whether the asymmetrical hierarchy prevailed or not. The main results prove that the agents (branches) work in competition rather than in cooperation, thus the dominance criterion rules inducing asymmetry. Contrary to expectations, the richest Euro Area presents a more hierarchical structure than European Union and is more reactive to any fluctuation of final demand. Also the classical Agribusiness complex, important for investigating new comers, presents a highly inductive triangular arrangement and plays an intermediate function.

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Introduction

Scientific works, published in the context of input-output analysis, had a suddenly rise in the turn of XXI century. This increase has been made possible by the availability of updated input-output tables put forth by the main international (and national) statistical offices (OECD, UN, Eurostat, US-BL etc.) so helping scholars to apply this model mainly developed by Leontief (Leontief, 1986). These organizations recognize that intersectoral input-output matrixes are a fundamental tool to study the interrelations of an economic structure. Since the pioneering work of Chenery-Watanabe (1958), their use to establish a hierarchy in economic systems by triangulation method has a long tradition even if finding an exact algorithm is technically very complex since the problem is NP-hard and computationally heavy for matrixes of large dimension (over 50)[2]. According to Korte and Oberhofer (1971, pp. 512-513), it is an important analytical tool in economics since it performs, among others, the following tasks: i) It sheds light on the functioning of the economy from a structural point of view; ii) allows comparison between economies of different countries and periods; iii) can be used to influence optimally cycles and growth; iv) is useful for forecasting and economic planning.

This study tries to cast new light into the black box of the rules governing the transformation of the economic structure in growth process. Inter-temporal, cross-sectional and simulated comparisons have been made on European Community, Union and Euro Area input-output tables (1965-2007) aiming at verifying above all whether the asymmetrical hierarchy prevailed. Moreover, the validity of some scholars' statements about the connections between the level of hierarchical arrangement and the dimension, richness and technological standards have been investigated comparing whole European Union (27 countries) and Euro Area (17 countries) economies. Finally the classical case of Agribusiness complex in its evolution has been deeply studied in view of the development unbalances of new comers (mainly countries from Eastern Europe).

1. The database

In order to examine the structure of economic systems, it needs a complete set of macro-level data that only the intersectoral input-output tables can offer. The use of these tables implies the acceptance of input-output scientific framework (Leontief, 1986).

For this instance, we have used Eurostat five yearly symmetric input-output tables (1965, 1970, 1975 and 1980) pertaining to various aggregates of the European Economic Community in 44 sectors and annual tables of the European Union and of the Euro Area (2000-2007) in 59 branches (Eurostat 1976; 1978a; 1983; 1986; 2008a; 2012). The first series was compiled using the old system of national accounts ESA-70 (Eurostat, 1978b) and the NACE-CLIO classification (Eurostat, various years), while the second is applying the ESA-95 (European Commission,

[2]An exact description of the problem and a synthesis of its development, inclusive of authors' approach is contained in Section 2.

1996) and the CPA, NACE-Rev. 1 and NACE-Rev. 2 classifications (Eurostat, 1996; 2008b). In particular, the old series 1965-1980 consists of 12 aggregate domestic and total symmetric input-output matrixes at d.u. prices relative to EUR6, 7 and 9.

The new set of annual domestic and total product by product symmetric input-output tables 2000-07 is composed by 32 matrixes at basic prices of the 27 countries European Union and of the 17 countries the Euro Area.

These two series are only partially comparable due to changes in the European accounting system and in its classifications (Eurostat, 1978b; 2008a).

To apply the triangularization algorithms described below, the well-known domestic and total (imports included) vertical coefficients are calculated by dividing the transactions (domestic and total) by the total production at départ-usine or at basic prices ($a_{ij} = x_{ij}/p_j$) in accordance with the time series considered.

2. The triangularization problem and its methods

Triangularization problem consists in exchanging rows and columns of a matrix so as to minimize non-zero coefficients above the main diagonal. Many authors proposed heuristic techniques, founded on a suitable (but not exhaustive) sequence of rearrangements. Simpson-Tsukui (1965) make comparisons between sequences of symmetrical elements and interchange of a single branch at each step. Implementation is easy and the method is very fast and useful to initialize other heuristics. Korte-Oberhofer (1971) test all possible interchanges of two sequences of adjoining branches, and choose the best terminating when no interchange improves the solution (local maximum). Fukui (1986) applies the same principle of Korte-Oberhofer method, but three sequences of branches are involved. Other works implement heuristic techniques (e.g., Chiarini, 2004, p. vi), but heuristics, even sophisticated, cannot ensure optimality because the function to be optimized is not convex, so that these algorithms may end at a local maximum and even if absolute optimality is attained, it cannot be detected[3]. As in every heuristic, examples of bad performance can be constructed (Howe, 1991). Branch and bound methods can solve this drawback, but, for large matrixes, they become inefficient and achieve only suboptimal results with estimation of errors (Haltia, 1992; Östblom, 1997). Other studies implement different exact algorithms using linear and integer programming to find the absolute optimal solution without any threshold, initialization with heuristics, or ring shift permutations (Grötschel et al., 1984; Dietzenbacher, 1996; Kondo, 2010; Piccinini and Chang, 1997; 2007; Chiarini, 2004; Charon and Hundry, 2007).

Because of the complexity of their method these algorithms have been disregarded by most economic studies in favor of those more user-friendly, such as Simpson-Tsukui and Fukui. The method developed and used by the authors has a very simple code, and, in its enhanced version, even when it does not succeed

[3]In our experimental work we found cases of Fukui's algorithm success (unlike other simpler algorithms).

in solving the optimality problem it gives very strict bounds from below and from above for the optimal solution. In the present study the exact solution was reached in 42 cases out of 44, and in the remaining two cases the confidence interval was less than 10^{-4}.

The exact terms of the problem can be so described. Let M be a square non-negative matrix. By P a permutation of its rows and columns (the same for both) is denoted; this operation is called rearrangement of the matrix. Let $T(M)$ denote the total sum of the elements outside the diagonal. To each rearrangement P the sum $S(M,P)$ of all the terms that lie below the diagonal is associated. The *linearity coefficient of M under rearrangement P* is the ratio

$$L(M,P) = S(M,P)/T(M)$$

By the name of *linear ordering problem or triangularization* of the matrix M it is meant the search of the rearrangement that maximizes the linearity coefficient among all rearrangements. Since the number of arrangements is finite (even if big) that is an actual maximum, and it is assumed at least by one rearrangement. The *optimal linearity degree* $L^\circ(M)$ is thus defined as

$$L^\circ(M) = L(M,P^\circ) = \max\{L(M,P),\ P \text{ rearrangement of } M\},$$

where P° is an optimal rearrangement.

