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Seaports Activity (A)synchronicity, Trade Intensity and Business Cycle Convergence: A Panel Data Analysis

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Abstract:
In the present paper we suggest and test a general model that aims to explain the determinants and the extent of parallel moving (i.e. the synchronization) of trading ports activities. The model adopts a macro-approach and its main constituents are a) the business cycle (GDP) convergence, b) the intensity of trade between the countries of origin and destination, and c) the variables associated to international shipping developments. The present study makes possible the identification of distinct influences on the link between a given country's economic and port activities influences which can traced back mainly to macro policies. The elaboration of such determinants and their relationships contribute to a better understanding of the dynamics of port throughput and facilitates infrastructure planning and strategic policy decision. The present paper's conclusions feature a framework for modeling the relationship between ports and shipping activities. Panel data from European main ports for the period 1986-2010 were used for the empirical investigation and a dynamic panel GMM estimation technique was employed. Model simulations are conducted and provide evidence that an increase or decrease of port business cycle synchronization is a) attributed to the technical and structural characteristics of ports and, b) greatly influenced by the general macroeconomic environment.

Key Words:
Port throughput, business cycle synchronization, bilateral trade, GDP Convergence, shipping determinants

JEL Classification*:E32, F62, L91*

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1. Introduction

Transport services are currently occupying the second position in commercial services ranked by size on a worldwide basis and reflect the merchandise trade (UNCTAD, 2011). The world seaborne trade transports approximately fourth fifths of all goods traded globally; in 2010, the total weight of goods transported amounted to 8.4 billion tons (ibid). Transport systems affect the economic development directly by enhancing trade and indirectly by improving competition and the efficiency of commodities exchange.

Economics are identified as key forces and predictors of trends, which influence transportation (ICF, 2008). International trade and economic growth of national economies are directly related to the growth of sea transport systems, their mobility, and in extension to the ports' throughput. This process is also subject to the phases of trading partners' economic cycles and their idiosyncrasies, the level of activity and the structure of national economies. In extent, the trade patterns of the trading partners are an important influence on national and global transport systems (Rodrigue, 2010). Within this framework the nature of the association of economic and trade activity and maritime transport has been a subject of interest in both the maritime (Fink *et al.*, 2002; Boske and Cuttino, 2003; Meersman and Van De Voorde, 2005; Stopford, 2008) and port economics disciplines (Goss, 1990; De Monie *et al.*, 2011).

The rise of globalization intensified the economic linkages among states, regions, countries etc. and led to the formation of a highly integrated international economic environment. In effect, the mainstream economics research focus has been redirected from the pace of single countries' growth to the transmission of aggregate fluctuations across various regions and the synchronization of their business cycles attitudes (see the workforce of Backus *et al.*, 1994). The shipping and port industries are considered typical and traditional globalized economic sectors. However, a parallel shift of research outputs on the effects of maritime transport systems synchronicity is yet to be established and studied. Admittedly, the dependency of port throughput on GDP growth (Vanoutrive, 2010) and bilateral trade (Janssens *et al.*, 2001) is supported in the literature, but there is a lack of empirical studies tackling the relationship of both bilateral trade and GDP with the port throughput (cf. Pallis *et al.*, 2011).

This gives rise to a number of research questions. Indicatively: is the throughput convergence the outcome of business cycle convergence? Does the extensive trade between two countries lead to throughput convergence? Is this the sort of relationship that affects the long run performance of the ports' correlation or does it affect the adjustment towards some long run relation? And finally, in what way does shipping impact ports' throughput convergence? The present research is based on synchronicity theories and tools; it employs a panel data analysis and uses dynamic Generalised Methods of Moments (GMM) techniques to generate knowledge on the aforementioned issues.

The research findings suggest that GDP convergence plays an important and positive role in port throughput co-movement. On the contrary this phenomenon is becoming insignificant for ports located in adjacent countries. Trade intensity has a negative but significant influence on port throughput convergence indicating a form of "cargo specialization". Concerning shipping variables, fleet development causes a divergence of port throughput activity mainly due to ports' structural characteristics (infrastructure developments). Finally, freight rates (nominalised by distance) affect port activities positively due to some comparative advantages they offer.

The remainder of the paper is organized as follows: Section 2 provides a literature review on business cycles synchronization theory from both a theoretical and an empirical perspective. Section 3 redefines the port throughput activity grounded on bilateral sea-trade relationships and analyses in brief its influential determinants. Section 4 introduces the theoretical model (panel data analysis) while Section 5 outlines the methodology adopted (Generalised Methods of Moments) and the sample used in the present study. Finally, the results of the present study are outlined in Section 6 while Section 7 concludes and presents policy implications.

2. Business cycle synchronization

Persistent trade liberalization and rapid financial integration have gathered steam over the last decades. Until then, the greatest part of economic research focused on single country-models, studying the effects of factors such as demand, supply, interest rates, exchange rate regimes and other macroeconomic determinants of business cycles (Kydlant and Prescott, 1990; Blachburn and Ravn, 1992).

