The Waves of Containerization: Shifts in Global Maritime Transportation

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Abstract

This paper provides evidence of the cyclic behavior of containerization through an analysis of the phases of a Kondratieff wave (K-wave) of global container ports development. The container, like any technical innovation, has a functional (within transport chains) and geographical diffusion potential where a phase of maturity is eventually reached. Evidence from the global container port system suggests five main successive waves of containerization with a shift of the momentum from advanced economies to developing economies, but also within specific regions. These waves are illustrative of major macroeconomic, technological and sometimes political shifts within the global economy. They do not explain the causes, but simply the consequences in the distribution in container traffic and growth (or decline). Yet, they provide strong evidence that containerization has a cyclic behavior and that inflection points are eventually reached, marking the end of the diffusion of containerization in a specific port or port range. Future expectations about the growth of containerization thus need to be assessed within an economic cycle perspective instead of the rather linear perspectives.

Keywords: Maritime transportation, Ports, Containerization, Economic cycles.

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Introduction: the spatial and functional diffusion of the container

Waves and Container Port Development

After more than half a century since its introduction, the container continues its spatial and functional diffusion within global transport systems. Diffusion can be investigated at the level of the container shipping network in terms of growth in the intensity and connectivity of ports, but such an approach would require a substantial dataset to review all the shipping services. A simpler approach is to look at the geographical growth structure of individual container ports. Containerization has diffused to an extensive array of locations and supports a wide variety of supply chains, from retail goods, parts and commodities. Such diffusion is far from uniform, on par with the changes in the commercial geography of the global economy. This is particularly the case relative to the export-oriented strategies of Asian countries that have rebalanced a global trade system that used to revolve around the economic triad (North America, Europe, and Japan). In light of these economic and technological changes, economic cycles are offering a relevant perspective to investigate the spatiotemporal evolution of containerization. Furthermore, there are three other reasons to consider and understand waves when analyzing containerization. The first is that containerization waves are indicative of global changes in a broader economic environment. The second reason is that the waves of containerization raise the general question of the circular relationship between maritime transport and economic development. The third relates to forecasting future containerized traffic, an exercise that commonly considers growth processes in a linear fashion while the extent and rate of the growth is nonlinear; cycles are a relevant perspective to articulate this nonlinearity.

Waves (the term 'cycle' is used interchangeably) are amply covered in the business and economic literature but many of their aspects, such as duration and amplitude, are subject to debate. The duration of a wave is related to the process being looked at. One of the longest, the Kondratieff wave (often referred to as a K-wave), usually imply a time frame of 45 to 60 years and try to depict technological diffusion within economic systems (Barnett, 1998). Kuznets waves (15 to 25 years; demographic changes), Juglar waves (7 to 11 years; major investments in fixed capital) and Kitchin cycles (3 to 5 years; manufacturing and inventory cycles) refer to events of shorter duration and have been evidenced (Korotayev and Tsirel, 2010). Changes are usually measured through growth rates of an economic activity, such as GDP, production, commodity prices or sales. A notable branch of investigation concerns product life cycles and the shifts in the geography of production as a product goes through distinct phases. These usually involve introduction (or adoption), growth (or acceleration), peak growth, maturity and eventual degeneration (e.g. Hayes and Wheelwright, 1979). There is also a seasonality in many commercial activities, particularly in retail, which can be considered a cycle occurring annually. Waves are also covered by the geographical literature on the spatial diffusion of innovations (e.g. Hägerstrand 1963, Alves and Morrill, 1975; Rogers, 2003) with many processes following a diffusion process that can be contiguous or hierarchical.

The conceptual usage of waves within maritime and port studies is much more limited, but implicitly implied in port development models (e.g. Bird, 1963; Hayuth, 1981), in particular for the literature addressing the diffusion of containerization (e.g. Levinson, 2006; Notteboom and Rodrigue, 2009; Rodrigue, Comtois and Slack, 1997). Yet, these approaches consider containerization as a whole and have not looked at what cycles imply at the individual port level and the fact that different ports have been part of different growth patterns and thus part of different economic cycles. While studies looking at the dynamics of individual port or port range are common, global investigations appear much less prevalent (e.g. Fremont, 2007; O'Connor, 2010; Ducruet and Zaidi, 2012). One reason that can be advocated for this shortcoming is that such an approach requires familiarity with global macroeconomic processes and international trade, areas where port studies have conventionally not placed much focus.

The wave approach can be applied to an individual container port, a port range, or to the whole global port system to better capture their temporal and spatial dynamics. The framework offered by Kondratieff waves (K-waves) appears suitable since its time frame matches the functional and spatial diffusion of containerization (45 to 60 years). Thus, it is argued that containerization is a K-wave process, which is obviously incomplete and characterized by different levels of maturity depending on the markets. It is also argued that within this K-wave, specific phases in container port development are taking place, such as introduction, acceleration, peak growth and maturity (Figure 1). Yet, what these phases imply in the geographical diffusion of port containerization is not clear and needs to be identified. For an individual port, a K-wave represents the full realization of its hinterland (gateway) and foreland (hub) potential in light of geographical and site characteristics. For a port range, a K-wave relates to the setting and interrelations of its ports to service its commercial hinterland, implying a rank/size outcome in the port structure with a few major gateways dominating. Often, there are few major drivers (hinterland or foreland related) behind each wave, which explain the evolution of a set of ports. However, it should be noted that two very different ports (i.e. hub and gateway) can belong to a same wave, even if their drivers are different. What matters here is the shape of their trajectories over time, namely when they adopt, develop, and reach a stage of maturity.

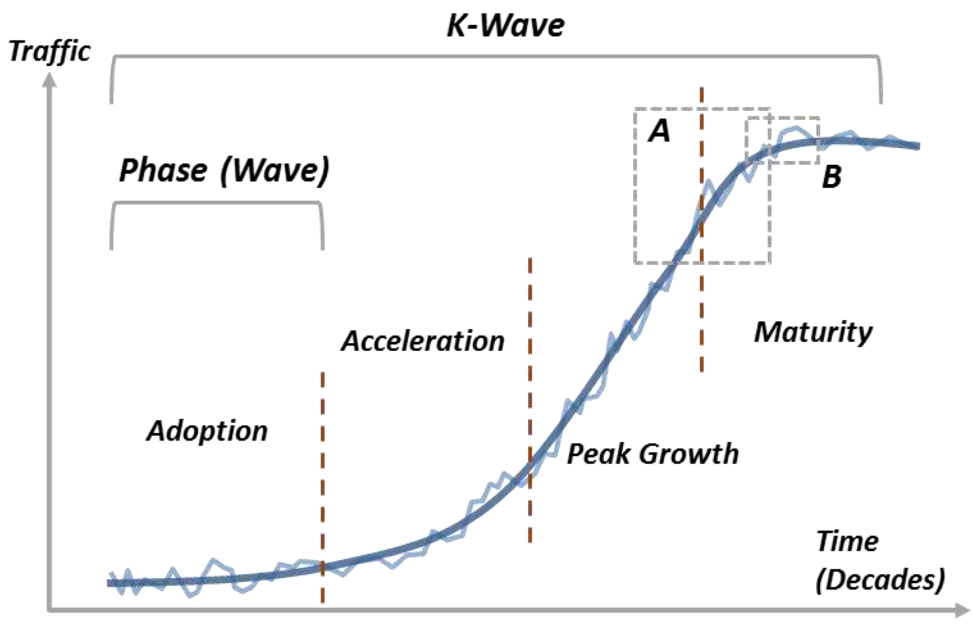

Figure 1 : The K-wave, Phases of Containerization

A transition (also called medium wave) considers the changes taking place within a K-wave where the system is undertaking a shift from one phase to another; an inflection point taking place over a few years. For instance, during a transition a port may shift from peak growth to maturity due to changing market conditions, such as demand saturation in its hinterland. Transitions are therefore particularly useful at identifying the time frame and the conditions associated with this shift. Otherwise, there is no change in the growth conditions and patterns during the considered time frame and thus a port remains within its existing phase.

Methodology

The paper investigates economic cycles as components of the demand of containerized maritime transport over a K-wave, and this mainly at the global level. Within this temporal framework the paper tries to identify specific growth phases of the geographical diffusion of containerization that can be statistically evidenced. It will also look at recent transitions that can underline which segments of the container port system have achieved a phase of maturity.

Before analyzing the waves of containerization, the evolution of global container throughput and its concentration level is investigated. We apply the Gini coefficient, a widely used index that measures the deviation from a perfectly uniform distribution of container throughput between ports (Kuby and Reid, 1992, Notteboom, 1997, 2010).

The identification of phases (waves) within the K-wave will rely on cluster analysis where a large sample of container ports is categorized according to their growth pattern, namely its time frame and scale. Hierarchical Cluster Analysis (HCA) is a statistical method commonly used for finding relatively homogeneous clusters of observations based on their measured attributes. From a dataset, HCA finds groups (clusters) that minimize their endogenous dissimilarity according to a set number of groups. Initially it places each observation in a separate cluster and then combines the clusters sequentially, reducing the number of clusters at each step until only one cluster is left. When there are N cases, this involves N-1 clustering steps. This hierarchical clustering process can be represented as a dendrogram where each step in the clustering process is illustrated by a join of the tree until only one branch is reached. It is for the analyst to decide on the relevant number of groups, but such a choice is made in light to have the minimum number of groups possible with an acceptable level of dissimilarity. The Ward clustering procedure takes into account the chi-square distances between the profiles and the associated observations (Everitt, Landau and Leese, 2001). This way it provides a decomposition of inertia with respect to the nodes of a dendrogram. The total dissimilarity of the dataset is reduced by a minimum at each successive level of merging the observations.

Cluster analysis has been used to identify the long waves of containerization between 1970 and 2010 in five-year increments. There are two reasons for using five year increments instead of annual data. The first and most important reason is that the approach on long waves focuses on long term trends of maritime transportation, rather than on short term traffic fluctuations (mainly linked to local specificities of ports, outside the scope of the study). Selecting five-year intervals is therefore an approach that captures long term trends while avoiding short term variations. The second reason is incomplete data over long time series covering a large number of ports. The HCA is particularly well adapted to the identification of long waves because it allows the distinction of homogeneous clusters of ports simultaneously based on the variation of their shares of global container throughput and on the shapes of their trajectories over time. A review of the literature underlines that this methodology appears to have had limited application to the dynamic analysis of cycles (e. g. Kuczynski, 1980) and even fewer applications to port studies could be identified (Guerrero, 2010). For instance, HCA has mainly been used in a static way, to classify ports by their function and performance levels (e.g. Tongzon, 1995; Ducruet, Koster, Ven der Beek, 2010). This methodology has also been applied to processes in other fields of geography. Two recent papers on the vegetative seasons of French wineyards (Bonnefoy et al, 2013) and on the demographic trends of Romanian cities (Camara, 2011) have used HCA in such a fashion. The HCA technique has also been used to categorize trends over time in statistics (Maharaj, 2000, Warren Liao, 2005). According to Maharaj: "results show that it is possible for [time] series on different levels but having similar patterns to cluster together" (Maharaj, 2000, p. 312).