Of course, the value of $L^\circ(M)$ ranges from 0.5 (random matrix) to 1 (total order matrix)[4]. This is a combinatorial problem of dimension $n!$, and is an NP-hard problem, hence in the case of large dimensions (usually over 50 for input-output) it can be computationally heavy.

The problem can be formulated in a different form using graphs. A *graph* is a set of nodes connected two by two by an arc. When the direction is relevant, as it happens in input-output study, the graph is oriented[5]. When a positive number is associated to each arc the graph is called *weighted* graph (0 means a non-existing arc). Therefore the numerical data of a positive matrix M can be associated to a weighted oriented graph, that does not depend on the rearrangement. It will still be denoted by M. A graph that contains no cycle is preordered, so that it generates one or more linear order structures, corresponding to the optimal rearrangement(s). The presence of cycles does not allow the construction of any order relation: hence it is necessary to cut a sufficient, but not redundant, number of arcs, so that all cycles vanish. An elementary way of performing the task is the following *Procedure E*:

a) Initially the ordered list is empty.

b) A node for which the incoming arcs start only from the ordered list is chosen. If no such node exists, the node for which the sum of incoming arcs starting outside the list reaches the minimum is chosen.

[4]It may be remarked that actual permutations can give also values of $L(M,P) < 0.5$, since when a rearrangement P is inverted its linearity is $1 - L(M,P)$.

[5]Sometimes it is called digraph.

c) The node is added to the ordered list.

d) If the length of the list is less than the number of nodes (= dimension of the matrix) return to step b).

Should a certain number of cuts have already been performed by any technique, the above algorithm allows to find out a total order, if any, or otherwise to construct a suboptimal order consistent with the given system of cuts.

After the rearrangement of the matrix the arcs that are cut appear in the upper part of the matrix. Let W be the total weight of the cut arcs, and P be the associate rearrangement: it holds

$$L(M,P) = (T(M) - W)/T(M), \quad \text{where } L(M,P) \leq L^{\circ}(M).$$

Thus, the system of cuts that reduces the oriented weighted graph into a pre-ordered graph paying the *least penalty* for the cuts (i.e., minimize W) gives the optimal linearity degree and allows an optimal rearrangement through procedure E. This is an integer programming problem, that can be formalized as follows. The non-zero arcs of the graph are listed (from 1 to N); the weight of each arc is recorded in the vector $\mathbf{w}$, and the number of cuts performed on each arc is stored in the vector $\mathbf{n}$. We list all the cycles that exist in the graph, from 1 to K. Each cycle is built by a certain number of arcs (no matter the order of the list), hence the cycles can be described by a matrix $A \equiv \{a_{ij},\ i = 1, ..., K;\ j = 1, ..., N\}$, where value 1 means that the $j-th$ arc belongs to the $i-th$ cycle, 0 that it does not belong. Vector $\mathbf{1}$ denotes vector $(1, ..., 1)$. Using these notations the condition that all cycles have been cut becomes

$$A\mathbf{n} \geq \mathbf{1},\ n_j \text{ non-negative integer} \tag{1}$$

while the objective function to be minimized (total weight of cuts), is

$$\min \langle \mathbf{w}, \mathbf{n} \rangle \tag{2}$$

The problem of integer programming may be computationally heavy. A simpler problem is the released problem of *fractional cut*, where each cycle is requested to have partial cuts x_j of non-negative weight such that the total weight of cuts along each cycle is at least 1.

$$A\mathbf{x} \geq \mathbf{1}, \quad x_j \geq 0 \tag{3}$$

$$\min \langle \mathbf{w}, \mathbf{x} \rangle . \tag{4}$$

This is a standard linear programming problem. Of course, the fractional cut problem in some cases has a total weight less the integer cut problem, as is classically shown by Moebius's structure (compare Grötschel and Piccinini-Chang 97). Denoting by $FC^{\circ}(M)$ the minimum of the fractional cut problem divided by $T(M)$, in general it holds

$$L^{\circ}(M) \leq (1 - FC^{\circ}(M)).$$

Strict equality holds when the optimal system of fractional cuts happens to be already a system of integer cuts. In the actual Input-Output tables this situation is almost always true. The dual of the fractional cut problem is the maximal circulation problem along the graph; u_i represents the flow along the i-th cycle. The problem is to optimize (6) under the constrains (5):

$$A^t\mathbf{u} \le \mathbf{w}, \quad u_i \ge 0, \tag{5}$$

$$\max \langle \mathbf{1}, \mathbf{u} \rangle \,. \tag{6}$$

For each admissible (i.e., satisfying (5)) system of flows $\mathbf{u}$, let $C(M, \mathbf{u})$ be the circulation $\langle \mathbf{1}, \mathbf{u} \rangle$ divided by $T(M)$; thus, the *degree of circularity* $C^\circ(M)$ of a matrix is defined as

$$C^\circ(M) = C(M, \mathbf{u}^\circ) = \max\{C(M, \mathbf{u}),\ \mathbf{u} \text{ admissible circulation on } M\}.$$

By duality, $C^\circ(M)$ coincides with the minimum of the fractional cut problem, so that $C^\circ(M) = FC^\circ(M)$. Since, in general, it holds $L^\circ(M) \le 1 - C^\circ(M)$, for any rearrangement P and for any admissible system of flows $\mathbf{u}$ it holds

$$L(M, P) \le L^\circ(M) \le 1 - C^\circ(M) \le 1 - C(M, \mathbf{u}). \tag{7}$$

The sequence of inequalities (7) is fundamental, since it gives an upper estimate, that together with the left estimate, allows to fix a reference window where $L^\circ(M)$ must lie. It can be observed that (7) holds however P and $\mathbf{u}$ are found, even by different techniques and by different authors.

In the integer case, when $L^\circ(M) + FC^\circ(M) = L^\circ(M) + C^\circ(M) = 1$, the solution of the optimal circulation allows to find the optimal rearrangement. In fact, in view of duality, the knowledge of the optimal circulation allows to detect the optimal structure of cuts and procedure E allows to find immediately the optimal rearrangement. The contrary does not hold, since there is no fast way of constructing the optimal system of flows starting from the linear order[6].

Should the exact solution be unknown, experimental P^e and $\mathbf{u}^e$ can be found out with any procedure and by any author, so that the confidence window[7]

$$W^e(M) = [1 - C(M, \mathbf{u}^e)] - L(M, P^e) \tag{8}$$

can be improved by different methods and also by heuristics.

