Analysis of Network Analysis Tools Possibilities in Area of International Taxation

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Abstract. In modern era of globalization, we face every day to new business models, technologies and way of enterprises achieve their revenues and gain profits. Under these conditions is quite harder to tax internationally operating businesses when we realize that actual network created of bilateral and multilateral treaties in not so perfect as we would assume. From these facts arises the research question. Is actual network of bilateral tax treaties perfect? If no, where the weak parts are? And finally, and most importantly, how can we measure it? In our research paper we analyze which tools of social network analysis can be used to measure and examine nature of bilateral tax treaties network. By understanding answer to this research question, in future we would be able to fully use all the SNA tools, that are most suitable for network of bilateral tax treaties and treaties like them. Furthermore, we can predict which tools are on the other hand not suitable for this type of network.

Keywords: Bilateral tax treaties, Network, Taxation, Social network analysis

JEL classification: *H20, D85, L14*

1 Introduction

When studying such global entity as network of bilateral tax treaties (from here only BTT), it is needed to use tools that meet the needs and copies features of this entity. If we want to observe how network works or need to predict how subjects in this network may act in future, we must precisely choose specific tools to successfully achieve our aims. (Kubicová J. , 2021) Network analysis is one of the youngest analysis methods that is nowadays available to use. In this part of work we analyze, in which areas and how social network analysis (from here only SNA) has been used until now and how it has evolved from the original theory of graphs. Then Graph theory was born in solving a puzzle about the so-called " Seven Bridges of Königsberg ", when in 1736 the mathematician Leonhard Euler first mentioned the possibility of solving the puzzle using a graph. (Sporns, 2022) (Ławniczak, a iní, 2020)

The advantages of solving problems with the help of the graph are that the graphs are easier for the recipients to visually perceive than the mathematical formulation of the problem. By use of graph theory, it is possible to search for the shortest paths connecting different points on the graph, search for possible connections between people, suggestions for friendships on social networks, monitoring the spread of viruses, GPS, studying molecules, links between them and the like. Graph theories are unique because they can connect nodes / entities through the relationships that connect them.

In many studies, we also come across the term Social Network Analysis. Using this method, it is a process of examining social structures using networks and graph theory. SNA is one of the ways to examine networks of nodes connected by certain relationships using graph theory. In SNA, the edges of graphs capture, for example: information transfer, connections (relationships) between entities or even business networks, which multinational companies create by their mutual interactions, ownership interests in subsidiaries and the like. The concept of social network analysis is first mentioned in history in connection with the sociologist George Simmel or Émile Durkheim. (Hollstein, 2021) The advantage of the SNA approach in the field of international business and taxation is the similarity, between social networks, and networks of companies or countries connected through relations. The relationship between graph theory and SNA is very close. It is possible to say that SNA is more technically advanced, but it builds on graph theory. The difference between SNAs is that it is possible to examine the network using graph theory, but it is possible to attribute certain properties to nodes as well as edges that affect their position and importance in the network.

From the above-mentioned circumstances, it follows that the SNA method is an ideal method for examining contractual relations between countries in international treaties network. One of the examples can be the examination of bilateral or multilateral contractual network relations between nationals in the field of international taxation. The network of contractual relations between countries is a complex entity with a complicated and dynamically changing structure. As we have recently been witnessing the trend of international treaties abuse in the field of international taxation by companies, we perceive the need to choose a suitable research theory, which in our opinion is SNA. This methodology can capture important characteristics of international networks such as double taxation treaty networks. On the other side SNA is flexible enough to absorb and promptly react to changes in the real network of international treaties.