An analysis of Changes of Port Share (CPS) in global container throughput will be used to identify the nature and extent of transitions between long waves. Here, these transitions are called medium waves. The method used (CPS) is less sophisticated than HCA because it only takes into account the variation of the port shares of global container throughput between two time points. It allows to determine whether the trends identified for the long waves is continuing or if there is a divergence. For this purpose the focus is put on the 2000s decade, one that has seen fundamental changes in the structure of global shipping networks with the rapid rise of new ports, namely in China, but also of transshipment hubs at intermediary locations. This period has also seen since 2008 the most significant commercial shift since the beginning of containerization with a significant drop in traffic among the bulk of the world's major container ports, particularly in Europe and North America. The analysis CPS considers two periods, one acting as a reference and the other as the case to evaluate the difference from the reference period. If an observation has the same share of the total traffic in the case period compared with the reference period, then its shift share is close to zero. A negative CPS implies that an observation has less traffic than expected (if its share remained constant), while an increasing CPS (positive) implies the opposite. The analysis is very useful to evaluate the level of divergence from a reference distribution and to identify observations that are standing out.

Global shifts in production and transportation

The Dynamics of Containerization

Containerization has been the most dynamic physical component of globalization, far exceeding the growth of the value of exports and the GDP (Figure 2). As globalization developed, each new individual, GDP or export unit was associated with a higher level of container flows. While up to 1980 the growth of container port throughput was on par with the growth of the value of exports and GDP, a divergence was noted afterwards; they were decoupling. Each unit of GDP was associated with a greater level of exports and even greater levels of container throughput. Nevertheless it should be noted that this decoupling between maritime container transportation and GDP in the early 1980s is not specific to the container market. The same trend has been observed, for instance, in the context of European short sea shipping (Verny, 2007). It was the outcome of industrial location changes and their impact on freight distribution. The irregular and limited growth of ton-kilometers in the late 1970s and early 1980s was mainly a result of an increase in distances travelled. The development of free trade agreements and the decline of tariffs have also contributed to the growth of trade in the last four decades, underlining a decoupling between GDP and exports. It is still too soon to measure the impacts of the financial crisis of 2008-2009 on free trade agreements, exports and container volumes. Protectionist attempts on trade remain so far marginal (Kee at al. 2013).

Containerization entered the acceleration phase of its diffusion cycle as a fundamental support of export oriented strategies pursued by Asian economies. Therefore, an array of growth factors is at play to explain the substantial growth of containerization and more interestingly the contribution of these factors in time varies. For instance, in the 1970s, growth involved the substitution of general cargo handling tools by the container. In the 1980s and 1990s the growth of international trade was a strong driver while in the 1990s and 2000s the development of intermediary hubs played a role.

While additional traffic resulting from economic growth is the most salient factor, imbalanced trade flows (empty containers) and the configuration of shipping networks relying on transshipment hubs (double counting of containers) have also contributed to additional containerized flows and port handlings. As economies of scale were applied to maritime shipping, transshipment became more salient. The quantity of containers being transshipped increased from roughly 11per cent of all cargo handled by container ports in 1980 to about 30 per cent in 2010.

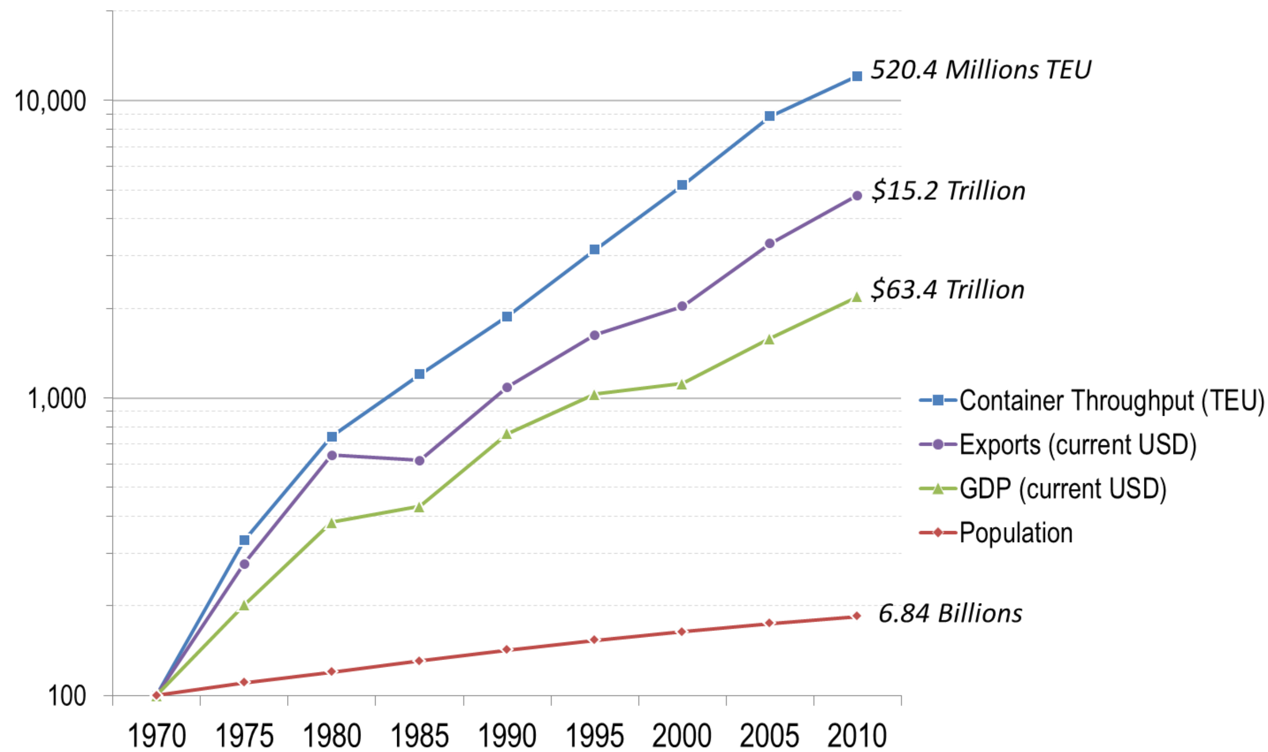

Figure 2 : Global Trade and Container Throughput (1970=100)

Also, Figure 2 brings forward questions about the additional growth and diffusion potential of containerization in light of receding economic opportunities (production and consumption) and the expected demographic shifts, namely the stabilization of the global population in the next decades as well as its ongoing aging (Lutz et al., 2001, 2008). For instance, if container throughput was to double from the 520 million TEU figures observed circa 2010 to 1 billion TEU, then what would be the level of related consumption and the physical capacity of transport infrastructures to handle such a level of material flows? Obviously, this question cannot be readily answered and on several occasions in the past such points were raised and turned out to be invalid. Still, the K-wave perspective underlines that maturity will eventually be achieved for global containerized freight distribution and that close attention must be paid to identify inflection points. Future expectations about the growth of containerization thus need to be assessed within an economic cycle perspective instead of the rather linear perspectives in which containerization is generally considered.

Identifying Port Containerization Phases

At the global level, the four phases of the product life cycle have been inferred to the development of containerization (Notteboom and Rodrigue, 2009; Rua, 2012), which follows an S-shaped curve. During the *adoption* wave of the early 1960s, containerization was still an unproven technology with a few competing standards in terms of sizes and latching systems. The services offered were specific (point to point), mostly using converted cargo ships. Containerization demonstrated that it was achieving productivity gains since it involved a much more efficient form of port operations. During the early 1970s, containerization entered its *acceleration* wave and was recognized as a promising mean of transportation. New services and consequently new networks were being established, which multiplied its productivity, with growing volumes and the beginning of the application of economies of scale, both for modes and terminals. In the 1980s, pendulum services, which would become the standard network configuration for containerized maritime shipping, were being set across maritime ranges, particularly the Atlantic (Slack, 1999).

By the 1990s, containerization became the dominant support of global trade and entered its *peak growth* wave. Its diffusion was massive, particularly in industrializing economies such as China. Network development was facing growing complexities, which led to the setting of major transshipment hubs reconciling regional and global shipping networks. As economic cycles theory underlines, systems eventually reach a phase of *maturity* where growth is much less related to diffusion but with standard economic changes and the exploitation of remaining niches, both functional (e.g. the containerization of commodities) and locational (e.g. a new transshipment hub at a low deviation location). It remains uncertain to what extent this phase may have already been achieved in some parts of the world. For instance, the maturity of containerization in Japan appears well established with limited growth prospects and may also emerge in parts of North America and Europe. Yet, in regions such as Latin America, Africa, South Asia and the Middle East, containerization still has substantial potential for growth.

Shifts in Traffic Concentration

The use of concentration measures, particularly the Gini coefficient, is prevalent in port studies, even if the coefficient is a technical measure that does not reveal the processes behind the changes in the level of concentration (Notteboom, 2006). Based on a sample of ports derived from Containerization International and having a traffic of more than 150,000 TEU in 2010, the number of such container ports grew from 57 in 1970 to 317 in 2010 (Figure 3). Compared to the growth in traffic the number of ports have followed an S-shaped curve as it has increased rapidly in the late 1970s and then slowed down in the 2000s. The number of ports appears to be a leading indicator for the growth of containerized traffic and the recent stabilization in the number of container ports may be indicative of a forthcoming stabilization of containerized traffic.

The concentration of cargo has also changed considerably between 1970 and 2010. The Gini coefficient reveals two distinct periods, mainly resulting from the strategies of global shipping alliances and terminal operators. The first (1970-1990) is characterized by an uninterrupted trend of concentration of container throughput (from 0.57 to 0.70) with the emergence of mega hubs (e.g. Hong Kong, Singapore, Rotterdam, Hamburg). The second (1990-2010) is characterized by a stabilization of the trend with the coefficient hovering around 0.70. This can be attributed to two main trends. The first being the growth of container ports in developing economies, particularly China, and the second is the setting of new transshipment hubs in locations that previously saw limited containerized trade (e.g. Dubai, Gioa Tauro, Algeciras, Panama).