In particular, it was known from the very beginning of the search for linear ordering of matrixes that an easy heuristic for the system of flows was to consider only the binary cycles, that in the matrix, whatever the rearrangement, correspond to simultaneous non-zero values in cell (i, j) and in its symmetric (j, i). Let $\mathbf{u}2$ denote this system. For each cycle the maximum allowed flow is the minimum

[6]Anyhow the knowledge of an optimal or suboptimal arrangement allows to find some heuristic very powerful for a good choice of "promising" cycles, that help to accelerate the simplex method for finding optimal circulation. The knowledge of a suboptimal circulation allows the construction of a suboptimal order, hence can improve the left side bound.

[7]The arguments about released problem, duality and confidence windows were thoroughly discussed in Piccinini and Chang, 2007.

between the two values. Hence a simple (but rather loose) estimate is easily reached

$$L^{\circ}(M) \leq 1 - C(M, \mathbf{u}2) \tag{9}$$

The value $1 - C(M, \mathbf{u}2)$ received the somehow misleading name of *theoretical linearity* of the matrix, and was denoted by the symbol l^*. This number means that there exists a matrix M^* with the same couples of symmetric values, but endowed with a special structure in which the lower term of the couple always lies above the diagonal[8], so that actually $L^{\circ}(M^*) = l^*$. Any other ordering of the symmetric couples leads to a lower value for $L^{\circ}(M)$.

A sketch of authors' method is now given (compare Chang-Piccinini 1997, 2007 for the mathematical and procedural full details). The core of the method is the search of an integer solution of the dual problem (5)–(6). The finding of $C^{\circ}(M)$ or of a suitable suboptimal estimate is performed by the simplex method. The problem of the huge number of cycles is overcome by working on "smart" selections of cycles found out using Floyd's algorithm (Floyd, 1962). A *path restricted unimodularity* is searched, that is only unitary pivots are chosen, hence only unitary (provisional) cuts are determined. When the procedure stops, either for optimality (case O) or for impossibility of finding a unit pivot (case S), Floyd's algorithm is used for a new battery of cycles containing no cut. Should no more cycle be available, if the last exit was (O) the optimal solution is found and integrity of solutions is ensured. In the case (S), the estimate of the confidence window according to (8) is expected.

The enhanced version of the method tested in the present paper improved the (S) terminal phase. The use of procedure E allows to find suboptimal rearrangements. One possibility is to start from the (S) solution, but this is not very efficient when the lack of optimality is large. It may be more advisable to use a simplified matrix A, where data below a certain threshold are set to zero, and to look for the exact solution. Usually, a better linearity coefficient is achieved. Whatever the suboptimal order is, there is the possibility of *sectional optimization*, namely a square submatrix along the diagonal is abstracted, and the algorithm is used to find its optimal rearrangement.[9] In small dimension problems (20–25 rows), usually path restricted unimodularity is preserved, hence the partial rearrangement P^e improves $L(M, P^e)$. An expert system (or the user in the supervised case) repeats the procedure on the sequence of new re-ordered matrix until no further improvement is obtained. A final check is to reorder the whole matrix starting from the current suboptimal order; actually often the choice of cycles is simpler and allows path-restricted unimodularity until optimality is certified.

An attractive conjecture is that path restricted unimodularity holds whenever an integer solution of problem (3)–(4) can be found.

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[8] The property is stable under any arrangement of the matrix, hence the property cannot be achieved by a generic matrix M through arrangement.

[9] Actually only the columns and the rows containing the submatrix are changed, and the parts lying above the submatrix, rearranged, remain in the upper triangle, so the parts lying below. Similarly for the rows: the left/right of the submatrix lies below/over the diagonal and, rearranged, still stays below/over.

3. Discussion of the main results: the hierarchical structure of EC, EU and EA (1965-2007)

In the structural analysis, some basic concepts such as those of dependence, independence, hierarchy and circularity or multi-regional interdependence have been widely accepted (Leontief, 1986, p. 166). Following Leontief, these concepts derive from a particular typology of the economic structure: a) circular or mutually interdependent (symmetrical dependence); b) independent; c) hierarchical or asymmetrical dependent; and d) multi-regional interdependent that in some cases takes a block-diagonal form.

A natural order structure of the economy can be made triangular with suitable arrangements. From past studies, it may be argued that the economic growth can produce the forming of more or less compact blocks, sustained at the base by a nucleus of intermediate productive branches (Simpson and Tsukui, 1965). It can also favor the concatenation among branches by means of their progressive specialization and differentiation (Leontief, 1986; Chenery and Watanabe, 1958). Any dissolution of blocks involves a re-composition of the economic structure in a block-diagonal or triangular form. During the whole transformation process, the formation of circular relationships among branches takes place. Due to the modification in the composition of aggregates (notably the countries of European Community, Union and Euro Area), in the number of branches, in classification and accounting systems, it is not possible to establish where the fundamental structure of the economy is going, whether toward greater asymmetry and reactivity to any changes happening inside or the contrary. This is the dilemma to which even the Nobel prize Leontief was not able to give a definitive answer and till now scholars are discordant. The attempt of this study is *inter alia* to cast a flash into this black box.

European aggregates[a]	Euristic Degree of linearity		Optimal Degree of Linearity (L°)	Degree of Circularity (C°)	Theoretical Linearity (l*)
	Simpson - Tsukui	Fukui			
EC6-1965D	0.85759117	0.85757940	0.8579079	0.14209210	0.8852777
EC6-1970D	0.85401789	0.85505873	0.8550611	0.14493890	0.8873708
EC9-1970D	0.84936883	0.84936251	0.8494286	0.15057140	0.8817202
EC9-1975D	0.86540901	0.86540901	0.8654094	0.13459060	0.8908107
EC7-1980D	0.85739044	0.85739044	0.8573904	0.14260960	0.8823065
EC9-1980D	0.85770894	0.85770894	0.8587776	0.14122240	0.8838542
EC6-1965T	0.86241903	0.86322235	0.8632224	0.13677760	0.8897137
EC6-1970T	0.85959278	0.85959278	0.8595929	0.14040710	0.8909524
EC9-1970T	0.85473716	0.85473143	0.8547941	0.14520590	0.8847106
EC9-1975T	0.86627481	0.86627481	0.8662748	0.13372520	0.8914440
EC7-1980T	0.85892011	0.85892011	0.8591983	0.14080170	0.8845728
EC9-1980T	0.86094468	0.86094469	0.8609453	0.13905470	0.8864342

[a] 6,7,9 = n° EC countries; D = Domestic Matrix; T = Total Matrix.
Source: our triangularization of Eurostat matrixes

Table 1: Degree of linearity and circularity (1965-1980) of European Community (EC) economies (44 branches)