2 Overview of basic terms of SNA

A graph is a set of vertices / nodes and edges that are connected in one whole. The term node can represent various objects, countries, territories, entities, persons, and the like. Edges can connect nodes in any way. When describing the nature of graphs, it is necessary to distinguish between the term "tree" and "graph". While the tree has a so-called node, which can be considered as the starting point, and the other nodes are connected to it, and each other node creates a single link to its parent's node, this is not the case with the graph. (Carrington, Scott, & Wasserman, 2005) Based on the properties of the edges, we can distinguish between edges with and without direction. For graphs where the edges have the direction of the trajectory to be performed when moving between nodes, we distinguish between the origin node and the destination node. (Cordeiro, Sarmento, Brazdil, & Gama, 2018) While at the edges without direction, a two-sided shift is possible both from node A to B and vice versa. This difference between the edges then gives a precondition for the emergence of different types of graphs. If we have edges indicating the direction in the graph, it is a diagram, graph with edges indicating only one-way movement between nodes and vice versa, a graph where two-sided movement is possible is called a multigraph. (Camacho, Panizo-LLedot, Bello-Orgaz, Gonzalez-Pardo, & Cambria, 2020)

The edges of the graph can also be assigned a weight. The weight of an edge can expresses different circumstances of the relationship between two nodes, such as: cost, the amount of transmission of a certain unit across a given edge per unit of time, the distance between two nodes, and the like. In general, we can perceive the evaluation of edges as: distance, time, cost, capacity (or in other words edge permeability). The expression of how the vertices are connected to each other is called incidence, it can be written in various ways, such as: incidence table, matrix, or in the form of a graph diagram. (Zulehner, Hillmich, & Wille, 2019) Incidence matrices can describe both evaluated graphs when the edges of the graphs have different weights, and unevaluated, when the edges of the graphs are equivalent without weights. The incident matrix in the case of a non-oriented graph, a graph without edges with a given direction, also called a multigraph, has a specific shape in that around the main diagonal of the matrix the elements of the matrix are arranged in a mirror image. This representation is since the route from node A to node B carries a certain value that applies reciprocally in both directions, since the path of movement between points does not have a specified strict direction. In the case of an oriented graph or otherwise called an orgraph, the incidence matrix is not symmetric.

One of the tasks that can be easily solved using graph theory is to find the path between the nodes and optimize the path between the two nodes. However, if we request a path, it is necessary to determine the appropriate condition that the path should meet. It is possible to require finding the shortest route between country / node A tax haven / node X. However, the most beautiful route, in terms of the smallest number of countries involved in transferring profits, may not be characterized by the lowest costs of transferring such company profits from country / node A to X. When searching for a path between monitored nodes, it is therefore necessary to determine the correct criteria that the path should meet.

In general, when working with network analysis, we may encounter the following basic concepts:

Open network - In the context of international tax avoidance treaties, we consider a network of countries linked by contractual relations as a model of an open network. (Kurt & Kurt, 2020) In this model, there is room for the emergence of structural holes, which we observe, in the case of real application of bilateral agreements. If there is a structural hole in the system of nodes connected by edges, it is possible to get from node A to node C, where the existence of a direct path A-C is not necessary, just through node B, which forms a structural hole. We also face a similar problem with companies that are shifting profits between jurisdictions with a view to reducing their tax base. In doing so, they use a network of international double taxation treaties to their advantage.

If the transfer were made directly between jurisdictions that do not have a double taxation treaty, the situation could lead to double taxation of the same income. However, companies want to avoid this, which leads them to abuse tax avoidance treaties by exploiting a structural hole - a third country that has a contractual relationship with both original nodes - countries. It is therefore important to see peripheral, peripheral countries that are not contractually linked to more countries, while monitoring countries that have a wide network of international double taxation treaties that can be used as bridges between countries on the periphery of the network with countries in core network. (Kubicová J. , 2011) (Kubicová J. , 2017) It is precisely these nodes, which are structural holes, that are characterized by the fact that they lie mostly between different areas of higher density than they are located just inside the cluster of nodes, and thus in areas of high density. (Walker, Kogut, & Shan, 1997) Further research confirms that when companies are in a system reminiscent of an open network, their strategies are more independent and have more freedom. (Walker, Kogut, & Shan, 1997)

Network structure with closed core and peripherals - In this case, it is a network structure where the nodes in the core of the network are closely interconnected, but outside the core, individual nodes not connected to the rest are connected to the peripheral nodes. (Camacho, Panizo-LLedot, Bello-Orgaz, Gonzalez-Pardo, & Cambria, 2020)Such a structure may also reflect a network of countries linked by bilateral tax treaties.

