The Maritime Chain as a Complex Adaptive System

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ABSTRACT

It seems to be useful to present to the scientific, academic and professional community what constitutes the "state of the art" of current empirical trends applied to global maritime trade flows: the conceptual framework CAS (Complex Adaptive System), which looks at the global maritime system as a complex system in which operate relatively independent parties who constantly seek, learn and adapt to their environment, which will provide an overview of the forces at play. The maritime chain represents the maritime, port and logistics markets, which, although segmented, enable the transport of goods from the producer to the consumer. The maritime market is the most important component of integrated supply chains, not just because all the other modes derived from it and depend on, but also because of the importance that the main actors are assuming, namely in the delimitation of the origin and destiny of trade flows. The applicability of CAS to the whole maritime chain is therefore the challenge we assume in this paper.

INTRODUCTION

If the phenomenon of globalization on a large scale, as the technological and geopolitical changes has characterized the market for contemporary international trade, containerization revolutionized the technique and fueled the transformation process of shipping transportation. The weight of maritime trade (90%) globally, transforms it into a magnifying glass to examine the global economy and its geographical architecture (Notteboom and Ducruet, 2010). And that shipping transportation affects - in volume and ports of call - all integrated transport networks downstream, rail, road, inland waterways.

However, there is a great silence and lack of information about the importance of maritime trade - "*sea blindness*". As an example of the size and importance of this sector, it is noted that Maersk operates more than 600 ships, is the largest company in Denmark and contributes with 20% to GDP. These ships use more fuel than the entire nation (in: Rose George, *Deep Sea and Foreign Going: Inside Shipping, the Invisible Industry that Brings you 90% of Everything*).

The transport demand is a derived demand, as it responds to the needs of the organization and functioning of society - the more developed and more complex an economy is, the greater tends to be the number and extent of travel of people and goods. The international transportation of goods has been growing faster than GDP. That is, the intensity of TK transported per unit of GDP is increasing in the case of goods (plus shift and higher level of product). This trend reflects, on the one hand, the complexity of the production process with greater diversity of goods travelling more as new markets enter in the globalization process and production phases of a product are decomposing in space (Moreira, 2012).

Maritime transport of goods expanded rapidly in recent decades and this growth highlights the presence of several independent rational agents (regulators, transport companies, shippers, ports and port authorities, terminal operators and shipping agents). We can observe that within the global maritime system this large number of independent rational agents plays a role, and that through their mutual interactions, determine the development and growth of the sector of the maritime industry.

This article looks at some interesting conclusions drawn from a recent study published by Ducruet and Notteboom (2010)[1], who examined the main features of the World Network of Maritime Transport, devoting attention to the reconfiguration of containerized transport lines, based on the analysis of indicators of ports hierarchy in accordance with graph theory and complex systems theory.

The relevance of this study is twofold: i) To highlight the importance of studying the maritime component of the GDN (Global Distribution Networks) and help fill this gap, assuming that the other two components of the maritime chain (port and logistics markets), depends on it; ii) To publicize the complex systems theory applied to the study of international shipping. The global maritime network

[1] Debugging it, however, from its more "technical" component in order to enable a better understanding by those who are not familiar with this theory.

depends crucially - such as social networks and the Web - of human interactions and exchange of information, whether in delineating the routes either in the choice of ports of call, stretches and passages.

The argument of this analysis is organized as follows. In the next section, we summarize the main features of the actors in relation to worldwide movements of goods. Section 2 provides a detailed discussion of the CAS methodology applied to the maritime chain. Section 3 gives us a simple way to know the results obtained and limitations on work done by Ducruet and Notteboom. In Section 4 we discuss some practical effects collected via the CAS approach to international maritime trade; benefits and challenges. We conclude, in Section 5, with a research agenda for future studies that should be undertaken by the academic community and the urgent need to devote time and resources to the study of this subject, extending it to the whole maritime chain.

1. THE MARITIME CHAIN AND ITS AGENTS

The cargo shipping industry is composed of various sectors such as international shipping, maritime auxiliary services and port services, but this transmission chain does not end in its maritime dimension; the so-called *sea leg* - it extends by land (or waterway) to the logistic distribution centers, ending in door-to-door services that complements it.

In this perspective, studies about the maritime chain are not limited to the maritime shipping market, the port performance and the analysis of the supply chain: it covers studies on forecasting models of traffic flows, ranging from geopolitical cartography to the global perspective offered by world meta-geography, covering the problems linked to regional development and cohesion of territories, up to the microanalysis of the mechanisms of price formation. I.e., the problem of the study of this subject is of universal dimension and contributes to the deep knowledge of trends in global trade, the internationalization and the growing integration of an economy in the interwoven of global economy, to assess the potential of a region in that particular port is inserted and which priority investments should be invested to take the train of competitiveness (Moreira, 2012).

As for the maritime market and its main actors or stakeholders, they should be studied in more depth. It is vitally important to take precautions and anticipate global policies for the sector. In this case, the CAS approach hardly can tell us what will happen, but what happened. However, what happened may be indicative of the future, and thereby contribute to the development of prospective scenarios. Anyway, in empirical terms, what is the methodology or modeling that offers us this degree of infallibility?