European aggregates	Euristic Degree of linearity		Optimal Degree of Linearity (L*)	Degree of Circularity (C*)	Theoretical Linearity (l*)
	Simpson - Tsukui	Fukui			
EU 2000 domestic	0.82415258	0.82597481	0.8276916	0.1723084	0.8537313
EU 2001 Domestic	0.81992401	0.82299486	0.8292979	0.1707021	0.8582740
EU 2002 Domestic	0.82442576	0.82695645	0.8283759*	0.1715835 *	0.8534707
EU 2003 Domestic	0.82423946	0.82795434	0.8329239	0.1670761	0.8616793
EU 2004 Domestic	0.82666418	0.82963492	0.8318227	0.1681773	0.8570203
EU 2005 Domestic	0.82694386	0.82734970	0.8290128	0.1709872	0.8538818
EU 2006 Domestic	0.83108726	0.83294258	0.8345255	0.1654745	0.8581509
EU 2007 Domestic	0.83234251	0.83299220	0.8331445	0.1668555	0.8574879
EU 2000 Total	0.82342160	0.82391489	0.8239150	0.1760850	0.8504848
EU 2001 Total	0.81864795	0.81913605	0.8248758	0.1751242	0.8542230
EU 2002 Total	0.82039237	0.82266706	0.8251293	0.1748707	0.8503877
EU 2003 Total	0.82116401	0.82458580	0.8287056	0.1712944	0.8573315
EU 2004 Total	0.82174980	0.82570788	0.8277029	0.1722971	0.8529726
EU 2005 Total	0.82352681	0.82217678	0.8255847	0.1744153	0.8509302
EU 2006 Total	0.82570056	0.83058190	0.8309914	0.1690086	0.8544440
EU 2007 Total	0.82370579	0.82719076	0.8295527	0.1704473	0.8533781
EA 2000 Domestic	0.83248052	0.83315126	0.8334054*	0.1665522 *	0.8609319
EA 2001 Domestic	0.83247432	0.83286189	0.8335599	0.1664401	0.8618690
EA 2002 Domestic	0.83109094	0.83143653	0.8361254	0.1638746	0.8640377
EA 2003 Domestic	0.83231587	0.83606146	0.8382770	0.1617230	0.8698823
EA 2004 Domestic	0.83219498	0.83614236	0.8372842	0.1627158	0.8680130
EA 2005 Domestic	0.83578652	0.83721130	0.8372113	0.1627887	0.8702890
EA 2006 Domestic	0.83755797	0.83836031	0.8395422	0.1604578	0.8695757
EA 2007 Domestic	0.83784407	0.83843213	0.8396743	0.1603257	0.8633359
EA 2000 Total	0.82917690	0.82966452	0.8296646	0.1703354	0.8571389
EA 2001 Total	0.82695573	0.82960332	0.8297118	0.1702882	0.8574511
EA 2002 Total	0.82959834	0.82995714	0.8308473	0.1691527	0.8593709
EA 2003 Total	0.82930840	0.83092646	0.8328405	0.1671595	0.8640419
EA 2004 Total	0.82755983	0.83129776	0.8319883	0.1680117	0.8626096
EA 2005 Total	0.82932317	0.83248670	0.8324867	0.1675133	0.8648868
EA 2006 Total	0.83429986	0.83736837	0.8380381	0.1619619	0.8660557
EA 2007 Total	0.83167136	0.83227068	0.8333391	0.1666609	0.8572904

* Confidence window w* 0.00004-5; the value is the left bound of formula (7) hence may be compared with Fukui estimate.
Source: our triangularization of Eurostat matrixes

Table 2: Degree of linearity and circularity (2000-2007) of European Union (EU) and Euro Area (EA) economies (59 branches)

This essay purports to find the optimal triangular arrangement of all the 44 matrixes (1965-2007) of European Community (EC) and Union (EU) as well as Euro Area (EA) economies using the Authors' exact algorithm in the framework of the above points a) and c). The comparison of the results has allowed to draw some conclusions about the dominant typology of those structures and their fundamental structural transformations as the result of the economic development process. Preliminary, it must be pointed out that the application of the Authors' algorithm has achieved the optimum degree of linearity (L°) in 42 out of 44 cases (64 out of 66 adding the 22 inverses) and that in the remaining two the confidence window was negligible. Also in those two last cases an improvement over Simpson and Tsukui and Fukui heuristic algorithms has been obtained (Tabb. 1-2).

The main object of this section is also to verify the validity of statements made by some scholars (Korte and Oberhofer, 1971, p. 512-13) and questioned in an interesting work (Grötschel et al., 1984, p. 292) to which any final evidence has not yet been given.

As above explained, the degree of linearity is the ratio between the sum of coefficients below the main diagonal and that of all coefficients out of the diagonal. In this framework it can be interpreted as a measure of permeability of the economy as a whole. The statements (to be verified) regard the connections between the degree of linearity and: i) country GDP per capita (statement 1) and its trend (statement 2); ii) the dimension of the country (statement 3); iii) the technological standards (statement 4). A relation between the level of development and the sector ranking is also asserted (statement 5).

From the analysis of the input-output tables 1965-2007 performed using Authors' and Simpson and Tsukui and Fukui triangularization algorithms (in particular authors' exact one) it was possible to deduce what follows:

- the EC, EU and EA economic structures present an essentially triangular order for all matrixes, thus proving the existence of a dominant hierarchical arrangement characterized by asymmetric dependence between branches described above in c) (Tab. 1-2);
- the degree of linearity (Lo) of EU-27 countries is lower than that of EA-17 countries. This result is therefore a confirmation of statement 3 according to which "large countries have a lower degree of linearity than small ones". Moreover, in EU an higher number of large countries is present compared to EA and the former (EU) registers in fact a less hierarchical economic structure (Tab. 2);
- since Euro Area GDP in PPS (Purchase Power Standard) per inhabitant is always greater than that of European Union, this performance seems to disprove the above statement 1 which maintains that "Highly developed countries have a lower degree of linearity than less developed ones";
- during the period examined of nearly 50 years, trends were substantially univocal. In the first period (1965-1980), the tendency in the European Community was to maintain constant both the degree of asymmetry and that of mutual interdependence or circularity already acquired (Tab. 1). Actually, the degree of linearity, deriving from the triangulation of total coefficient matrixes, fluctuated but conserved its level (0.863 in 1965 and 0.861 in 1980) and that of domestic coefficients did the same before returning little over the baseline levels. In the second period (2000-2007), the trend for EU was similar notwithstanding a slight increase of asymmetry (the L° of EU total coefficient matrixes varied with fluctuations from 0.824 to 0.830 and those of domestic coefficients from 0.828 to 0.833) and respectively a specular decrease of symmetry or circularity (the degree of circularity – C° – of EU total coefficient matrixes has decreased from 0.176 to 0.170 and those of domestic coefficients from 0.172 to 0.167). In synthesis for EC and EU economies, during the last half century, an "essential" constancy of the level

of asymmetry with a tendency to a slight increase in the last decade was registered. This result seems in broad sense to give substance to the validity of the above statement 4 whereby "the degree of linearity is a structural constant that can be used to compare the technological standards of different countries";