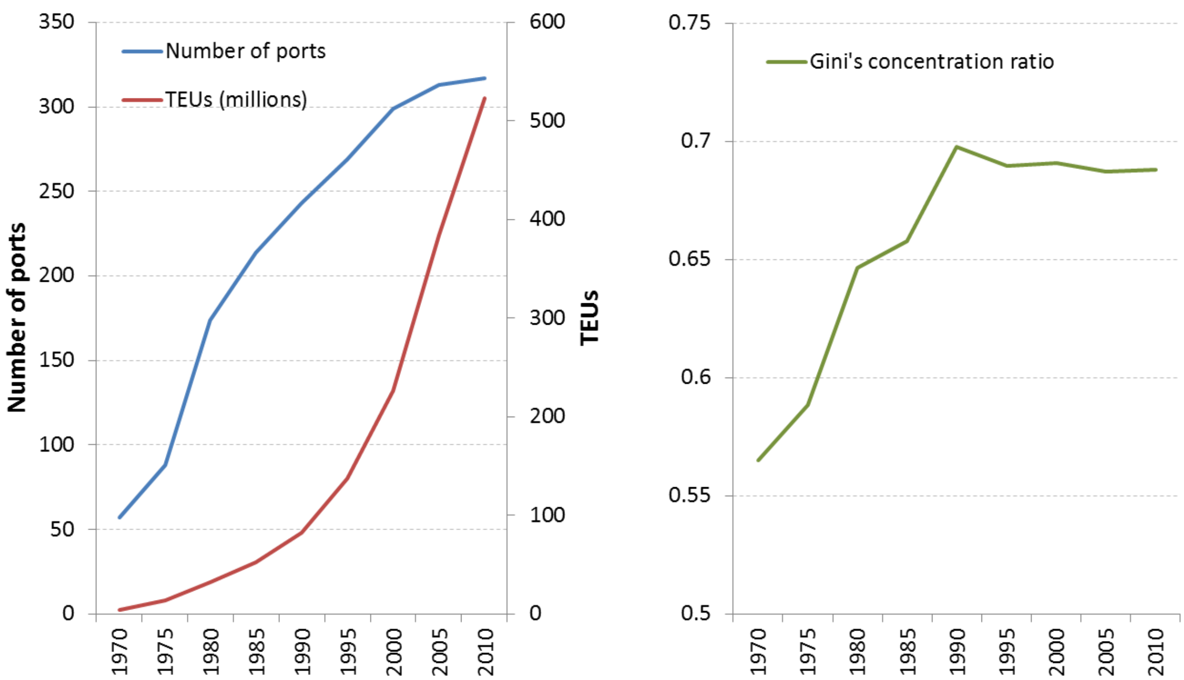

Figure 3 : Concentration of the Global Container Port System, 1970-2010

The trend of concentration from the 1970s to the 1990s is particularly evident at the top of the container port hierarchy (Figure 4). In 1970 7per cent of all ports (n=4) were handling 25 per cent of the total container throughput. In 1995, only 1 per cent of all ports (n=4) were handling the same traffic share while 7 per cent of all ports (n=28) where handling 50 per cent of the throughput. Since 1995, the trend, as evidenced by the Gini coefficient, has stabilized with around 21 per cent of all ports handling 75 per cent of the global throughput. Thus, between 1995 and 2010 there has been little change in the level of global traffic concentration, underlining that global container port system relies on different dynamics than concentration since the main hubs have already been established.

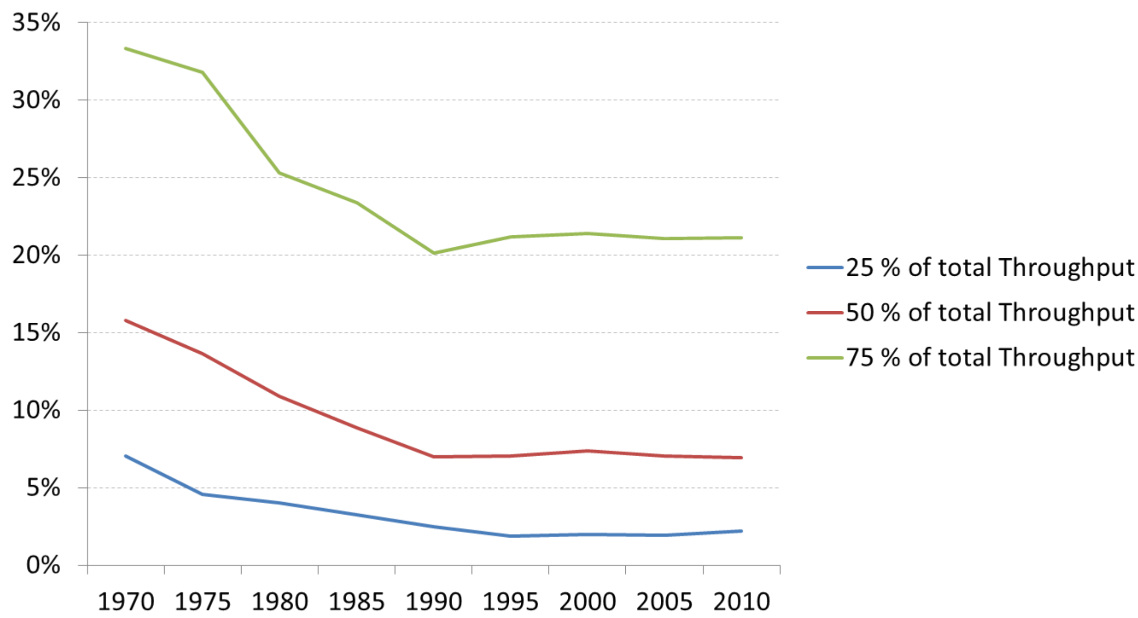

Figure 4 : Percentage of Ports Needed to Handle 25%, 50% and 75% of Total Container Throughput, 1970-2010

Waves of containerization

Identifying Long Waves

The data for the analysis was taken from Containerization International (CI) figures and retained over five-year increments that include nine periods from 1970 up to 2010. The main selection criteria was that the port should have exceeded a traffic of 150,000 TEU for a year in the time sequence and that data was available for 2010. A total of 316 container ports were retained for the analysis. However, there were 61 missing observations from the CI database out of a total of 2844 (316 ports x 9 time periods), the majority of them for ports of less than 500,000 TEU. For these missing observations a linear interpolation was performed from data available for adjacent years (e.g. calculating missing traffic data for 1985 using available data for 1984 and 1986). This enabled us to keep 61 ports in the sample by inferring traffic with a good level of confidence. If there was more than one missing data in the time sequence, then the port was discarded.

The comparative size of ports requires caution as several ports can be considered more statistical agglomerations than functional entities. For instance, the port of Shenzhen in the Pearl River Delta is composed of several large port facilities (e.g. Yantian, Chiwan, Shekou) that act as distinct operational entities with each port often servicing different hinterlands. The same observation applies to Guangzhou and Shanghai that are multiport (terminal) entities. The agglomeration effect may hide different dynamics and even membership to different waves, but because the data is collected at the port authority level, these nuances cannot be identified and analyzed here.

Applying the HCA methodology to the container port dataset resulted in the selection of seven classes where each component has a similar temporal and growth behavior (Figure 5). This result can be justified by the shape of the bar chart, which reveals the structure of the port dataset. Two ports are considered similar when their growth pattern between 1970 and 2010 are alike. Inversely, two ports are considered dissimilar if their trajectories are not alike. When the increase in dissimilarity level between ports is strong (measured by the intra-class variance), a level where grouping groups of ports that are already homogeneous has been reached. This criterion is taken into account to decide when to stop aggregating groups of ports. In this case, adding more classes, such as going from seven to eight classes does not drop the level of dissimilarity in a significant manner (10.20 to 9.36), while using less than five classes substantially increases dissimilarity (18.95 to 30.96). While seven classes appear optimal, the dendrogram underlines their respective distinctiveness and the relevance of using sub-classes in two cases. Therefore, instead of having seven waves (A to G), five waves can be identified (A to E) with two waves having phases (B.1 and B.2 as well as D.1 and D.2), that are close but differ slightly on the times of adoption and acceleration. The earlier the class branches out on the dendrogram, the more the class is distinct and cohesive.

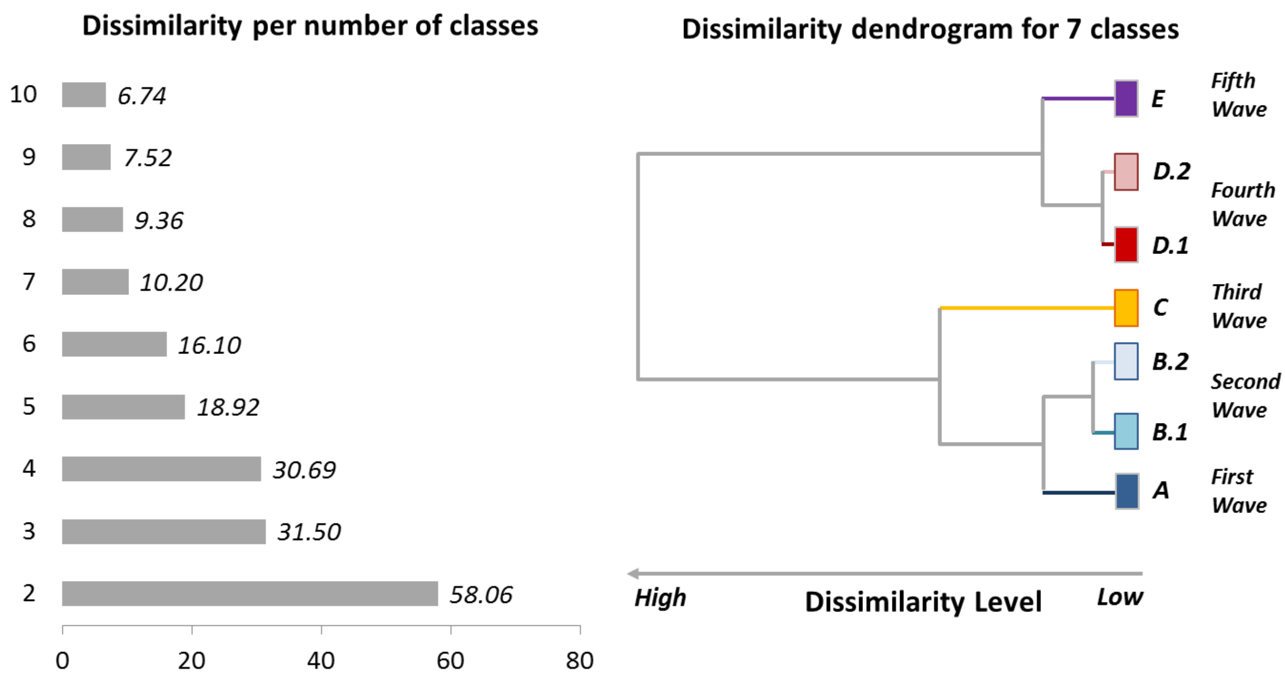

Figure 5 : Hierarchical Cluster Analysis Parameters of Global Container Ports, 1970-2010

By using HCA, the evolution of the global container port system can be divided into seven classes representing five long waves (Figure 6). Each wave represents a specific temporal growth pattern of containerization. It is worth underlining that the inclusion of a port to a specific class does not imply that the port was not handling container traffic in prior periods, but that traffic growth became significant in the wave the port belongs to. While at the aggregate level the growth of container traffic is high, each class depicts a different growth dynamic reflecting their specific development.