The role of port authorities also changed as the shipping system evolved. Its main functions now involve the optimization of processes and infrastructure, logistics performance, the promotion of intermodal transport systems, and relations with the hinterland tend to increase (process of port hinterland regionalization cf. Notteboom and Rodrigue, 2006)[2].

In light of these observations, the rationale of this paper is to analyze and publicize as shipping can be modeled through the use of CAS theory. The main objective will be to understand how patterns emerge in the global transport system.

2. SCIENCE OF COMPLEXITY AND COMPLEX ADAPTIVE SYSTEMS: MAIN FEATURES

Foster (2004) defines science of complexity in the analysis of connective properties that exist between elements of systems to find order forms that can be represented analytically in terms of "*graph theory, network analysis, power laws, diffusion models, agent-based simulation and replicator dynamics*". "Complex means, according to Foster, related to a state of "*ordered complicatedness*", i.e. a system is a network structure whose integrity is derived from a set of rules.

In the literature, CAS refers to a field of study in which its strategic analysis is based on reductionism[3] (bottom-up research). CAS are usually composed by a set of rational agents, self learners, independent and interacting whose mutual interrelations generate nonlinear dynamics and emergent phenomena. For example, rational shipping agents are continuously evolving, both in response to external stimuli as well as competition in the market. Following this perspective, one can avail to CAS the following assumptions:

- CAS refers to complex systems evolving and adapting permanently. Systems are dynamic and we cannot predict the future through them;

- However, it is essential to monitor information, trends, and are an essential tool for the development of prospective scenarios;

- The CAS is based on a reductionist approach: agents of lesser importance may explain the evolution of broader organized complex systems;

- Applied to world maritime networks, allows detecting externalities caused by the relocation of production to more distant economies;

- In a world without borders, with the economy being a single entity, the CAS is more advantageous compared to the traditional territorial approach.

According to Holland, 1998, (quoted by Caschili and Medda, 2005), Complex Systems are defined by observing particular characteristics within a given system,

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[2] Rodrigue, J-P. e Notteboom, T. (2006), Challenges in the Maritime-Land Interface: Port Hinterlands and Regionalization.

[3] Reductionism is a doctrine which states that smaller parts can explain the behavior of larger organized systems (bottom-up approach).

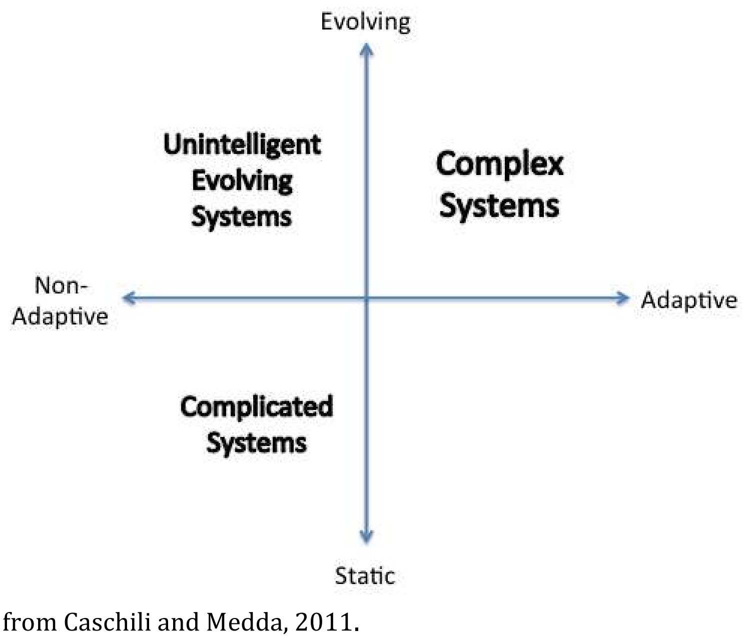
such as: emergence, self-organization/adaptation, nonlinear interactions and evolution. For example, emergent phenomena are classifiable as we demonstrate their behavior as unpredictable when we take into account each part of the system. Emergent phenomena are classified as those due to their unpredictable nature. Recessions and growth are examples of emerging phenomena in economies.

Moreover, a system is considered adaptive when the agents transform its actions as a result of events occurring during the interaction, (Kochugovindan and Vriend, 1998). In this regard, the adaptation may be viewed as a passive action in which the agents absorb information from the environment surrounding (or from the previous experiment).

Non-linearity means that the overall performance of the system exceeds the sum of its parts. What characterizes this peculiar class of complex systems are the processes of adaptation and evolution. Evolution is created by local interactions between the various agents. I.e., the evolution is generated by the mutual actions between agents. Based on the above definitions, complex systems are systems in evolution and adaptation.

Unintelligent evolving systems evolve through interaction processes, but do not adapt. Furthermore, complicated systems consist of numerous elements that interact but do not adapt or evolve in the system, (Caschili and Medda, 2011). Figure 1 shows how adaptation and evolution are incorporated into different classes of systems.