- in Euro Area, it happened the extraordinary fact of the introduction of the Euro. Its impact affected EA economic structure in the experimental period. From 2000 to 2003, the Degree of Linearity of EA total coefficient matrixes rose from 0.830 up to 0.833 and those of domestic coefficients did the same, rising from 0.833 to 0.838, while the Degree of Circularity of EA total coefficient matrixes decreased from 0.170 to 0.167 and those of domestic coefficients dropped from 0.167 to 0.160. It is well known that, in this period, the world was characterized by a high level of uncertainty from geopolitical, economic and especially financial point of view. This uncertainty, coupled with Euro introduction, contributed to a significant and sustained fall in equity markets and to an increase of volatility (BCE, 2013, p. 61). The result for Euro Area was a strengthening of the hierarchical arrangement or asymmetry and a weakening of the mutual interdependence or circularity. After on (2004-2007), there was, both for the close and the open EA economic structure, an ulterior reduction of the degree of circularity or mutual interdependence and the attempt to recover the levels achieved before the monetary revolution failed (Tab. 2). The effect was a further deepening of the asymmetry in EA hierarchical economy favored also by the increasing of US Dollar to Euro exchange rate. This performance contradicts the above statement 2 owing which "for highly developed countries the degree of linearity is almost constant or slightly decreasing over time"; in the EA case on the contrary the hierarchical arrangement of the economy was increased;
- for the European Community (1965-80), the degree of linearity/respectively circularity after the triangularization of the total coefficients matrixes is always higher/respectively lower than that obtained for domestic coefficient matrixes. That performance reversed itself both for European Union and Euro Area (2000-07). These contrasting trends may be attributed to the relatively lower level of globalization with financial protectionism in the period 1965-80 versus the higher level of globalization without financial protectionism in the period 2000-07[10].

Those performances demonstrate that in the former European Community the international division of labor favored an accentuation of the asymmetry in the structure open to foreign trade respect to the domestic, while in the EU and EA, the rationalization of domestic productive and integration processes among countries prevailed so that the economic hierarchy of the domestic structure became stronger.

That means that in the European economic systems of the last fifty years is persisting a hierarchical arrangement in which goods flows more probably from

[10]A due acknowledgement to F. Bortot for this important suggestion.

the top to the bottom of the triangular structure and not in the opposite direction (Korte and Oberhofer, 1971). This property of economic triangularity supports the hypothesis that, in these systems, the agents (branches) do not work in a context of cooperation but in one of competition in which the dominance criterion is prevailing (Perroux 1964, Chang 1994).

It is opinion of some qualified researchers that, during the growth process, the structure of economic systems, starting from a block-diagonality arrangement (Simpson-Tsukui), moves towards a triangular one and afterwards gradually to mutual interdependence (Leontief), but this last statement has not yet been proved. The results of this study seem to demonstrate the maintenance of certain level of asymmetry although both the degree of linearity and the economic system triangularity have been slightly increasing.

The above results must be ascribed to a real structural change in the economic systems and, more specifically, to the process of service expansion. In post-industrial, tertiary, quaternary and quinary services absorb the main part of employment and GDP of the economy while industry is dropping. Mature economies are characterized by the specialization of functions most of which originally belonged to industry, and at present are pertinence mainly of services, but to some degree also of satellite industries. Therefore as the growth process induced economic branches to develop circular interrelations at the same time specialization operated in the opposite direction transferring these functions to service or other industrial branches. These contrasting trends lead to a substantial stability of the asymmetric structure of economic systems which is lasting over time (Piccinini and Chang, 2007).

3.1. A new method to evaluate the similarity in the economic structures

Frequently Spearman ρ rank correlation coefficient is used to establish whether two hierarchical arrangements are similar (Spearman, 1904, pp. 72-101). As a former work asserted, that correlation measure "... can be an arbitrarily poor measure of 'similarity' between two (optimum) linear ordering" especially when the real input-output matrixes contain a great number of zero-entries (Grötschel et al., 1984, p. 288) and a plurality of optimal arrangements may rise. In the current real matrices, if all coefficients are considered (no threshold), zeros are infrequent. To filter data by thresholds generates zero-entries proliferation and the consequent enhancement of equivalent optimal rankings.

Moreover, the Spearman coefficient is too sensitive to branch or block interchanges. When blocks are independent, it can be high even if the change of linearity degree is negligible. Also, the Kendall τ correlation coefficient creates the same drawback (Yule and Kendall, 1950, p. 268). Furthermore, these indexes take into account only the ranking and not the weight of the various branches on the assumption that order change of a branch drawn at random is equivalent to that of any other. Corrections are possible, but still remain arbitrary.

To overcome these drawbacks and in accordance with Leontief (1986; p. 169), the Authors have developed a method, which consists in placing one matrix of coefficients into the optimal arrangement of a reference matrix and then to recalculate the degree of linearity in a context of sub-optimality. The results are placed in a "simulated linearity" table which reports on the column headers the reference matrix name and on the rows that of matrix under test. For each couple, the difference between optimal linearity and "simulated linearity" is always positive. But, this difference respects neither the rule of symmetry nor the triangular inequality, hence the half-sum of the two corresponding elements of the distance matrix has been calculated and then applied the Floyd algorithm to obtain a distance function that satisfies both rules (Floyd, 1962). This algorithm was applied to the complete dataset of 32 matrices.

Triangulated Coefficient Matrices [a]	COT 2000 EU	COT 2005 EU	COT 2007 EU	COD 2000 EU	COD 2005 EU	COD 2007 EU	COT 2000 EA	COT 2005 EA	COT 2007 EA	COD 2000 EA	COD 2005 EA	COD 2007 EA
COT2000EU	-											
COT2005EU	0.0013	-										
COT2007EU	0.0014	0.0006	-									
COD2000EU	0,0002	0.0014	0.0015	-								
COD2005EU	0.0016	0.0002	0.0007	0.0015	-							
COD2007EU	0.0020	0.0010	0.0015	0.0020	0.0008	-						
COT2000EA	0.0026	0.0039	0.0040	0.0028	0.0041	0.0046	-					
COT2005EA	0.0039	0.0026	0.0026	0.0039	0.0026	0.0034	0.0026	-				
COT2007EA	0.0020	0.0007	0.0007	0.0020	0.0007	0.0015	0.0034	0.0019	-			
COD2000EA	0.0048	0.0046	0.0051	0.0048	0.0044	0.0036	0.0045	0.0044	0.0051	-		
COD2005EA	0.0049	0.0039	0.0043	0.0049	0.0037	0.0036	0.0047	0.0044	0.0044	0.0034	-	
COD2007EA	0.0030	0.0020	0.0024	0.0029	0.0017	0.0009	0.0050	0.0044	0.0025	0.0026	0.0026	-

[a] COT = Total coefficient matrix; COD= Domestic coefficient matrix; EU= EU-27 contries; EA= EA-17 countries.
Source: Authors' elaboration on Eurostat data

Table 3: Distances between the rankings in European Union and Euro Area economic structures (2000-07).