Closed network - All individual nodes are interconnected with all other nodes. This model is not a suitable model for illustrating a network of bilateral tax treaties, as the treaties are not concluded between all countries. (Burt, Kilduff, & Tasselli, 2013) The advantage if a network of international agreements is a closed network is the absence of structural holes and a perfect flow of information within all the tops of the graph. This allows for greater trust between the various actors in the network. (Burt, Attachment, decay, and social network. , 2001) (Coleman, 1988)

Node (**node; vortex)** - In the conditions of examining the issue of income taxation from cross-border transactions, nodes would be represented by countries.

Edge - The edge of the chart could be a suitable carrier of information on the possible existence or non-existence of a bilateral contractual relationship between a given country and a selected other country. (Sathiyanarayanan & Pirozzi, 2017)

Structural hole (bridge hole) - arises when some nodes connect different areas of the network and form a single, or one of the few, paths that can connect nodes from these parts of the network.

Degree - A quantity expressing the number of concluded agreements on the avoidance of taxation of one monitored country with all other countries, which are part of the set of peaks / nodes of the chart.

Density - The indicator expresses the ratio of all existing contractual connections of countries to each other, to a value that expresses all possible connections even outside those existing between all countries. The higher the density in the observed graph, the more complex and perfect the network of bilateral tax treaties is, the more room there is for the existence of holes. It is possible to say that with increasing density from an open graph, the graph gradually becomes closed. (Marsden, 1993)

Node centrality - This is an indicator that indicates the extent to which a node is the centrality of the entire network. In the context of countries linked by international agreements, the country with the largest number of counterparties would be considered the most centralized. Central actors have more relationships through which they can obtain resources and are also less dependent on another individual actor. (Sparrowe, Liden, Wayne, & Kraimer, 2001)

Network centrality - If the facts indicate that a few countries have a relatively wide network of contractual relations with other countries and the remaining countries in the network do not have such many contracts, we are talking about strong network centrality. (Friedkin, 1991) (Valente, Coronges, Lakon, & Costenbader, 2008) In cases where all countries have a relatively equal number of contractual relations with counterparties, let's talk about the low centrality of the system.

3 Methodology and data

In this part of work, we take a closer look at the tools that SNA offers for studying of global tax agreements network. Tools that we have focused on in this research are centralities of network, namely: degree centrality; closeness centrality; betweenness centrality; eigenvector centrality. In one step we introduce and describe the tools that SNA offers, and simultaneously analyze if they are suitable for this type of network. Research aim, is to objectively analyze if specific tools are suitable for our purposes of tax treaties network, is done by "SNA tool test of suitability for BTT network analysis ". This test of suitability of SNA tools is divided into five more categories, namely: Suitability for network of BTT; Positive aspects of tool; Shortcomings of tool; Ease of results interpretation; The contribution of the tool to understanding how the network works. How can tools achieve their rating in this test is presented in Table 1). The higher rating tool achieves, the better interpretive power it has. In the results we present tools of SNA from lower to higher ratings achieved by the tools in our test. In results we present also wider description of possible application and interpretations of these tools in case of BTT network. It is needed to be mentioned, that one of possible weakness of this research could be a certain degree of subjectivity caused by the fact that the value of the total rating indicator is calculated from individual points that we, as authors, assigned to individual SNA tools. However, our effort was to approach the enumeration of positive and negative features of the given tools with the greatest possible degree of objectivity.