Figure 1: Graph of systems showing their ability to evolve and adapt



Source: Adapted from Caschili and Medda, 2011.

According to Brownlee (2007), a unified theory of complex systems seems to be still far away, but considers John Holland as precursor and a major contributor to the study of CAS theory applied to economics, which is hit by the need for a CAS unified theory. His approach is widely used in much of the CAS literature, especially in economic applications. Although the CAS is widely applied in studies of biological and social systems, the application to maritime transport is scarce.

In one of the Holland´s works, (1992), reported by Brownlee, he suggests the four properties and three mechanisms that CAS should own and which serve as a "*template*" to all the works on this theme. Also Caschili and Medda elect Holland as one of the most creative writers and the definition of either properties or mechanisms follow their formulation.

Four properties :

- Aggregation: the aggregation concept is twofold. The first aspect involves how the modeler decides to represent a system. What are the features to keep and which to ignore is of paramount importance. In this sense, the elements are aggregated into reusable categories whose combinations help describe scenarios, or more accurately, "*new scenarios can be decomposed into familiar categories*." The second meaning that can be attributed to the aggregation properties of the CAS relates to the emergence of global behaviors caused by local interactions, where agents tend to perform similar actions of other agents rather than to adopt independent settings. Furthermore, the aggregation often produces cooperation in which the same action of a number of agents produces results which are unattainable by a single agent. We can explain this concept through the example of the ant hill. An ant survives and adapts to different conditions, when its action is coordinated with a group of ants, but it will die if it works by itself. Similarly, in CAS approach, a new action will survive and induce global effects if adopted by a number of agents.

- Non-linearity: agents interact in a non-linear way so that the overall system behavior is more than the sum of its parts.

- Flows: agents interact with each other to create chains that vary over time. The recursive interactions create a multiplier effect (interactions between nodes generate results that flow from node to node by creating a chain of changes) and a recycling effect (in networks, cycles improve local performance and create striking overall results).

- Diversity: the persistence of the agent is highly connected to the context provided by other agents to define the "*niche*" where the agent survives. Loss of an agent generates an adjustment in the system with the creation of another agent (similar to the other) that will occupy the same niche and provide the most missing interactions. This process creates diversity, but introduces a new combination of features to the system. The intrinsic nature of CAS allows the system to be progressively adapted, of new interactions and enable to create niches (the result of diversity).

Three mechanisms:

- Tagging: agents use the tagging mechanism in the process of aggregation to differentiate other agents with particular properties, which facilitates a selective interaction between agents.

- Internal Models: these are the basic models of a CAS. Each agent has an internal model that filters the inputs into patterns and learns from experience. The model changes through interactions of agents, and changes influence future actions (agents adapt). Internal models are unique for each CAS and are a basic outline for each system. The internal model transforms inputs and filters into known patterns. After emerging a first occurrence, the agent must be able to predict the result of the same input, if it occurs again. Tacit internal models only transmit the system what to do in a given time. Obvious internal models are used to explore alternatives, or to look to the future.

- Building blocks: with regard to the human ability to recognize and categorize scenarios, CAS uses the mechanism of building blocks to generate internal models. The mechanism decomposes a building block situation evoking basic rules learned from all possible situations already encountered. The combination of the seven characteristics allowed analysts to define environments where adaptive agents interact and evolve.

In summary, the CAS is not a technique but a theory that makes use of various modeling techniques (agent-based techniques) such as connection graphs, gravity model, logit models, game theory and the use of mathematical instructions such as algorithms through specific computer systems (software).

If we consider shipping as a system we observe that a large number of independent, rational agents play an important role in making positions prevailing and increasing market share: PA´s, ship-owners, service providers, shippers. The maritime industry can thus in this perspective, be defined as a complex adaptive system consisting of relatively independent parts that constantly seek, learn and adapt to their environment, while their mutual interactions shape hidden but recognizable patterns.

3. AN APPROACH: A DUCRUET AND NOTTEBOOM MODELING APPLIED TO SHIPPING

Ducruet and Notteboom call on to various types of modulation within the science of complexity, looking at shipping as a complex system of relatively independent parts who constantly seek and learn to adapt to their environment, while their mutual interactions shape hidden patterns with recognizable regularities and evolving continuously. These authors examine the main features of the Global Cargo Ship Network (GCSN). Other studies of several authors focus on sub-networks such as shipping network of Asian trade, the basin of the Caribbean transshipment, the system service lines in the Mediterranean or network service lines of the North Atlantic. But this study is particularly interesting because it examines the full global network and gives us an insight into the macroscopic properties of the global maritime network.

Being a static model only analyzes the situation in a specific moment in time not giving importance to underlying factors, for example, the options of ship-owners for certain ports of call over others, or geopolitical conditions and business[4].