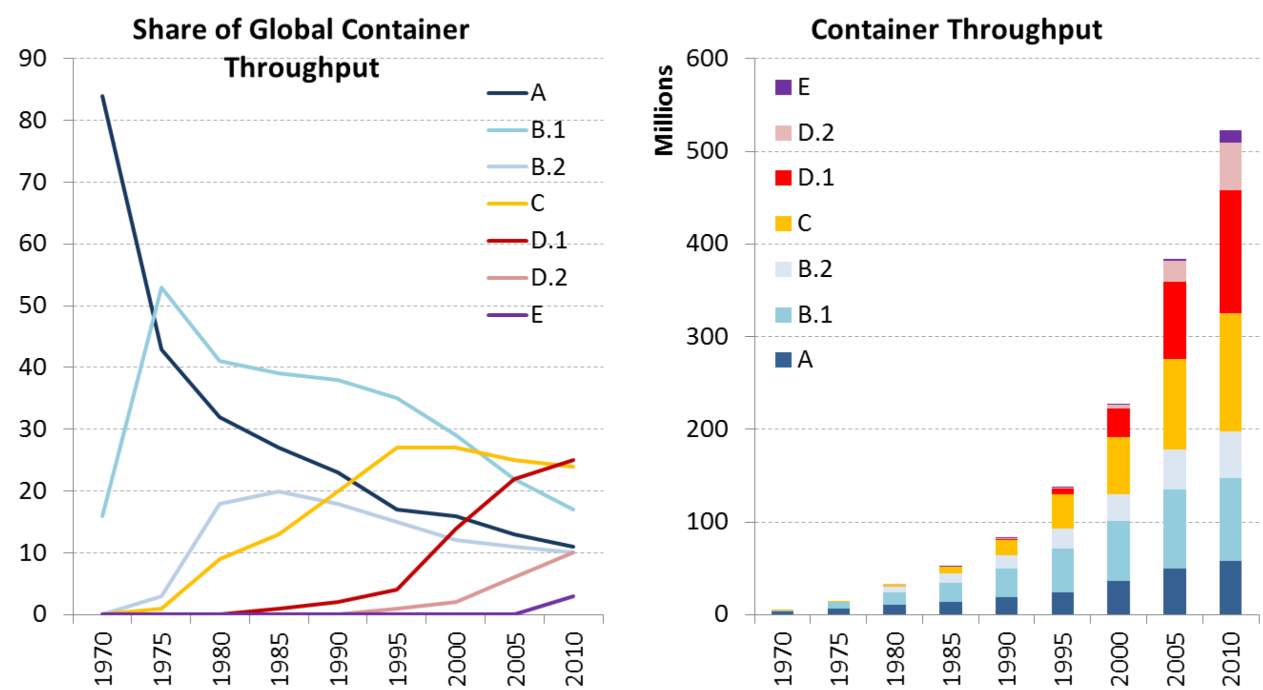

Figure 6 : Evolution of Absolute and Relative Container Throughput by Hierarchical Cluster Analysis Class, 1970-2010

Figures 7 to 11 each depict the global container traffic at a representative year of the seven waves (each decade from 1970 to 2010). It is important to underline that the classification range of each wave is different to better depict the relative importance of container ports at specific points in time.

First Wave (A): The Pioneers of the Triad

The first containerized services were established by Sea-Land in the late 1950s and early 1960s (Figure 7). By the 1970s, regular trans-Atlantic (Northern range of Western Europe and American East Coast) and trans-Pacific services (Japan, Australia to a lesser extent and American West Coast) were established through ports that were the first to adopt containerization and are thus considered to be the pioneers (e.g. New York, Yokohama, Oakland and Hamburg). They are almost all part of the economic triad which led globalization; North America, Western Europe, Japan and Australia. These ports accounted for the dominant share (about 80 per cent) of the global throughput in 1970, but this share fell rapidly afterwards. Few of these ports kept their primacy, which is in part explained by the fact that the rationale behind their emergence played to a much lesser extent or that limited room was available for terminal expansion.

A port site could be suitable to a specific volume, but once this volume has been reached, there are limited opportunities for port expansion. For instance, the initial primacy of Oakland was overtaken by the ports of Los Angeles / Long Beach covering a wider regional market and having more room for expansion and better inland connections. The exception is Australia where Sydney and Brisbane remained dominant gateways. The first wave underlines that several pioneers were able to initially capture the opportunities of containerization, but due to market or technical reasons, were unable to keep this initial advantage often because of factors completely outside their control such as a shift in trade patterns.

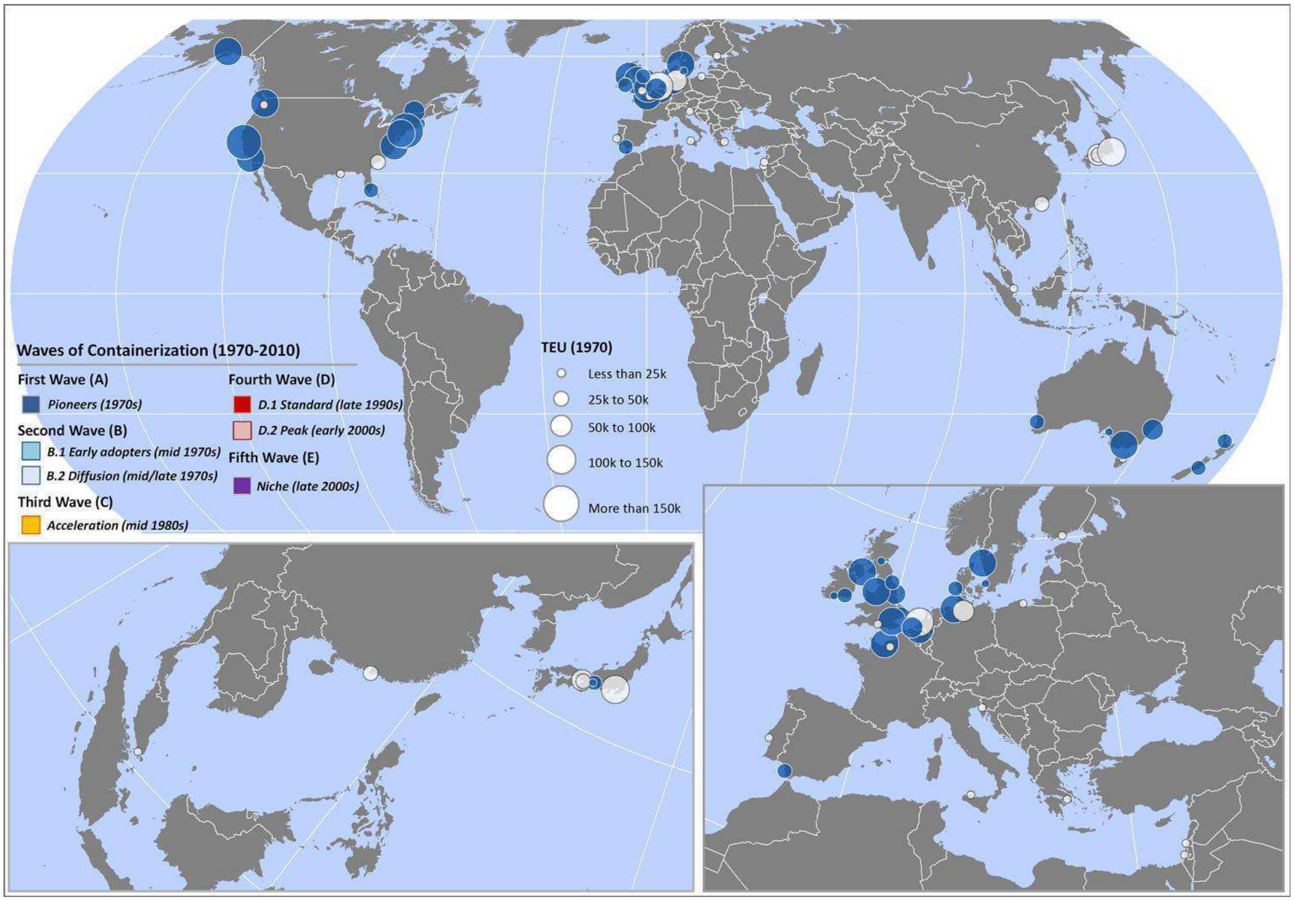

Figure 7 : The First Wave of Containerization, 1970 – The Pioneers of the Triad

Second Wave (B): Adoption in the Triad and its Periphery

The second wave represents an expansion of containerization within the triad as well as with its regional trade partners. It takes place in two phases with the first (B.1) occurring in the mid-1970s and accounting for a larger share of the world's throughput (Figure 8). While many of these ports were operational in the early 1970s, their market share increased and several became the world's dominant container ports, until overtaken by Chinese ports in the 2000s. This shift took place not because of a lack of growth for wave B.1 ports, but because of differential growth rates. Salient examples include Rotterdam, Tokyo and Hong Kong.

Wave B.2 began in the late 1970s and mostly took place in ports adjacent to the triad, such as in the Caribbean, Latin America, the Mediterranean, and among emerging East Asian tigers (Thailand, Taiwan and Hong Kong). From a pattern dominated by the triad, containerization undertook the initial phase of its global diffusion by embedding itself in commercial relations through a substitution effect of conventional break bulk trades. More intermediary locations in the Middle East (and India to a lesser extent) were also involved since the growth of containerized shipping between Asia and Europe presented opportunities to add port calls along pendulum routes. Figure 8 underlines that this wave (and the first wave as well) is dominantly bound to the dynamics spearheaded by North America, Western Europe and Japan.