The symmetrical distances derived by this algorithm can be in principle smaller than those which could result with the application of a more limited dataset. Therefore, the synthesis presented in Tab. 3, although of only 12 rows and 12 columns, has been derived from 32 rows and 32 columns dataset. These measures are substantially related to the phenomenon studied, while Spearman and Kendall correlation coefficients are "general purpose" linked only to the rank and independent from the assessment of what has generated it and from its sensitivity. The range of distance values relative to the new measure exposed in this study is much smaller than that of the above indexes even if the distortion in the case of EU and EA matrixes is weak due to few zero-entries. The distances obtained comparing various EU and EA hierarchical structures (2000-07) prove that the Degree of Linearity differences obtained using the symmetric Floyd distance are negligible, mostly in the order of thousandths (Tab. 3). That performance gives support to the above statement five which argues that "for highly developed countries the ranking of sector in different countries is similar".

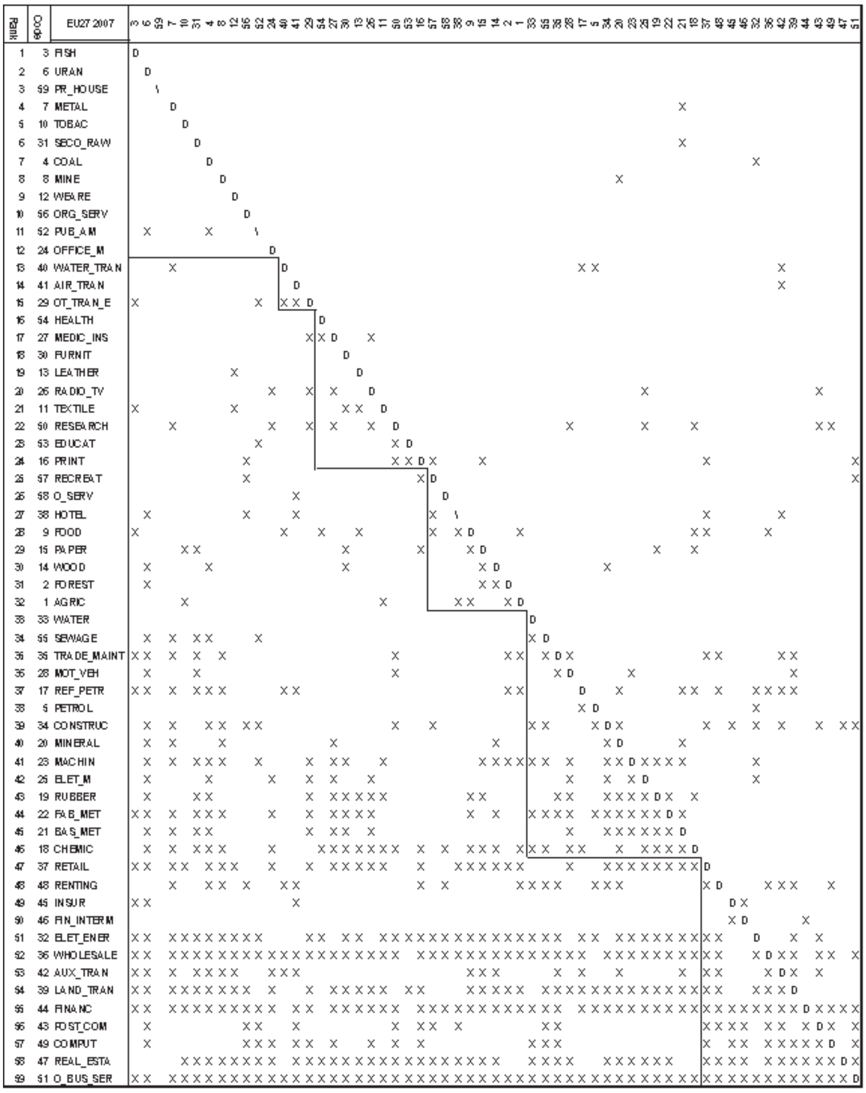
4. The triangularized structure of European economy and the role of Agribusiness

In the context of the input-output vertical model called also "demand-driven", the optimal order of the European (EC, EU, EA) matrixes (1965-2007) has been achieved through the application of Authors' algorithm. Examining the results, it was possible to reveal the basic hierarchical structure of the EC, EU and EA economy. For lack of space, only the results emerging from the EU domestic most recent matrix (2007) are discussed in order to establish what are the main suppliers of the whole economy.

The salient features of the EU-27 triangulated structure, with the reconstruction of the purchase links, are as follows[11] (Fig. 1):

- straddling the middle of the hierarchical structure (from 27^{th} to 32^{th} place) is placed the first main block called "Agribusiness" (examined widely afterwards);
- in the second half of the triangular structure (from 33^{rd} to 46^{th} place), is positioned the second main block of the system called "Metals and machinery". Its components result to be well integrated and are: "Collected and purified water, distribution services of water", "Sewage and refuse disposal services, sanitation and similar services", "Trade, maintenance and repair services of motor vehicles and motorcycles, retail sale of automotive fuel", "Motor vehicles, trailers and semi-trailers", "Coke. refined petroleum products and nuclear fuels", "Crude petroleum and natural gas, services incidental to oil and gas extraction", "Construction work", "Other non-metallic mineral products", "Machinery and equipment nec", "Electrical machinery and apparatus nec", "Rubber and plastic products", "Fabricated metal products", "Basic metals", "Chemicals, chemical products and man-made fibers";
- at the base of the triangular structure (from 47^{th} to 59^{th} place) are firmly positioned the principal suppliers of the economic system and of the majority of the branches; this third main block is called "Services" and is composed as following: "Retail trade services", "Renting services of machinery and equipment", "Insurance and pension funding services", "Services auxiliary to financial intermediation", "Electrical energy, gas, steam and hot water", "Wholesale trade and commission trade services", "Supporting and auxiliary transport services, travel agency services", "Land transport, transport via pipeline services", "Financial intermediation services", "Post and telecommunication services", "Computer and related services", "Real estate services" and the "Other business services". The last branch appears to be the main supplier of the EU economy;
- at the top of the triangular structure, are located 12 branches (from 1^{st} to 12^{th} place). oriented primarily to satisfy the final demand, that are variously related to other three main blocks (Agribusiness, Metals and machinery and Services);

[11] After first quotation, branch name is shortened.