Another major disadvantage is its inability to predict future trends or changes in the network. When the available data are summarized in series, the process in question cannot be studied through a controlled experiment. Doesn´t exist, in the words of Foster (2004), a historical temporal dimension, i.e., there is a time restriction. However, if time period is short, the environment remains stable enough to allow something analogous to a controlled experiment.

The study draws conclusions consistent with the idea that there are some routes with heavy traffic and few ports able to handle large-capacity cargo ships. The global maritime network is strongly polarized. In fact, the main service lines include in its Asia-Europe route, a mere 4-5 ports of call considered most important. Another conclusion the authors reached was that the amount of cargo handled by each port grows faster than the number of connections to other ports.

The hubs too do not have a high number of connections to other ports but the routes used are correspondingly connected by a larger number of vessels. Unfortunately, the work of Notteboom Ducruet and does not provide results of analysis of weighted networks over the years about the influence of the introduction of large cargo ships (post-Panamax) on specific routes (trans-Pacific, trans-Indic, Cape Route, etc).

The centrality of ports in a network (i.e., the importance of a node) may be inspected by other means instead of the topological number of gross links per node (degree k). In this case, the study uses measures of betweenness centrality[5].

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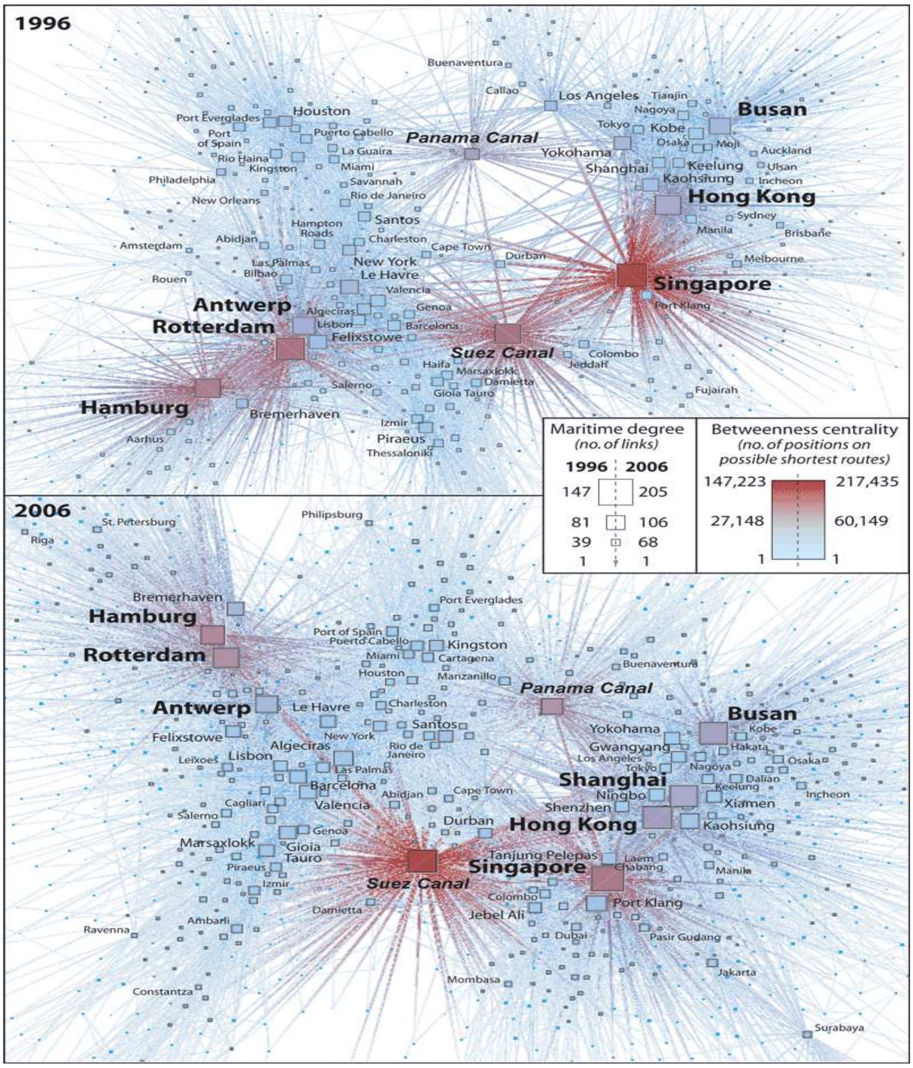
[4] For example, the decision of Maersk to relocate their operations from the port of Singapore to the neighboring port of Tanjung Pelepas in Malaysia, allowed this latter a huge volume of cargo and, concomitantly, has risen through port ranking (role that would not have if the decision had not been taken).

[5] The intermediate centrality (betweenness centrality) of a node is the number of topologically shortest paths that pass through that node.

Ducruet and Notteboom detect interesting anomalies in the centrality of certain U.S. and Japanese ports that are not on the top of the ranking in terms of network centrality, despite its traffic volume due to weak feeder connections (short-sea) and the fact that they are primarily gateway ports and not intermediate hubs. The must central ports in the network are located in Suez and Panama canals and in the Strait of Malacca.