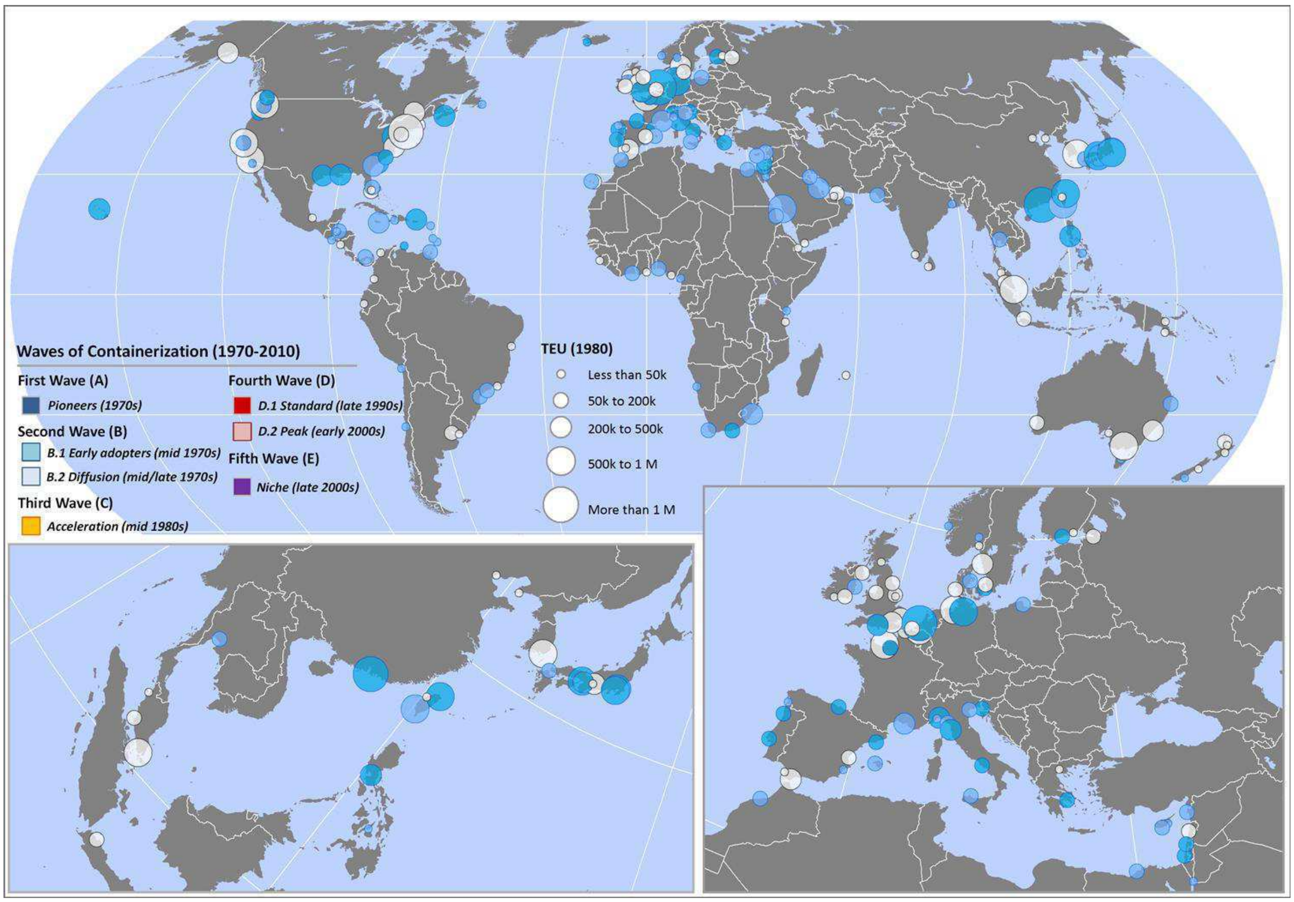

Figure 8 : The Second Wave of Containerization, 1980 – Adoption in the Triad and its Periphery

Third Wave (C): Internationalization

The third wave concerns the largest number of ports and captures the massive diffusion of containerization, particularly the incorporation of East and Southeast Asia (without China) in global trade relations through the beginning of offshoring as well as the emergence of early transshipment hubs (Figure 9). As the number of container ports increased, the network strategy to serve them favored a shift from point-to-point services along pendulum routes to the usage of hubs-and-spoke services. Indeed, several ports that emerged during this wave became major transshipment hubs through their intermediary locations along major shipping corridors such as Singapore, Colombo, and Dubai. Many of these ports are small market oriented city-states located on the edge of much larger countries (e. g. Indonesia [Singapore], India [Colombo], Iran [Dubai]) not so open to global trade. During that period (mid-1980s) it was difficult to get transport documentation that encompassed all the steps through to the final destination country; so containers were consigned to these hub ports, at which local freight forwarders and banks with good contacts in the destination country took responsibility of the final leg of the journey. This wave is statistically the most distinctive since the growth takes place in a similar time frame (mid-1990s) and at a similar level.

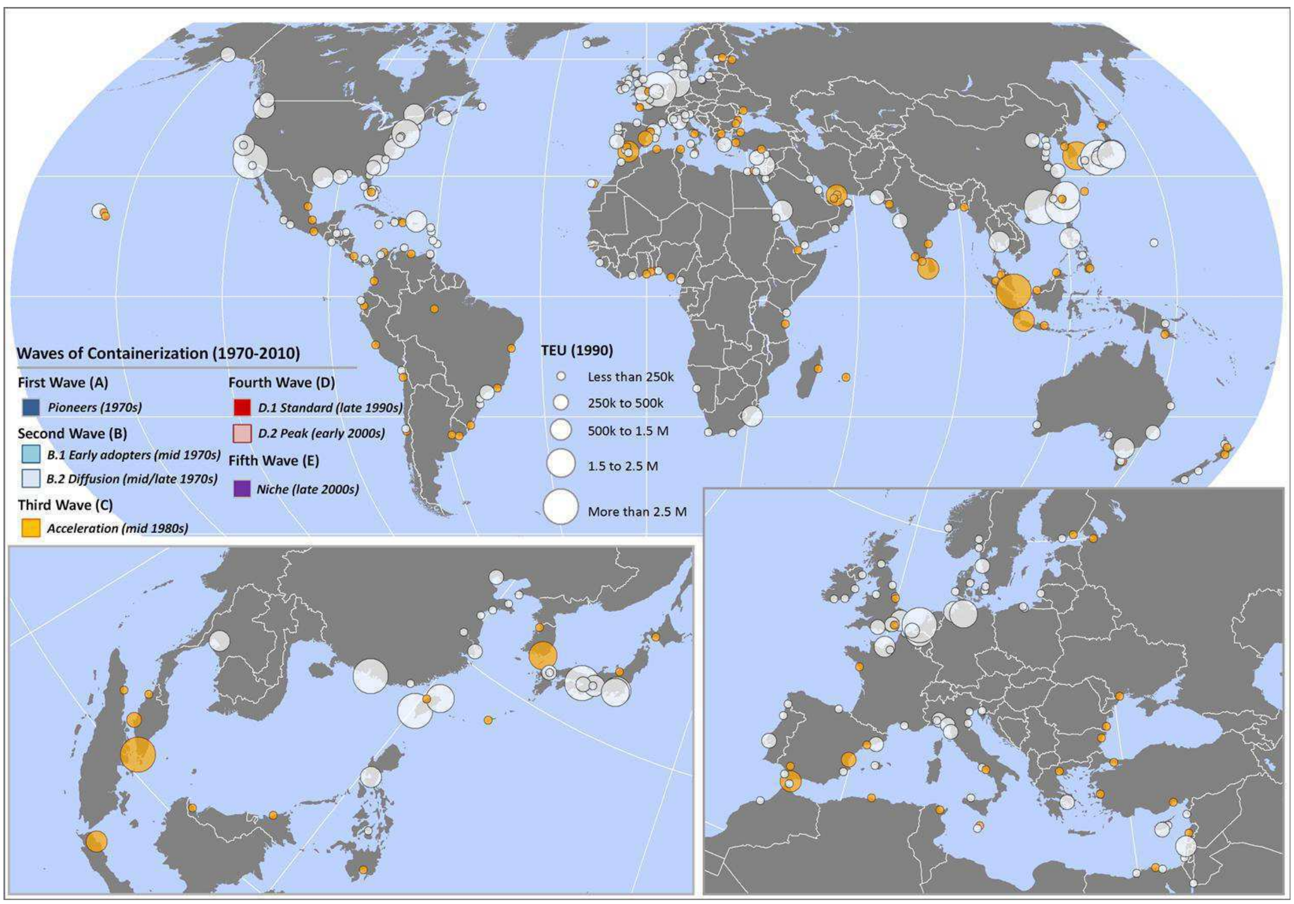

Figure 9 : The Third Wave of Containerization, 1990 – Internationalization

Fourth Wave (D): Global Standard

The fourth wave concerns two phases, D.1 and D.2, which are similar in their pattern and only different in their sequence (Figure 10). From the mid-1990s, the container became the standard mean for global freight distribution, particularly with the massive entry of Chinese ports in global shipping networks (D.1) and the emergence of post-panamax ships. Furthermore, this wave also represents the increasing regionalization of East Asian countries with the resulting trade growth as one of the drivers of the growth of East Asian ports. Several ports in this wave are new transshipment hubs that have been inserted to accommodate the growing network complexity and to better link regional ports to deep sea services (e.g. Salalah, Gioa Tauro, Colon, Freeport). New gateways are also emerging to accommodate growth in emerging economies (e.g. Vietnam, Mexico, India, Brazil).

The later stage of that wave (D.2) concerns China gateway ports that provide additional export capabilities (some spillover effect) for massive manufacturing clusters (e.g. Ningbo, Guangzhou). For the rest of the world, they mostly concern additional transshipment hubs being set by global terminal operators (e.g. Tanjung Pelepas).