Table 1. Brief overview of "SNA tool test, of suitability for BTT network analysis"

SNA centrality tool	
Short description of tool	
Suitability for network of BTT	*(Non -1 point/ week +1 point/ average +2 points /strong +3 points)*
Special positive aspects of tool	*(Each aspect +1 point)*
Shortcomings of tool	*(Each aspect -1 point)*

Ease of results interpretation	*(Bad -1 point/ good + 1 point/ great +2 point)*
The contribution of the tool to understanding how the network works	*(Bad -1 point/ good + 1point/ great +2 point)*
TOTAL RATING	

Firstly, test introduce the specific tool by its name and short description of the tool and its value interpretation. Then there are five categories, where tools can reach or loose points that creates their overall rating summarized at the end of the table (see Total rating). Now we introduce each of these categories. First of them there is Suitability of tool for network of BBT. As it is in all other research methods not all the tools that analysis offers can be used in case of the data with different nature. This reason led us to set this criterion as the first one. SNA tools can reach up to 3 points based on their suitability for BTT network analysis. However, if toll is completely not suitable for our purposes, then it can even loose up to 1 point of overall rating. In the phase of data preparation, we understandably tried to avoid completely unsuitable SNA tools. That the reason that neither of selected tools does not loses its total rating at this category. However, even if we have somehow made the firs raw selection of data, we wanted our test to be suitable also for other researchers in future. Thus, we have decided to make ranking of this and other criteria also with possibility of losing their points crating total rating. Next two criterions are aimed at more accurate description and knowledge of the SNA tool, while evaluating its positive and negative aspects. Each positive aspect of the instrument brings one positive point to the overall evaluation, while negative aspects deduct one point from the overall evaluation for each aspect. As we move on it is necessary to be able to interpretate the results of each research. Criterion of results interpretation ease can reward the tools by 1 or 2 points and can lower overall rating by 1 point if results are hard to interpretate. Contribution of the tool to understanding how the network works, rates possibility of tool to tell us how the network looks like, where are the strong and weak parts or nods of network and so on. The scale in the evaluation of this criterion ranges from -1 point to +2 points.

In next part of the work, we present results of our suitability test of SNA for BBT network use.

4 Results and discussion

Results of our SNA tool test of suitability for BTT network analysis may be able to bring this area of research to until now unexplored areas. All of our results can be used both for BTT network analysis and also analysis of any other bilateral or multilateral tax treaty network in field of international taxation. We believe that thanks to this test, in future we can easier choose the right tools to achieve specific aims on our way to examine the international treaty networks. Results of SNA tools test is displayed in Table A) in Appendix of this work.

Results of our test have revealed that out of all four centrality measures, the most suitable for analysis of international treaty networks, is Betweenness centrality. This tool of SNA has great ability to reveal the most important nods of network in case of transmitters of income to peripety of network (possible tax heavens) and other countries. Secondly, presence of high values of centrality indicates network imperfections and may be great evidence for a network imperfection. Another benefit is that even if this centrality measure characterizes nods, it has also ability to describe the network composition. Overall score of this centrality measure is 9 points. In case of suitability for network of international treaty networks test it reaches maximum points, in total 3 out of 3 possible. Similarly, this tool passed the test in following categories: ease of results interpretation and contribution of the tool to understanding how network works.

Closeness centrality and Eigenvector centrality have reached both total score 5 points. In case of Closeness centrality, only 1 point has been devoted for this measure in case of ease of results interpretation and contribution of the tool to understanding how the network works. Positive aspects of closeness centrality results from it ability to not only to describe the properties of the node, but also properties of the entire network, what more it can be used to specify peripety and core of network. Negative aspect of this centrality lies in fact that, not all nods represented by countries located on peripety of network must be "tax heavens".

Eigenvector centrality describes the point with the highest degree of prestige is characterized by the fact that it is connected by several one-way edges pointing from other nodes towards this node. In case of our type of network, we do not have edges with directive, it is still possible to use this tool to find the most prestige nod/country, that may pay important role in profit shifting. However, Eigenvector centrality is more suitable for networks with the direction of the interaction, thus it can be replaced by degree centrality at some types of networks.

Finally, the centrality measure, with the lowest total rating is Degree centrality. This SNA tool is very simple, and it describes only nods. It is useless in describing nods position in network, its prestige or any another attributes of nods. According to these facts its total rating has reached only 3 points.