Although shipping has gone through a period of tremendous expansion in the decade under review, the underlying network has a robust topological structure that has changed little in recent years. The container ships showed regular movements between ports, which can be explained by the nature of the service they provide as opposed to bulk carriers and tankers that tend to move in a less regular path, because they change their routes according to demand for goods they carry. Finally, shipping seems to have gained a regional stronger dimension over the years (Figure 2).

Figure 2: Ducruet and Notteboom (2010). The World Maritime Networks and the centrality of ports.



In an analytical perspective, trade imbalances east-west are striking. The trans-Atlantic routes become less important with the advent of post-Panamax. In contrast grows the importance of the Mediterranean. Singapore remains the most central port of the global maritime system and Suez the most important passage. The greater or lesser centrality of a port, or it´s hierarchy, is given through the links and service calls for each port.

The nodal regions of Singapore and Hong Kong, together, represent in 2006 about 50% of global share. Rotterdam and Hamburg shows 19%. The network tends to be fragmented rather than polarized in some mega-hubs due to the growing importance of regional connections (feeder), hence the color intensity of some ports "fade away" over the decade. The image also gives us an idea of network vulnerability to global maritime passages, straits and channels. As an example of the vulnerability we have the case of the problem that has emerged in recent years with the occurrence of piracy in the territorial waters of Somalia (a country in institutional failure), as well as across the Red Sea, being necessary to opt for cargo insurance with the inevitable impact on goods final prices.

Although in 1996 the European ports appear as subordinate to Asians, such is not the case in 2006 and this is due to the fact that the "core region" of routes have been divided in half; strengthening ports in Europe and Asia, (although the Asian ones have grown much more in terms of hierarchy and volume), relegating other areas of the world to the periphery.

The direct consequence is that Asian countries have come to share their links with European countries. But, equally an existing phenomenon of regionalism[6] in trade happens due to the physical proximity that helps explain the increased importance of regional watersheds.

Comparing the developments in this decade one can draw the following conclusions: i) between 1996 and 2006, the trans-Atlantic routes lost significance after the entry into service of post-Panamax ships, ii) since then grows the importance of Mediterranean route via the Indian Ocean and Suez iii) there was an increase in the centrality of the eastern ports very largely due to the "China effect" on world trade.

For the development of modeling Ducruet Notteboom used the dataset from Lloyd's Marine Intelligence Unit (LMIU) for the year 1996 (a period of post-Panamax ships) and 2006 (introduction of vessels with a capacity of over 10,000

[6] Regionalism is a trend of Asian and American economies more focused within their trade due to the contraction of Western economies and increased trade among emergent countries (North-South).

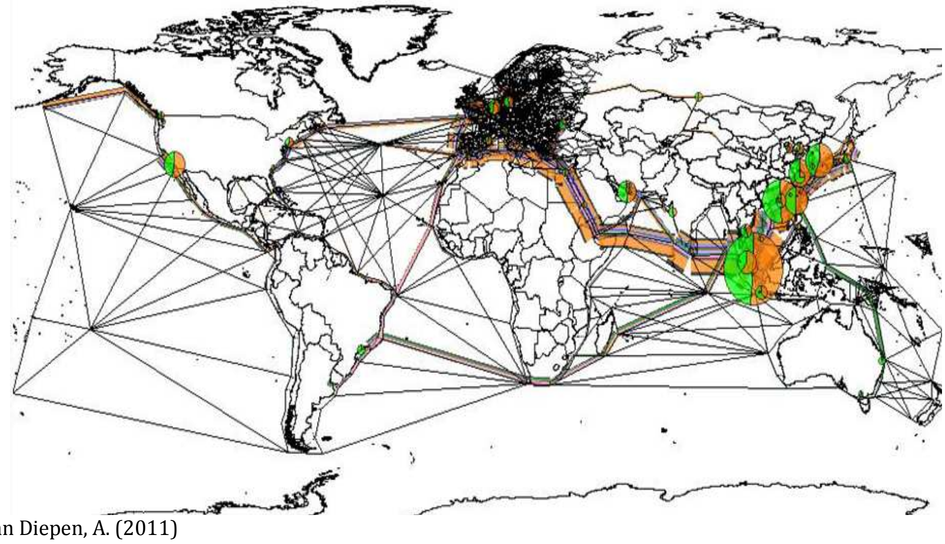
TEU). Some measures of graph of connections (Graph of All Linkages - GAL) indicate a tendency to this to belong to the class of small world networks[7].

Small world networks are a special class of networks characterized by high connectivity among the nodes (or, in other words, low clearance between the nodes). In the backdrop of the real economy this property is an underestimate value, for example, in the retail market, the connections between companies can create clusters of small specialized firms that gravitate around a large company (hub). This firms uses sub-peripheral small businesses to outsource manufacturing. Thus, both companies (the hub and peripheral) reach their goals and enhance economic system synergy.