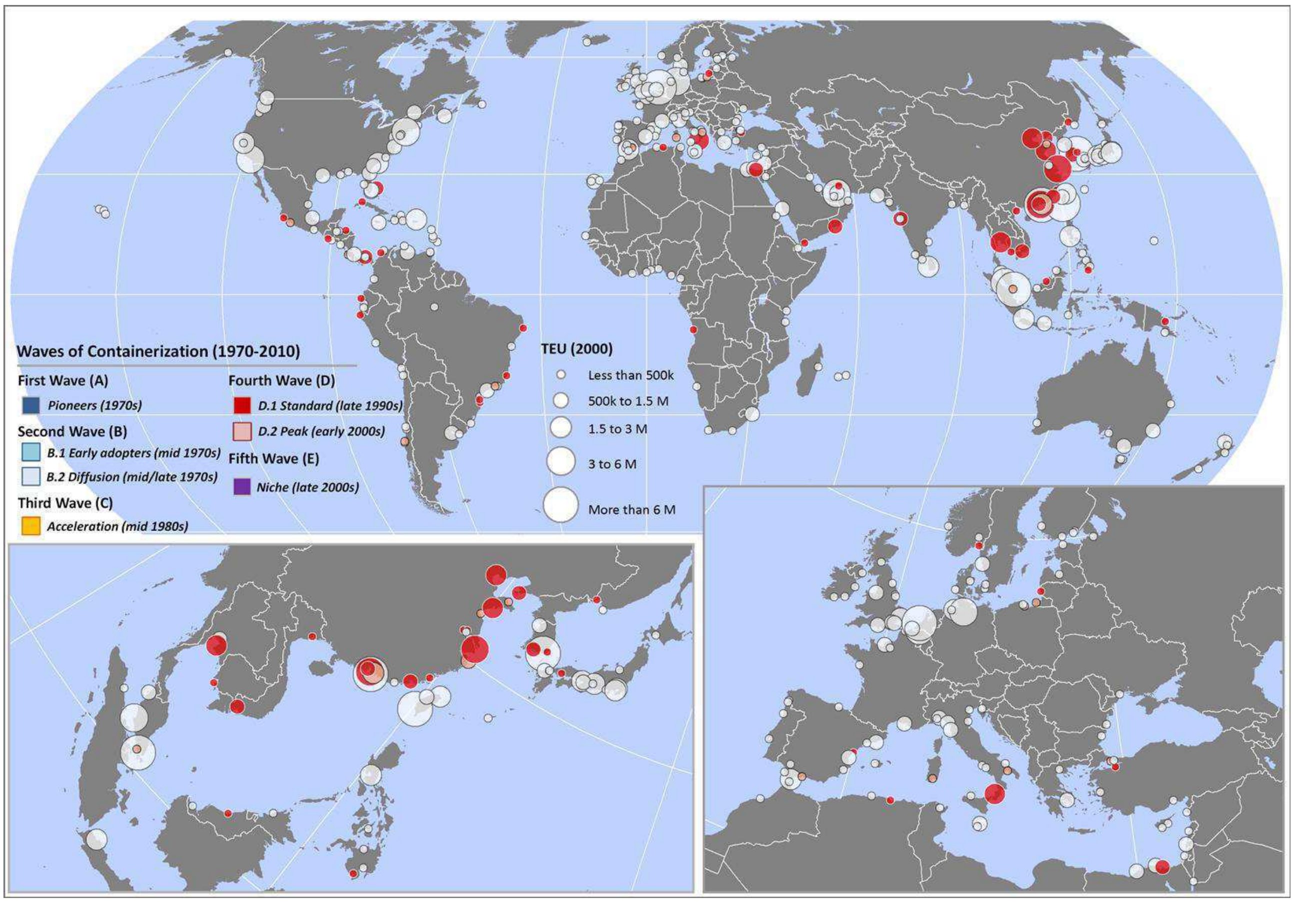

Figure 10 : The Fourth Wave of Containerization, 2000 – Global Standard

Fifth Wave (E); Peak Growth

The fifth wave concerns ports that have emerged recently (late 2000s) and is linked to peak growth in global container shipping. It is particularly one of niche ports filling a specific role, such as a new gateway to cope with congestion along a range (Yingkou or Taicang), or a new transshipment hub being inserted within maritime shipping networks (e.g. Tangier Med, Caucedo) (Figure 11). Prince Rupert in Canada is the only port of significance that has emerged on the North American west coast in recent years, capitalizing on short trans-Pacific transit times and a direct rail connection to the heartland (Chicago).

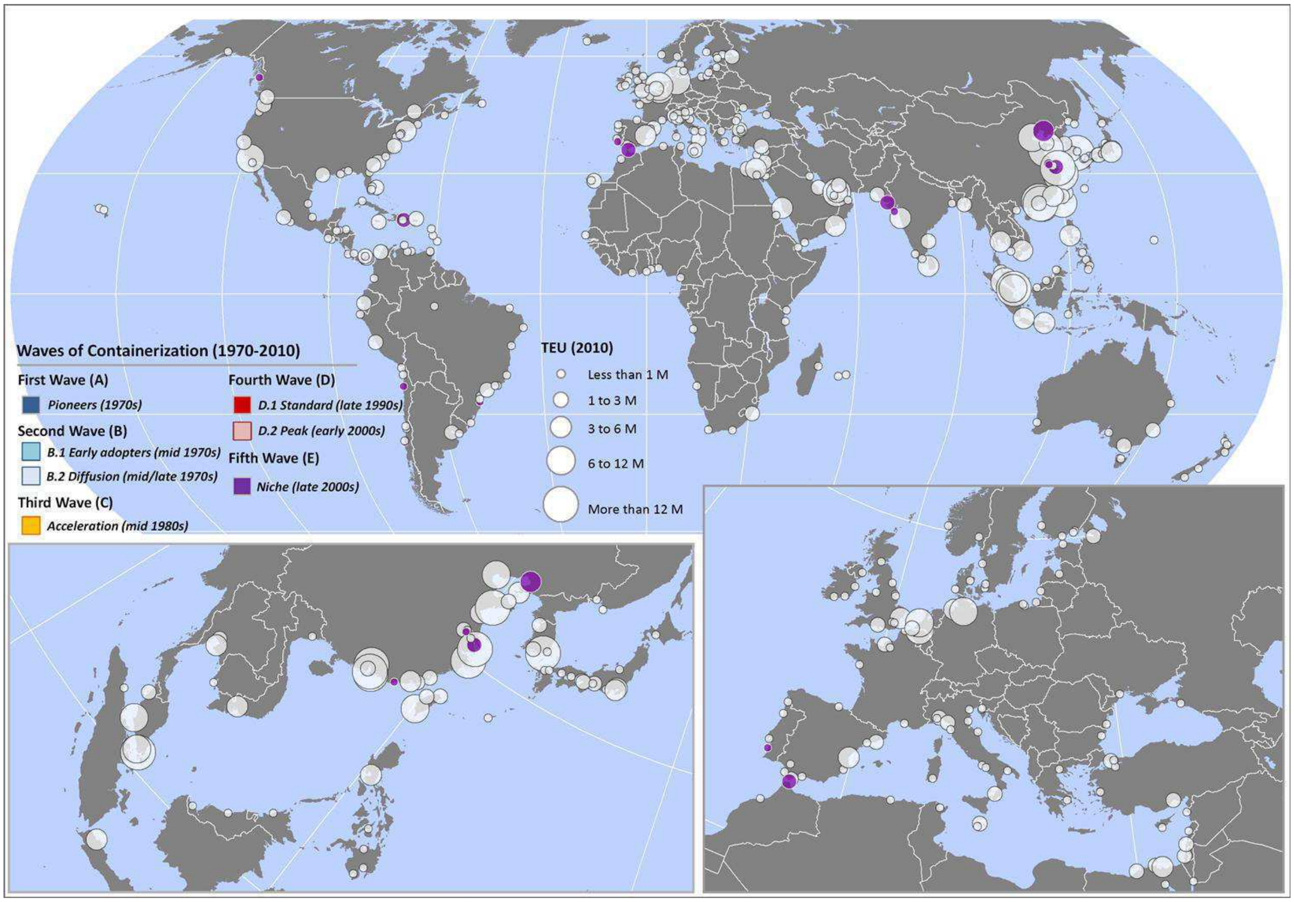

Figure 11 : The Fifth Wave of Containerization, 2010 – Peak Growth

The cumulative waves are depicted in figure 12, which shows global traffic in 2010 and the wave (cluster class) to which each ports belongs. Table 1 provides a synthetic overview of the characteristics and drivers of each wave.