5 Conclusion

Results of our test reveal, that the best tool for analysis of nods and network of international treaty networks, is Betweenness centrality, with the highest reached rating consisting of 9 points. Anther centrality measures as Closeness centrality and Eigenvector centrality have reached 5 points score. Finally, SNA tool with lowest rating is Degree centrality, that has reached only 3 points in total rating. According to these results we can say, that most suitable SNA tool for international treaty networks analysis is Betweenness centrality. With this tool we can identify structural holes that behave as a bridge between countries with no direct connections to tax heavens and tax heavens through intermediary nod, or country. Then also suitable tools are Closeness centrality and Eigenvector centrality. From these two we assume that according to their very common interpretation Closeness centrality is more suitable, as far as Eigenvector centrality is more common tool in directed networks.

According to these findings and results, countries, governments may in future use presented SNA centrality tools for their predictions in field of international taxation and combat thus aggressive tax planning by companies. On the other hand, companies located in other country can use network to help them in decision making, when investing in countries. As far as it is not illegal to use international treaties. However, it is important to mention, that is not legal to abuse them

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APPENDIX

Table 2) Results of SNA tools test

SNA centrality tool	Short description of tool	Suitability for network of BTT	Special positive aspects of tool	Shortcomings of tool	Ease of results interpretation	The contribution of the tool to understanding how the network works	TOTAL RATING
		(non -1 point/ week +1 point/ average +2 points /strong +3 points)	(Each aspect +1 point)	(Each aspect -1 point)	(bad -1 point/ good + 1 point/ great +2 point)	(bad -1 point/ good + 1point/ great +2 point)	
Degree centrality	It is a relatively simple way to measure the degree of centrality of a node. The CD value is given by the number of bindings that the node in the network acquires. The indicator does not talk about the structure of the network, it only characterizes the node.	week (+1 point)		1) it only describes the properties of the node, not the entire network (-1 point)	great (+ 2 points)	good (+ 1 point)	3 points
Closeness centrality	If a point is located on the periphery of the network, its distance to all other points in the network is greater than for points in the core of the network. The value of closeness centrality is calculated using the reciprocal value of the sum of the distances of the points to a given point, the edge points of the network will have lower values in the denominator due to the larger value. In contrast to the CD indicator, which was focused only on the characteristics of the point, in the case of the CC indicator we can talk both about the characteristics of the point and partly about the characteristics of the network.	average (+ 2 points)	1) it not only describes the properties of the node, but also properties of the entire network (+1 point) .... 2) it can be used to specify peripety (possible tax heavens) and core of network (+1 point)	1) Not all nods (countries) located on peripety of network has to be "tax heavens", thus it is needed to special detach real tax heavens from jurisdictions with low connections through BTT to other countries (-1 point)	good (+ 1 point)	good (+ 1 point)	5 points
Betweenness centrality	The CB indicator is a characteristic of a node. The CB expresses the probability of the shortest route between two points leading through the point being monitored. If the monitored node is used less times to create the shortest paths when connecting nodes, the CB value will be closer to zero. Such nodes, which are not located inside the network, but on the contrary on its periphery, will acquire values closer to zero. However, it should be noted that BC differs from the other mentioned methods of centrality measurement in that the larger the CB value of a given node, the more frequent the passage through the given node, while maintaining the assumption of passing the shortest routes.	strong (+ 3 points)	1) tool has great ability to reveal the most important nods of network in case of transmitters of income to peripety of network (possible tax heavens) and other countries (+1 point) 2) presence of high values of centrality is a great evidence of network imperfections (+1 point)		great (+ 2 points)	great (+ 2 points)	9 points
Eigenvector centrality	The degree of prestige is also determined by SNA, especially in the field of sociology. Prestige is mostly monitored in the case of graphs in which the edges have a given direction. The point with the highest degree of prestige is characterized by the fact that it is connected by a number of one-way edges pointing from other nodes towards this node.	strong (+ 3 points)	1) even if in our type of network, we do not have edges with directive, it is still possible to use this tool to find the most prestige nod/country, that may pay important role in profit shifting (+ 1 point)	1) tool is more suitable for networks with the direction of the interaction , thus it can be replaced by degree centrality at some types of network(- 1 point)	good (+ 1 point)	good (+ 1 point)	5 points