The degree distribution P (k)[8] shows that most of ports have few connections but there are a few hundreds of ports that are connected to other ports. However, when the authors examine the degree distribution in detail, they find that the overall network does not belong to the class of scale-free networks[9].

The previous Figure 2, which illustrates the work resulting from the modeling that Ducruet and Notteboom have carried out, only shows the modeling of the maritime component, the next one gives us to know the global distribution network, in a scenario of globalization marked by increased production of emergent countries and some stagnation of Western countries, on the horizon 2040 (Figure 3).

Figure 3. The Global Network Distribution on the horizon 2040



Source: Van Diepen, A. (2011)

[7]For a deeper understanding of this study is recommended further reading on: http://www.lboro.ac.uk/gawc/rb/rb364.html

[8] In networks theory the degree k is supposed to be the number of connections of each node.

[9] The scale-free networks are complex networks whose degree distribution follows the power law in which most nodes (vertices) has fewer connections, in contrast with the existence of few nodes with a high number of links, meaning that a node with a high degree (links) tend to connect to other high degree node. The probability of a node to connect to another node is directly proportional to its degree. Thus the scale-free networks are dominated by a relatively small number of nodes which we call hubs.

This modeling was performed for the preparation of the anticipated effects of global scenarios and long-term impact on the future volume of containerized cargo in the port of Rotterdam, using the modeling through the WCM (World Container Model) and technical transport modeling software called Omni-TRANS, covering three different scenarios for the horizon 2040. Scenarios covering a horizon of thirty years there may be not exempted from legitimate doubts and reservations about the ability to anticipate with a degree of acceptable certainty, an evolution in the system in the long term. However, this type of work has the virtue to bring us closer, and gives an example of what this article proposes to implement in empirical terms.

Although this modeling has not the characteristics of the underlying CAS (by contrast, the approach is top-down - *world trade megatrends; consequences on the global transport system; global scenarios, modeling scenarios*), provides us a practical example of the specific software platforms betake and the need and usefulness of developing anticipated scenarios, since ports cannot just rely on its own ability and performance but be attentive to developments produced worldwide.

4. COMPARISON BETWEEN MARITIME TRADE AND CAS

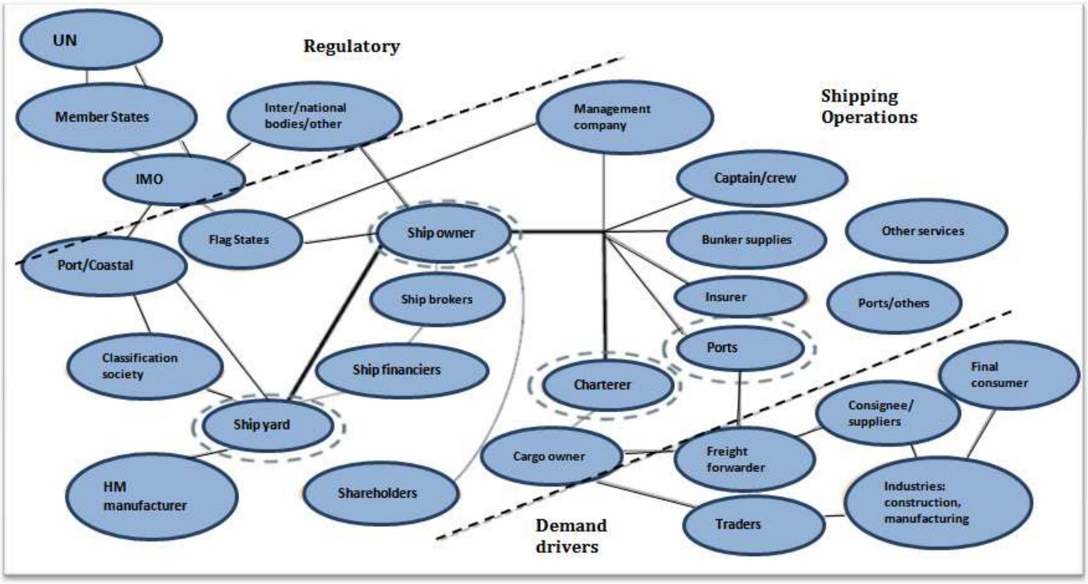
In the previous section it was made known a recent study that takes into account a static analysis of the global transportation network. From this it is concluded that a containerized network is a small world network. This evidence indicates that the underlying structure is not dominated by random rules, and that the complex organization emerges from the interaction of lower-level entities. In maritime transport, self-organization is identified as a bottom-up process resulting from nonlinear local simultaneous interactions between agents (i.e., ships, ports, maritime alliances and nations, according to the scale of analysis).

This allows us to realize that, regarding to the maritime network, the aim is to understand why certain ports are able to play a leading role and also estimate maritime trade trends, since shipping companies compete in the market according to their own interests.