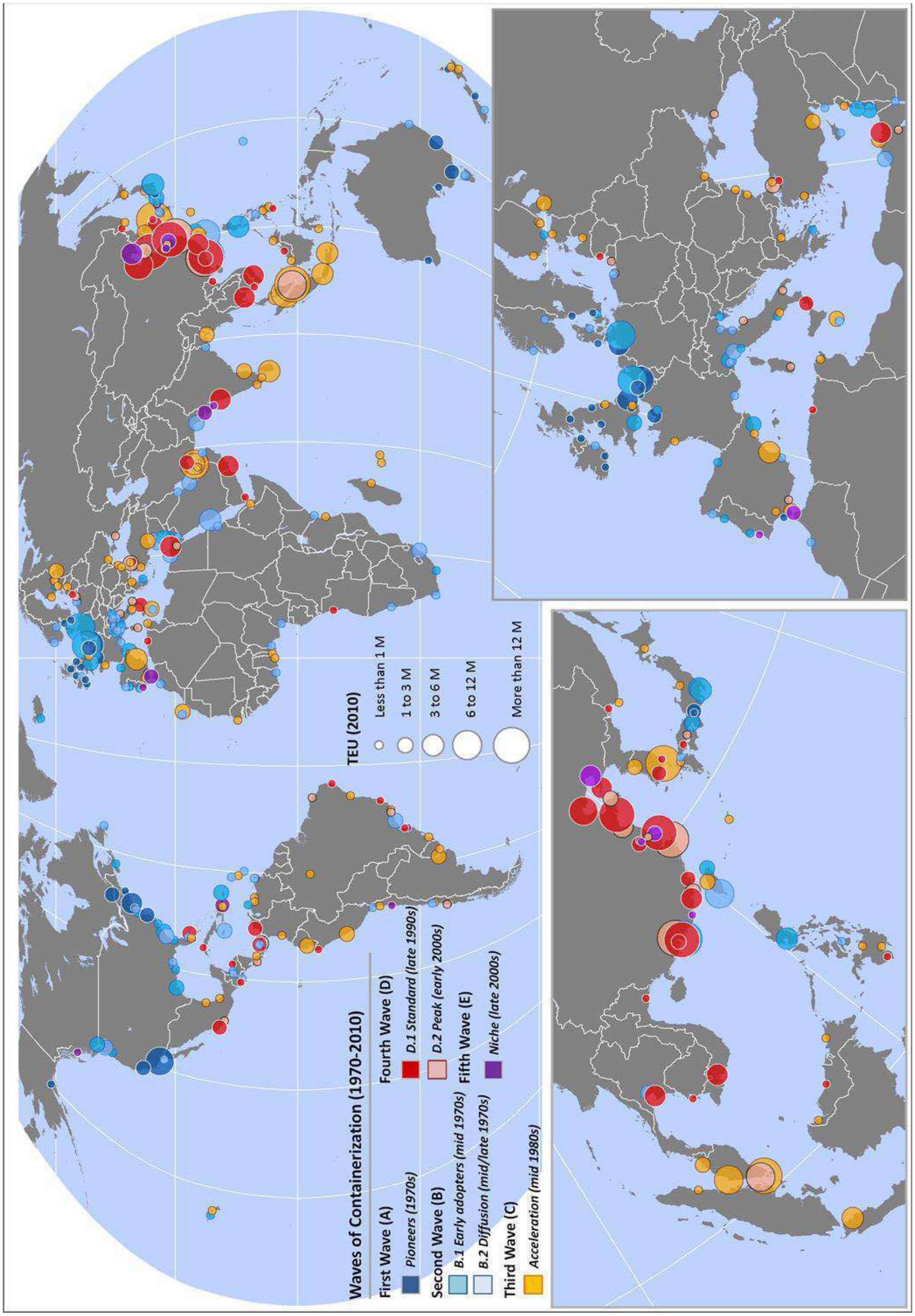

Figure 12 : Waves of Containerization, 1970-2010

Table 1 : The Waves of Containerization, 1970-2010

	First Wave (A)	Second Wave (B.1 & B.2)	Third Wave (C)	Fourth Wave (D.1 & D.2)	Fifth Wave (E)
Period	1956 (1965) - 1975	1970-1980 (B.1) 1975-1985 (B.2)	1980-1990	1995- (D.1) 2000- (D.2)	2005 –
Overview	Pioneer ports setting containerized operations in the economic triad (North America, Western Europe and Japan).	Expansion of the triad and its trade partners (Caribbean, Mediterranean, Asian Tigers).	Large diffusion in new international markets (Latin America, Middle East / South Asia, Southeast Asia).	The container becoming the standard transport support of the global economy. "The China Wave"	Peak growth and the setting of niches.
Driver	Early trade substitution.	Adoption of containerization.	Setting of global supply chains. Setting of transshipment hubs.	Expansion of global supply chains. China and transshipment hubs.	Spillover effect and new transshipment hubs.
Representative ports	Antwerp, New York, Los Angeles, Oakland, Nagoya	B.1: Rotterdam, Tokyo, Hong Kong B.2: Kaohsiung, Jeddah, Kingston	Singapore, Colombo, Busan, Dubai, Algeciras	D.1 Shanghai, Shenzhen, Gioa Tauro D.2: Ningbo, Tanjung Pelepas	Tangier Med, Caucedo. Yingkou, Prince Rupert

The analysis underlines that each wave lasts about 8 to 10 years, which is similar to the observations made by Kondratieff about the phases within a K-wave. The diffusion pattern is hierarchical, starting at the then absolute centers of the global economy (the triad) and adopting a pattern incorporating new locations within their respective spheres of influence. It is thus highly reflective of the change in the hierarchy of trade relations that took place with globalization and containerization.

Recent transitions

The selection of the time frame for the analysis of Changes of Port Share (CPS) relates to the 2000 - 2010 period, which on Figure 5 represents a critical juncture as the share of waves A, B and C was waning while wave D was fully asserting itself and wave E would be felt from 2005 onward. Containerization entered the inflection point with total traffic in the sample growing by a factor of 2.32 times over the decade (from 223 to 518 million TEUs), exceeding the combined absolute growth of all the previous decades.

The dataset is taken from Containerization International and includes annual port traffic from 2000 to 2010. Ports that had more than two missing yearly observations were removed from the dataset; a total of 264 ports were retained. 14 missing observations out of 2,904 (264 x 11) observations were estimated through linear interpolation using two adjacent years.

The analysis of Changes of Port Share (CPS) was divided over two periods, 2000-05 and 2005-10 to capture the shift in containerization that has occurred since then. The first period illustrates the fast growth where container ports in developing economies were incorporated in the global trade system (Figure 13) while the second period illustrates the impact of the financial crisis of 2008-09 on a global container transport system that was until then experiencing full-fledged and almost uninterrupted growth (Figure 14). It is important to underline that the results of the analysis of CPS must be interpreted in the global context of the container port system and not within respective regions (or port range).

A look at the ports that have experienced the highest gain and decline in share during the period is revealing as both the ports with the highest gain and decline are dominantly in Asia (Table 2). This underlines a growing divergence in regional containerization dynamics. A prime example of this trend is Hong Kong since the port dominated the Pearl River Delta (Wang and Slack, 2000). In the 2000s it became the world's major port that has lost the most significant share of its traffic even as this traffic increased from 18.1 million TEU in 2000 to 23.7 million TEU in 2010. This underlines capacity limitations challenges in its ability to service its hinterland in light of the substantial growth of other ports in the Pearl River Delta (Shenzhen and Guangzhou).

Table 2 : Analysis of Changes of Port Share (CPS), Ports with the Highest Gain and Decline, 2000-05 and 2005-10

	2000-05	2005-10
Highest gain	Shenzhen (+25,54), Shanghai (+23,21), Ningbo (+9,96), Tanjung Pelepas (+9,39), Qingdao (+7,35), Dubai (+6,60), Guangzhou (+6,12), Tianjin (+5,16), Xiamen (+4,07), Jeddah (+2,88), Dalian (+2,54), Hamburg (+2,29)	Guangzhou (+12,57), Ningbo (+12,34), Shanghai (+9,54), Tianjin (+7,28), Qingdao (+7,09), Lianyungang (+5,07), Yingkou (+4,58), Taicang (+3,77), Balboa (+3,75), Dalian (+3,40), Port Kelang (+2,84)
Highest decline	Hong Kong (-22,15), Singapore (-15,34), Kaohsiung (-8,41), Manila (-6,04), Felixstowe (-5,48), Kobe (-4,26), San Juan (-3,96), Rotterdam (-3,53), Tokyo (-3,55), Keelung (-3,30), Gioia Tauro (-3,25), Long Beach (-2,93)	Hong Kong (-13,18), Kaohsiung (-7,16), Singapore (-5,60), Busan (-6,01), Hamburg (-5,99), Long Beach (-5,56), Los Angeles (-4,50), Rotterdam (-2,97), Algeciras (-3,16), Gioia Tauro (-2,82), Tacoma (-2,66), Charleston (-2,63)

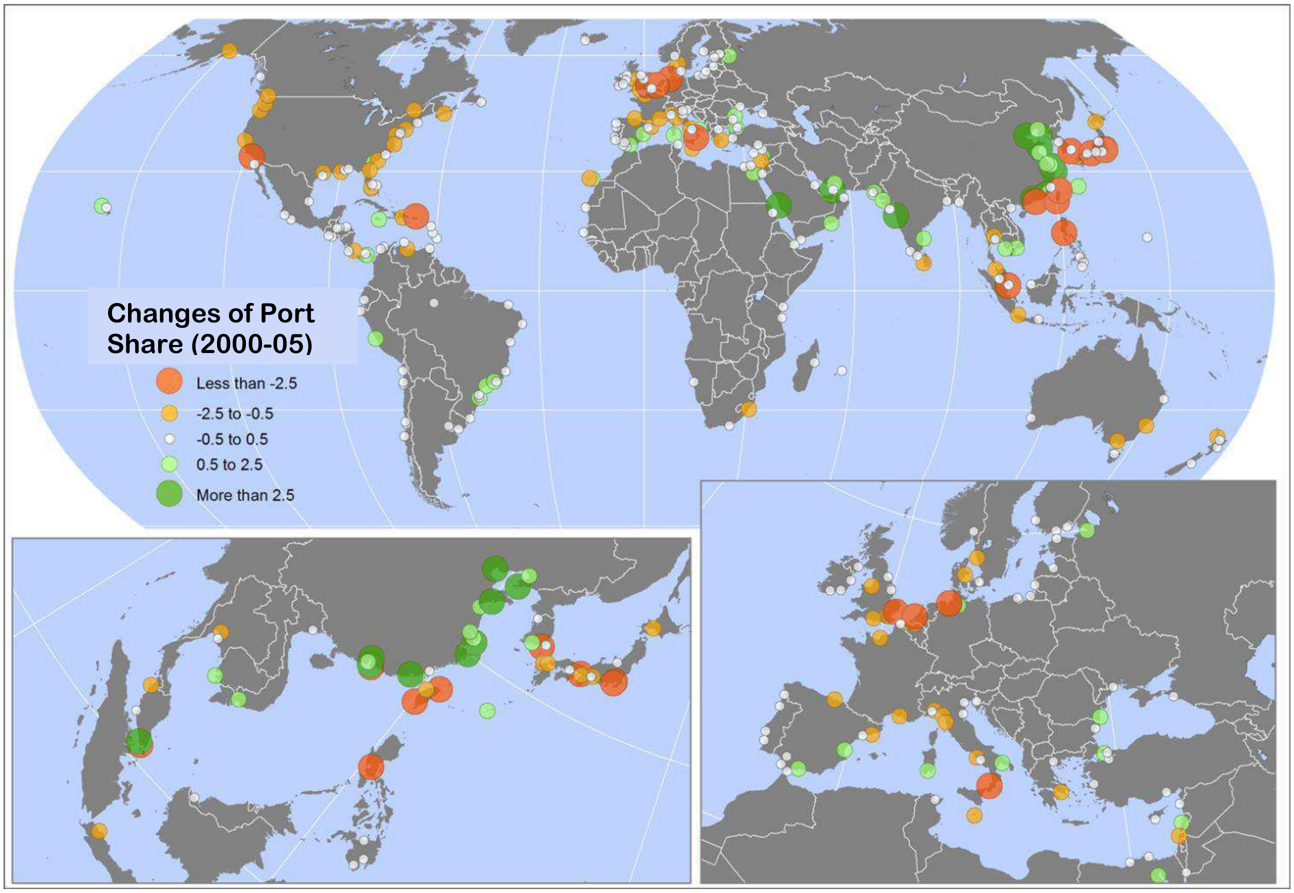

Figure 13 : Changes of Port Share (CPS), 2000-05

A significant trend relates to the shift-share decline of the ports of the triad, that show signs of maturity. Within Pacific Asia, there is a rapid shift from Jakota (Japan, Korean and Taiwan) to mainland China. The strengthening and some rebalancing of transshipment hubs along the Singapore – Gibraltar corridor is being noted. Dubai is one of the main gainers, a process concomitant to the emergence of Dubai Ports World as a major global terminal operator and the growing role of Dubai as a transshipment hub. A maturity within the North American and Northern European ranges is taking place with an across the board drop in the share of containerized traffic. A rebalancing of transshipment hubs is being observed within the Mediterranean and the Caribbean towards hubs offering higher levels of efficiency, with Valencia and Algeciras gaining.

Although the financial crisis of 2008-09 was characterized by a significant decline of global container throughput, this decline was far from uniform. The transition unfolding from 2005, therefore, includes both growth and rationalization processes. The ongoing relative decline of Singapore and Hong Kong is being noted on par with ongoing containerization along coastal China as its export-oriented development model peaked. There is a strengthening of transshipment hubs along the Singapore – Suez corridor, with Dubai continuing to dominate. At the same time, a rationalization of transshipment in the Mediterranean to the main advantage of Valencia and Tangier

Med is taking place. The steep decline of the share of North American ports is marginally counterbalanced by the strengthening of niche gateways (Lazaro Cardenas, Savannah, Prince Rupert) and an ongoing rebalancing of transshipment in the Caribbean to the advantage of Panama and Cartagena. There is an overall advantage to South American ports linked to ongoing economic growth, their integration to the global economy, particularly to the trans-Pacific trade.