Source: Authors' elaboration on Eurostat data

Figure 1: EU-27 Triangulated Domestic Input-output Table (2007).

- immediately after there is a small secondary block called "Transports" (from 13^{rd} to 15^{th} place) which includes "Water transport services", "Air transport services and other transport equipment", "Other transport equipment", connected with various branches of the Metal and machinery block and in particularly with two basis branches for the functioning of the whole economy: "Supporting and auxiliary transport" and "Land transport" (53^{rd} and 54^{th} place respectively);
- finally, from 18^{th} to 26^{th} there are some branches variously connected to the three main blocks, from the purchasing-side.

Such an ordinal structuring was already broadly detected in other previous studies (Chang, 1987).

4.1. Position and Composition of Agribusiness

It is well known that Davis and Goldberg (1957) of the Harvard Business School proved, using input-output technique, the presence in the US economy of a complex of sectors called "Agribusiness" (AB). They define it as "the sum total of all operations involved in the manufacture and distribution of farm supplies; production operations on the farm; and the storage, processing and distribution of farm commodities and items made from them". Their conception involves substantially all activities linked upstream and downstream to agriculture: a very innovative approach in a scientific world dominated by sectorial analysis.

Subsequently, numerous works demonstrated the presence in various countries of a complex of branches, strongly interrelated, whose first and second main suppliers were respectively agriculture and food industry (Chenery and Watanabe, 1958; Simpson and Tsukui. 1965; Chang, 1985). But in agricultural economics studies a dichotomy arose among scholars between those who continued to center their attention on agriculture (Agribusiness approach) and those who revolved their focus on food industry (French School approach; Malassis, 1973). The role of primary production versus food function was exalted in their respective studies (Corsani, 1986; see also Bortot, 1988 for comparison of the two approaches).

In this subsection, the aim is to verify the position of Agribusiness complex (Chang, 1981;1985) and that of its sub-systems, linked to both branches, and to identify the structural changes involved in the last 50 years.

In Graph. 1, the block of Agribusiness (AB) is integrating with its main buyers and, only for representation, the coefficients greater than/or equal to $1/2n$ (n is the number of branches) have been highlighted.

		Order	1	5	9	18	19	21	25	27	28	29	30	31	32
		Number	3	10	12	30	13	11	57	38	9	15	14	2	1
Order	Number	Group of Products	FISH	TOBAC	WEAR	FURNIT	LEATHER	TEXTILE	RECREAT	HOTEL	FOOD	PAPER	WOOD	FOREST	AGRIC
1	3	FISH	X												
5	10	TOBAC		X											
9	12	WEAR			X		T								
18	30	FURNIT				X									
19	13	LEATHER			X	T	X								
21	11	TEXTILE	X		X	X	X	X							
25	57	RECREAT							/						
27	38	HOTEL							X	X					
28	9	FOOD	X				X		X	X	X				X
29	15	PAPER		X		X					X	X			
30	14	WOOD				X						X	X		
31	2	FOREST										X	X	X	
32	1	AGRIC		X				X		X	X			X	X

Source: Authors' elaboration on Eurostat Data

Graph 1. EU-27 (2007) Agribusiness complex main domestic (X) and total linkages (T) = 1/2n

Agribusiness has a nearly perfect triangular form and is composed, from vertex to base, by the following branches:

- "Recreational, cultural and sporting services";
- "Hotel and restaurant services";
- "Food products and beverages";
- "Pulp, paper and paper products";
- "Wood and products of wood and cork";
- "Products of forestry, logging and related services";
- "Products of agriculture, hunting and related services".

The AB main supplier is Agriculture, that presides the triangle base, and establishes three significant sale relations with Hotel, Food and Products of forestry as well as with itself (intra-industry relationship).

Inside of AB complex operate the following two sub-systems:

A) the Food System which is located at the vertex of the AB triangle and consists of the following branches:

- Recreational and Hotels that buy one another and as well from themselves;
- Food which is currently the main supplier of this system and the second of AB with its deliveries to Recreational and to Hotel. Moreover Food is connected, on the purchase side, with itself and with Agriculture and is also one of the main suppliers of the very Agriculture. Actually the existence of a structural purchase/sale or circular relationship between them has been long recognized, since livestock production buys feed for animals from Food industry as well as sells to the latter primary agricultural products to be processed;
- Food System also acts as a supplier of the branches above the AB block, i.e., those closest to the final demand such as: "Fish and other fishing products" (to supply feed), Membership organization, Water transport, Air transport, "Health and social work services" and "Leather and leather products" through the delivery of skins coming from the slaughtering industry. Regarding the branches underlying the AB block, the Food System is among the main suppliers of Chemicals, Wholesale trade and Retail trade.

B) The Forest System which is situated at the base of AB triangular structure and it is composed by these branches:

- "Pulp, paper and paper products" which buys from itself and from both "Wood and products of Wood" and "Products of forestry, logging and related services";
- Wood which purchases, within the block, only from Products of forestry as well as from itself;
- "Products of forestry" that buys from Agriculture and from itself.

About relationships with the branches above it, Forest system results to provide meaningfully with Wood and with Products of forestry the following branches: "Uranium and thorium ores", Pulp and paper, Agriculture and Tobacco. Pulp and paper are also a leading provider of: "Secondary raw materials", Wood and "Coal and lignite". Last "Furniture, other manufactured goods" has as its main suppliers the branches Pulp and paper, Wood and "Wearing apparel; furs".