The introduction of technical innovation makes a company more competitive and establishes new rules on the market that force other companies to co-evolve in this direction in order to stay profitable. This adaptation process was witnessed on shipping in different ways, with the introduction of new technologies, such as improvements in fleet (launched of post-Panamax ships) and management processes in ports (automation services of loading and unloading), the strategies of vertical integration of operations (as a way to control the distribution chain), horizontal integration, through the formation of alliances, partnerships and agreements (sharing of ships, containers or terminals) or, more recently, with the use of "slow -steaming"(as a way of rationalizing energy costs).

As shown in Section 1, the international shipping consists of a large collection of entities (Figure 4). Many agents interacting / interrelated, whose interactions create non-linear trends. In this case, the most interesting questions revolve around understanding of how a maritime system evolves in relation to exogenous shocks (coevolution).

Figure 4. The Maritime System (main agents).



Source: Own elaboration (from Caschili and Medda, 2011).

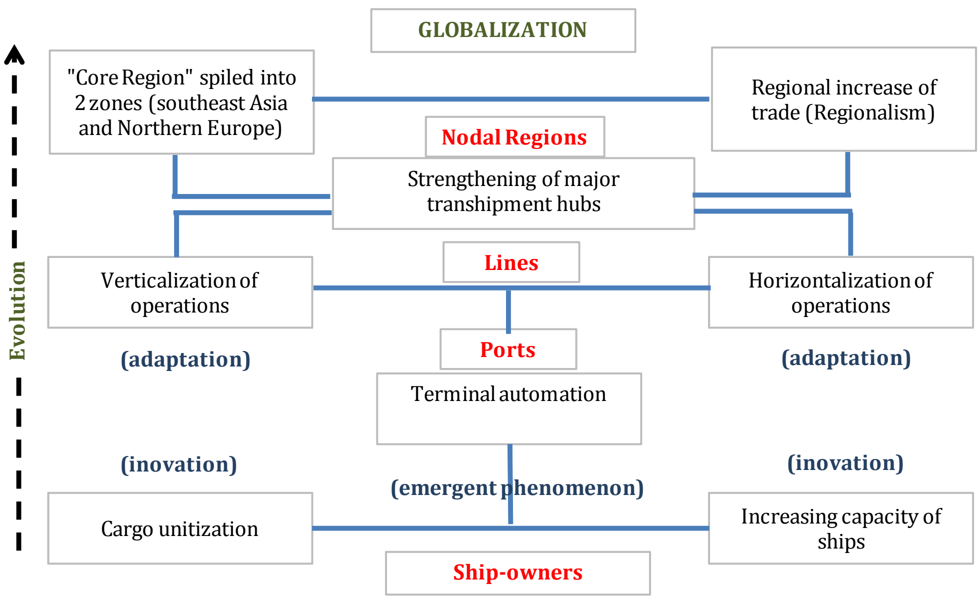
In light of the foregoing, cooperation between agents (shipping companies, port authorities, logistics networks and so on) should be included in the modeling. Similarly (and in accordance with Caschili and Medda), the economic alliances in international trade agreements play a significant role in defining the flows of trade and development. For example, China's entry into the WTO has affected the bilateral negotiations between China and the countries of the WTO and other international trade agreements show similar impacts on the processes of international trade (NAFTA, Mercosur, ASEAN-AFTA).

Another emerging phenomenon that must be considered is the scale of importance of alliances between large ship-owners (a marked tendency for the oligarchy), incorporates the definition of routes, scales, cargo volume and the corresponding determination of the hierarchical degree of ports. On this issue, especially remember the recent agreement between Maersk, CMA-CGM and MSC, the so-called P3, which brings together the three largest shipping companies in the world.

In this sense, the CAS application to international maritime trade helps us to better understand the role of alliances in trade, the effects of the creation of new alliances, or the admission of new members into existing agreements (Emergency). The aforementioned represents some of the questions that an application CAS should be potentially able to respond when political constraints are included in the agents with “modeling behavior".

Figure 5 gives us a picture of Globalization (the outcome of Evolution) and adaptation strategies of agents to changes in the environment (Emergency), in a bottom-up approach – containerized market.

Figure 5. Bottom-up approach applied to international shipping.



Source: Own elaboration.

The unitization of cargo and increased vessel capacity (technological innovation) , gave rise to an emergent phenomenon: it “forces” terminals to incur in an increased automation of container handling in order to respect the ship turnaround times; loads that previously took days to be loaded / unloaded began to be so in just a few hours .

In the later stage and facing the growing demand and availability of cargo, the ship-owners have adopted strategies that have passed through verticalization of operations and not despised the opportunity to operate their own terminals and distribution networks on land, especially railroads (getting the domain of the distribution chain from origin to destination). Another adaptive strategy was in the horizontal direction: through mergers, acquisitions, alliances and consortia (sharing of ships, containers and terminals). The next phase illustrates the result of moving loads to an unparalleled magnitude; the strengthening of various dedicated transshipment hubs and the origin of several nodal regions. The end result is the process of globalization represented by open trade between nations which only occurred because of the large capacity and economies of scale that just shipping can provide.