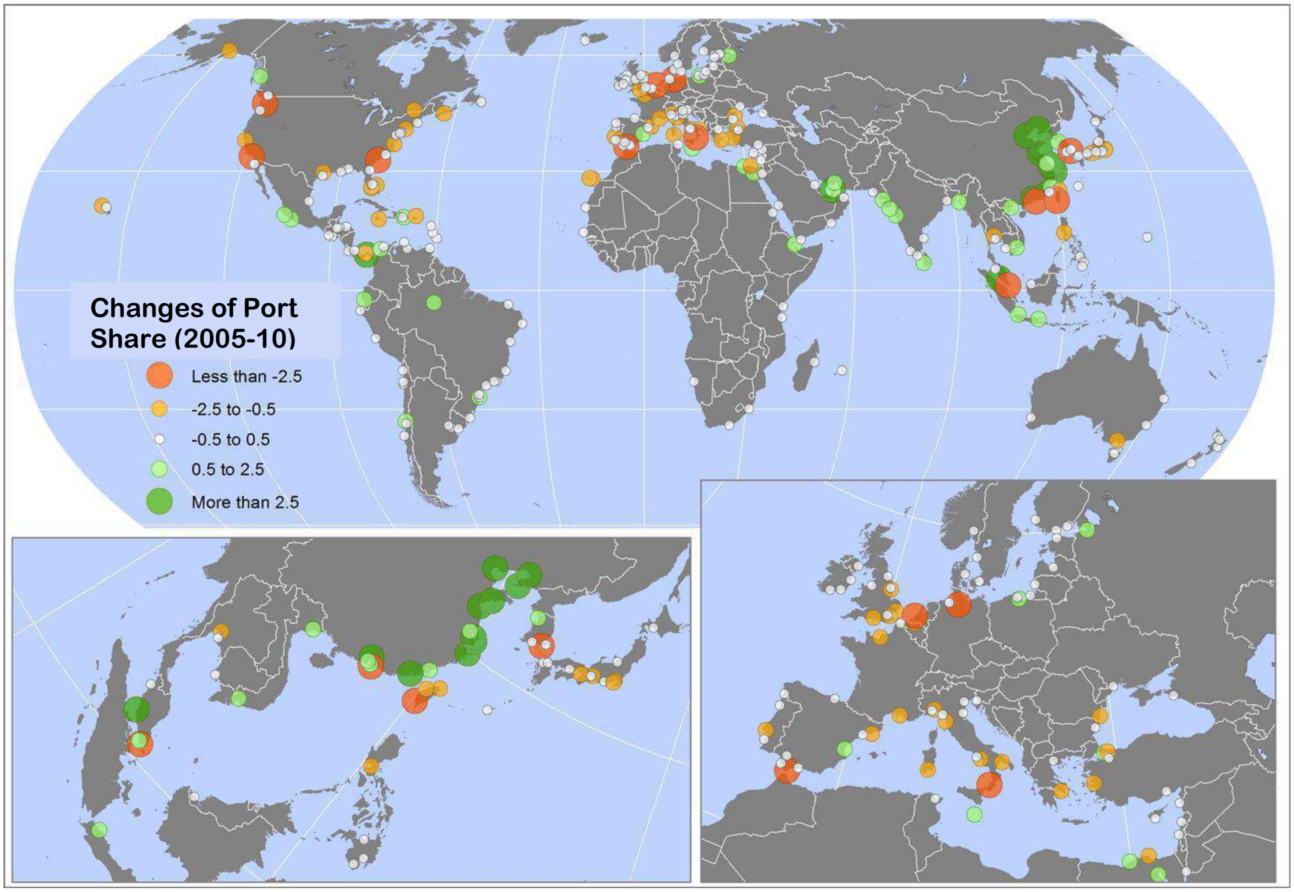

Figure 14 : Changes of Port Share (CPS) 2005-10

Conclusion

This paper provides evidence of the K-wave behavior of containerization through a decomposition of its phases. The container, like any technical innovation, has a market and diffusion potential where a phase of maturity is eventually reached. Evidence from the global container port system suggests five distinct waves of containerization with a shift in the momentum from advanced economies to developing economies, but also within advanced and developing economies. This pattern is reflective of the process of economic globalization from the initial dominance of the triad to the incorporation of export-oriented economies in the global trade system and the emergence of major transshipment hubs. These waves span about 8 to 10 years each, which matches the patterns initially identified by the work of Kondratieff.

Transitions, particularly in light of the impacts of the financial crisis of 2008-09, are illustrative of an inflexion and a shift in the patterns of global container port growth. The tendencies depicted by a shift-share analysis have shown that the core growth has focused mainly on coastal Chinese ports as well as on emerging transshipment hubs along the Asia-Mediterranean trade route. South Asia and Latin America have also fared comparatively well. In the same region, ports like Shanghai, Shenzhen and Ningbo are achieving peak growth while ports like Hong Kong, Singapore and Kaohsiung have achieved maturity. This is illustrative of the economic and manufacturing rebalancing that has taken place in the last decade.

While cyclical behavior has been identified within the global container port system, these waves are simply illustrative of major macroeconomic, technological and sometimes political shifts within the global economy. They do not explain the causes, but simply the consequences of such shifts in the distribution in traffic and growth (or decline). Yet, they provide strong evidence that containerization has a cyclic behavior and that inflection points are eventually reached, marking the end of the diffusion of containerization in a specific port or port range. Future expectations about the growth of containerization thus need to be assessed within an economic cycle perspective instead of the rather linear perspectives in which containerization is generally considered, particularly among commercial actors. This paper focused on the port level. It would be revealing if more detailed analysis could be performed at the port range level as well as if cycles can be observed within the configuration of shipping networks.

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Appendix. List of ports

First Wave (A)	n=36	Antwerp, Los Angeles, New York-New Jersey, Bremen-Bremerhaven, Felixstowe, Nagoya, Zeebrugge, Le Havre, Oakland, Melbourne, Seattle, Sydney, Hampton Roads, Montreal, Auckland, Gothenburg, London, Miami, Liverpool, Fremantle, Teesport, Anchorage, Helsingborg, Esbjerg, Philadelphia, Lyttelton, Belfast, Grangemouth, Adelaide, Hull, Dunkirk, Yokkaichi, Boston, Cork, Cadiz, Waterford
Second Wave (B.1)	n=40	Hong Kong, Rotterdam, Hamburg, Long Beach, Tokyo, Yokohama, Manila, Kobe, Vancouver, Osaka, Keelung, Barcelona, Houston, Southampton, San Juan, Charleston, Haifa, Genoa, Ashdod, Honolulu, Jacksonville, Piraeus, Livorno, Baltimore, Naples, Bilbao, Leixoes, Shimizu, Halifax, New Orleans, Helsinki, Port Elizabeth, Trieste, Wilmington NC, Lisbon, Reykjavik, Portland OR, Copenhagen Malmo, Rouen, Ghent
Second Wave (B.2)	n=64	Kaohsiung, Jeddah, Savannah, Santos, Durban, Kingston, Alexandria-El Dekheila, Tacoma, Bangkok, Karachi, Dammam, La Spezia, Marseilles, Brisbane, Valparaiso, Casablanca, Cape Town, Shuwaikh, Mombasa, Cristobal, Aqaba, Lattakia, Dublin, Paranagua, Puerto Cortes, Abidjan, Lagos, Cebu, Koper, Kitakyushu, Gdynia, Aarhus, Port Sudan, Santo Tomas de Castilla, Venice, Port of Spain, Kolkata, Santa Cruz de Tenerife, Limassol, Port Sultan Qaboos, Douala, Wilmington DE, Walvis Bay, Burnie, Devonport, Gulfport, Palm Beach, Vigo, Otago, Oslo, Savona, Apra, Ravenna, Pointe-a-Pitre, Alicante, Mobile, Acajutla, Arica, St John's NL, Bergen, Mumbai, Palma de Mallorca, Port-au-Prince, Larnaca
Third Wave (C)	n=89	Singapore, Busan, Dubai, Port Kelang, Tanjung Priok, Valencia, Colombo, Surabaya, Khor Fakkan, Algeciras, Marsaxlokk, St. Petersburg, Incheon, Buenos Aires, Taichung, Callao, Chittagong, Chennai, Penang, Las Palmas, Guayaquil, Damietta, Mersin, Beirut, San Antonio, Puerto Limon, Hakata, Puerto Cabello, Port Everglades, Johor, Izmir, Veracruz, Montevideo, Buenaventura, Rio Grande, Djibouti, Tauranga, Belawan, Davao, Mina Zayed, Tema, Altamira, Port Louis, Thamesport, Rio de Janeiro, Naha, Rades, Manaus, Dar es Salaam, Kotka, Dakar, Tuticorin, La Guaira, Tomakomai, Lome, Cotonou, Odessa, Kochi, Rio Haina, Iquique, Salerno, Thessaloniki, Tarragona, Riga, Vostochny, Salvador, Lirquen, Niigata, Tallinn, Kota Kinabalu, Kuching, Point Lisas, Napier, Haydarpasa, Nantes, Cagayan de Oro, Rauma, Kandla, Seville, Fort-de-France, Port Reunion, Toamasina, Makassar, Barranquilla, Varna, Hamina, Immingham, Kahului, Kawaihae
Fourth Wave (D.1)	n=48	Shanghai, Shenzhen, Qingdao, Tianjin, Xiamen, Dalian, Laem Chabang, Jawaharlal Nehru, Saigon New Port, Port Said, Salalah, Gioia Tauro, Shahid Rajaee, Colon, Gwangyang, Zhongshan, Cartagena, Manzanillo, Fuzhou, Freeport, Nanjing, Haiphong, Itajai, Bin Qasim, Constantza, Nantong, Ulsan, Aden, Vladivostok, Puerto Barrios, Suape, Luanda, Yangzhou, Klaipeda, Gemlik, Puerto Quetzal, Bintulu, Vitoria, Havana, Sihanoukville, Bejaia, Hiroshima, General Santos, Ensenada, Paita, Sao Francisco do Sul, Castellon de la Plana, San Diego
Fourth Wave (D.2)	n=24	Ningbo, Guangzhou, Tanjung Pelepas, Lianyungang, Balboa, Ambarli, Yantai, Quanzhou, Zhangjiagang, Lazaro Cardenas, Jurong, Sokhna, Taranto, Cagliari, Gdansk, Novorossiysk, San Vicente, Malaga, Sepetiba, Kaliningrad, Mizushima, Pecem, Caldera, Ancona
Fifth Wave (E)	n=15	Yingkou, Taicang, Tangier, Mundra, Puerto Caucedo, Jiangyin, Shantou, Cai Mep, Pipavav, Portonave, Prince Rupert, Zhenjiang, Sines, Coronel, Mejillones