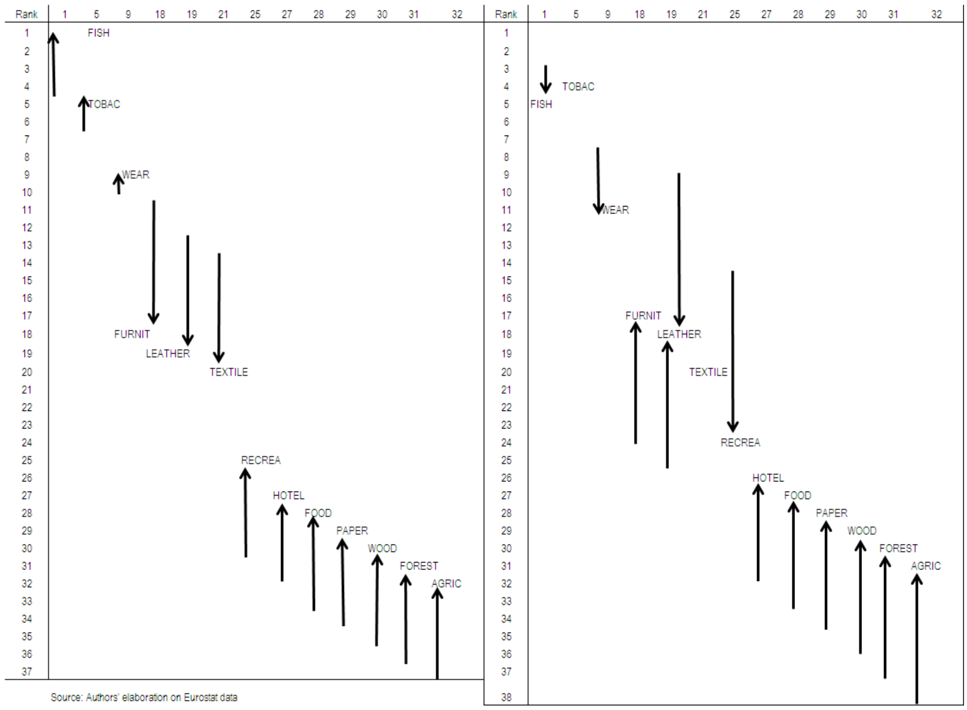
Regard to Forest system sale relations with the branches ranking downstream, Pulp and paper branch (inside it) is one of the major provider of "Rubber and plastic products" and of Chemicals, while the branch of Wood plays the same role with its deliveries to "Crude petroleum and natural gas".

Remark that Agriculture, with its deliveries, creates a *trait-d'union* inside the AB between both the subsystems. Furthermore the branch of Recreational, with its purchases and sales from/towards the "Printed matter and recorded media" branch, generates, inside of the AB, a first round indirect linkage with Pulp and paper. Finally Agriculture gives rise to a second indirect round linkage with Wood, so ensuring the integration of Printing and publishing with the AB and especially with the Forest system.

Considering the industries originally component of the AB complex (Chang. 1981), it was possible to reconstruct the so called "Textile system", since EU, not being endowed by enough natural fibers, has to resort to imports. Therefore it is already positive that Wearing branch reveals a significant purchase link with European domestic agriculture. Wearing, typical final production, is located up to the 9^{th} place of the triangular structure and establishes purchase relationships with Leather and with Textiles, as well as with other branches at the base of the economy triangle. It is thus detectable a link between the Textile system and the Food system through the linkage that Leather forms with Food since Leather purchases skins from the slaughter industry. The branch of Textiles in turn is placed at the 21^{st} place and is not entertaining other significant purchase relationships with the subsequent branches until Agriculture (32^{th} place). Textiles branch is also connected with the second main block of the economy "Metals and machinery" and in particular with some of its main suppliers that are "Machinery and equipment", Rubber, Chemicals, as well as with some service sectors standing at the base of the third block.
Considering the hierarchical order of the 2007 coefficient total matrix (import of goods and services included), the results confirm (for AB) the structure described above for the domestic matrix with a maximum slip down of 1 or 2 positions. This means that, due to imports, the AB block is somewhat more intermediate.

From the inter-temporal 2000-07 Migration graph (Graph 2, left side), of the AB branches in EU-27 countries, calculated on the optimal arrangements of the total matrix, the following trends are found:

- AB complex stands in 2007 within the 32^{nd} place of the 59 position ranking (in 2000 stood within the 37^{th} place);
- "Tobacco products" tends, among all branches, to settle itself at the vertex of the economy triangle closest to final demand. Also the branch of Fish shows the same trend;
- the most final branches, like Wearing, Leather and Furniture glide down considerably towards the AB block;
- the block of Agribusiness in turn moves itself towards a higher position, confirming its tendency to become less intermediate and so approaching the AB more final branches, standing up in the asymmetrical structure of the economy.



Graph 2. - Agribusiness Complex Inter-temporal Migration Graph 2000-2007 (Left EU-27, Right EA-17 countries).

In EA (Graph 2, right side), the final sequence of the hierarchical order has become substantially the same of that of EU, except for the interchanging position of Tobacco and Fish at the top of the triangle. Hence the differences at the start vanished. This is the result of both light industry (Wearing, Furniture, Leather and Textile) compacting and the upward migration of Agribusiness Block toward its main non-food processors.

In synthesis, Agribusiness presents a highly inductive triangular arrangement in a hierarchical structure already strict. Due to its location in the center of the economy it plays an intermediate function. Eventually some of its original branches (Wearing, Leather and Textiles) moved closer to final demand ranking among the main clients of the economy. Recently there is a slight tendency both in EU and EA of the AB block and of its final branches to approach themselves. Finally the real innovation consists in the insertion of a typical post-industrial branch (Recreational, cultural and sporting services) at the top of the block. That branch generates linkages with the Food System (backward) and with the Printed matter and recorded media system (circular). This last is also linked to the Pulp and paper inside the AB so strengthening its internal cohesion.

5. Conclusions

In the last fifty years, the EU and EA economic structures observe the dominance of an asymmetrical development pattern characterized by hierarchical dependence. Lacking theoretical directions, some scholars have controversial opinions about the *sequentia temporum* of various typological structure, thus the Black box should be revealed. The horn of the dilemma lies in determining whether, during the development process, there is an increase of circularity (mutual dependence). On the contrary, the results of this study seem to support a slight weakening of circularity in favor of a strengthening of asymmetrical dependence. Authors' hypothesis is that in post-industrial economies the rationalization of services may lead to a better division of labor, restoring a hierarchical dependence pattern. If that trend will continue, last statement could achieve a general value since the structures of mature economies have proved to be very similar.

Furthermore, the performance described above seems to provide, from a theoretical point of view, a significant empirical evidence to the hypothesis that make the hierarchy or asymmetric dependence, instead of the mutual interdependence, the hub of a different theory of structural analysis based on the dependence/dominance among the economic "agents". According to the theory of unbalanced growth, the activation of the system, caused by a variation of final demand, occurs mainly through the so-called backward linkages determined by input purchases (Hirschman, 1958). Although backward linkages are considered the development *primum mobile*, also the forward linkages, induced by sales, have their relevance. Those last strengthen the backward linkages by engendering a pincer movement able to help investment decisions. If the structure is hierarchical, the more it becomes asymmetrical, the higher is the probability that a variation of final demand produces its effects from top to bottom of the triangular structure and not in the opposite direction, inducing a cumulative development. For European Union and Euro Area, the inference of this study seems to support the interpretation that the hierarchical structure of the economy favors the permeability of the system to any variation of final demand inducing a growth in case of increase and a de-growth in case of decrease. If an asymmetrical structure is prevailing, the task of policy makers is facilitated both in the expansion and in the regression phases of economic cycle. They may attempt, in the first case, to contain inflation e.g. augmenting taxation while in the second case to incentivize final demand reducing fiscal pressure (or by monetary base reduction and respectively expansion).

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