5. PRACTICAL CHALLENGES AND BENEFITS OF CAS AND FUTURE RESEARCH

In an article published in Nature, Farmer and Foley (Nature 460, 685-686, 2009), called for more applications of CAS in economics, stating that "*agent-based models have potentially a way of modeling the economy as a complex system, as Keynes tried to do, having taken into account human adaptation and capacity of learning (...)*".

Unlike the classical top-down approaches, whose modeling components are carefully designed and evaluated, CAS theory proposes bottom-up methods based on modeling of simple interactions between its components (or agents) that generate complex, robust and flexible phenomena and macro regularities. Applying CAS to shipping can be useful for various purposes. Some of them are listed below:

i) To test standard economic theories and encourage innovation;

ii) To complement any gaps about the spatial patterns of distribution chains;

iii) As analyzing the global shipping networks provides a vigorous and necessary complement for understanding the processes of globalization and regionalization;

iv) Understand the functioning of markets and offer solutions for sustainability and development;

v) To understand the spatial structure and organization of the economies, the formation of regional hubs, clusters of business and industry alliances;

vi) To understand why certain types of cooperation between shipping companies seem to be more adaptable than others and know which factors regulate the stable relationship between them;

vii) To provide policy makers with a set of comprehensive tools capable of solving problems of growth, distribution and well-being connected with the trends of world trade;

viii) To put in place an integrated multidisciplinary approach between the areas belonging to the social sciences. The multidisciplinary communication can allow discerning clues from different areas and accelerating the theoretical and practical advances.

According to Holland (2006), it is necessary to incorporate complexity to the study of economics, a more general theory rather than to characterize the application of ideas and concepts in an ad-hoc posture. This is due to the lack of a universally accepted complexity theory. Even the application of CAS theory does not obey to a common theoretical framework in the application of its concepts. Most of these notions are derived from physical, chemical and biological studies, and their assumptions are "*restricted to the specific content of scientific models used*".

However, economic systems are clearly complex systems, since they are highly interconnected, adaptive, self-organizing and emerging. The scientific community should take steps to building a more sustainable ontological structure as scholars and modelers must draw from this framework, a common approach.

Citing Kochugovindan and Vriend (1998) "*It seems especially difficult to incorporate the essential fact that the interactions taking place between economic agents in reality are not determined by their given position in a grid, graph, or lattice or by some kind of anonymous matching device*", which makes the modeling, and in particular the use of logic models, difficult to perform.

The change in the economic paradigm is not only limited to the changes in the economic model to which the nations have to respond as it represents the displacement of the *locus* of world trade, as different countries occupy the top positions on the international scene; it is in face of this new environment that such studies should be performed and hence its importance.

Despite difficulties and challenges, the application of complex systems theory to international shipping should be promoted, and extend the studies to other agents that are an integral part of the maritime chain (ports, land networks; roads, railway) which completing the architecture movement of loads as a way to take into account the accessibility to the hinterland (Ducruet and Notteboom, 2012: p. 21). Add new elements and actors in a broader approach, can give rise to surprising results. This is also economy of the Sea.

A simple example of the above and that could appeal directly to the decision makers of Portuguese national ports policy is as follows: if the CAS allows us to extract potentially likely developments and adaptations of the systems through the analysis of the decomposed simplest parts, so will eventually be possible to predict that will happen in the northern Iberian peninsula port system after the “sudden conversion" of the port of El Ferrol to containerized cargo segment (Figure 6).

Figure 6. The port of El Ferrol in the Iberian port system.

Source: Own elaboration.

El Ferrol is a port of equal size in comparison to Lisbon in cargo volume but with a predominance of bulk solids, handling no containers before (residual). The questions are the following: will Ferrol competitive hinterland override the one of A Coruña port (covering the north of Galicia, Asturias, León and may even extend further south? The Salamanca Logistics Platform will fall into the orbit of Ferrol? Why invest in a new container port at the entrance of the Cantabrian and only 19 km from the port of A Coruna? Does it a good bet or a miscalculation? Are they expecting loads increase from the enlargement of Panama? And what about the already existing overcapacity in some European terminals? Does it will allow economies of scale in a port of reduced dimensions? The 2-gantry cranes hastily transported from Algeciras with a cost of 2 million in transportation obey to what strategy? What's the rush?

Has anyone lost his time analyzing the new dynamics that this new player will output in the segment and what effects will originate in the neighboring ports, including the analysis to negative effects that a possible diversion of cargo from the port of Leixões will produce, knowing that the operator of both container terminals in the two ports is the same (TCL)?

These are some questions that arise when a particular agent decides to innovate which will lead to a response by the other agents involved: whether to maintain its market share, degree of competitiveness or viability of their operations. Questions that need anticipatory answers and that forms the background that one want to achieve through the application of complex adaptive systems theory to the entire maritime chain.

In conclusion a few brief notes about what was being presented throughout this paper.

The CAS study, although it is a difficult task is equally exciting. The returns are likely to be proportional to the difficulties. Many scientists believe that the reductionist approach provided by CAS is the best way to understand anything; some even believe that is the only way. But the true findings certainly end up being the ones that are taken from each interpretative reading.

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