The wave of globalization gave rise to the study of business cycles across and within various countries and the understanding of their (correlated) economic behavior. This is mainly due to the extended number of cross-country links that affect macroeconomic co-movements. The term synchronization is used when the business cycles of two countries move in phase (Anderson *et al.*, 1999) due to the "international transmission of idiosyncratic shocks through economic linkages such as trade or finance" (Akin, 2006:2). The extent to which links, such as bilateral trade and economic integration (to name but two) influence synchronization has been the subject of a significant number of scholars' outputs in recent years (Savval *et al.*, 2007; Larsson *et al.*, 2007; Artis *et al.,* 2011; Bordo and Helbling, 2011).

A substantive number of theoretical studies highlight the role of trade as a transmitting mechanism that leads to GDP growth convergence (Canova and Dellas, 1993; Frankel and Rose, 1998; Kose *et al.*, 2003; Herrero and Ruiz, 2008; Ramanarayanan, 2009; Artis and Ocubo, 2011). Bilateral trade activity generates both supply and demand side spillover effects across economies. On the demand side, an investment or consumption boom in one country generates increased demand for imports. At the same time, the country's trading partner experiences an increased demand for exports. The result is a positive business cycle correlation. It follows that if demand shocks predominate or if the intra-industry trade is prevalent, then business cycles across economies tend to become more similar. Thus, common trends of growth lead to converging consumption and production structures and therefore enforce trade intensity.

Theoretical arguments exist however in favor of both thesis, namely as to whether trade intensity leads to more or less correlated business cycles. Scholars suggest that if international trade is based on the classic comparative advantage argument of the Heckscher-Ohlin type specialization (Heckscher and Ohlin, 1991), industrial structures will be influenced and lead to the development of less synchronized business cycles (Eichengreen, 1992; Kenen, 1969; Krugman, 1993; Calderon *et al.*, 2007 – for the case of developing countries). In opposition, Kose and Yi (2001) argue that intra-industry vertical specialization establishes stronger trade ties between countries and hence higher synchronization.

Given the inconclusive theoretical framework, the effect of trade intensity on business cycle correlation became the subject of empirical studies which demonstrate that higher trade integration, increases cross-country output correlations, especially among advanced economies (Rose, 1998; Dees and Zorell, 2011). In addition international trade is recognized as the most important transmission channel of business cycles (Otto *et al.*, 2001). In the same vein, Gruben *et al.*, (2002) made explicit reference to the intra-industry trade and its positive effects on business cycles co-movement[4]. The effects of economic specialization are also the subject of empirical models, yet the latter lead to quite contradictory results. The hypothesis according to which countries with highly similar industrial structures tend to be more correlated is in some cases presented as valid (Imbs, 2003, 2006), in others as not robust (Baxter and Kouparitsas, 2004) and in others still as not significant (Clark and van Wincoop, 2001). Moreover, Ramanarayanan (2009) accentuates the role of intermediate goods across economies[5] (with examples drawn

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[4] However Frankel (2004) doubts the usefulness of distinguishing between intra-industry and inter-industry trade from a synchronization perspective. He notes that trade in inputs and intermediate products, constituting as it does a large share of today's trade, gives rise to positive correlations and yet it may be recorded as inter-industry trade.

[5] This view of "sui generis" vertical type of intra-industry trade, in which the same product may cross borders of countries that exhibit large differences in factor endowments several times during the manufacturing process, exhibit similar co-movements in their business cycles.

from automobiles and auto-parts) corroborating Stockmann's view (1988) on the importance of sectoral shocks between countries.

3. Port throughput and its main determinants

3.1 Port throughput: Definition

The term "port throughput" describes the quantity of cargo and passengers passing through a port on a daily basis, from their arrival at the port to their loading onto a ship, or from their discharge from a ship to the exit (clearance) from the port complex (US Department of Defense, 2005). The maximization of handled tonnage stands among the most quoted economic objectives set by European Port Authorities (ESPO, 2010) and largely defines a ports' competitive position.

A theoretical analysis implies that port throughput is greatly influenced by fundamental macro-economic determinants such as the economic activity, international trade, maritime trade and generalized costs of the logistic chain (Meersman, 2009). The establishment of such a relationship is straightforward. An increased economic activity combined with low levels of logistic chain costs enhance the demand and exchange of goods and consequently enhance international trade, which in turn directly impacts the maritime trade. Finally, the relationship of maritime trade and port throughput is direct and close.

A significant amount of the scholars' efforts is dedicated to the in-depth understanding of the factors that influence the ports' efficiency through the use of "frontier" approaches and the analysis of data such as land area and employment in terms of input and throughput volumes in terms of output (cf. Vitsounis, 2011). Nevertheless, the application of "frontier" methodologies for the justification of ports' throughput is based on a micro-approach and largely concentrates on the ports operational efficiency. Nevertheless, and despite the port economics literature increasing expansion since the mid 1990's (Pallis *et al.*, 2010), a detailed analysis of the macro-economic determinants influencing a ports' throughput is largely absent. Such an analysis could also be considered as a tool for a better understanding of the future fluctuations by identifying the determinants that are acting as leaders or lagers on the ports total throughput.

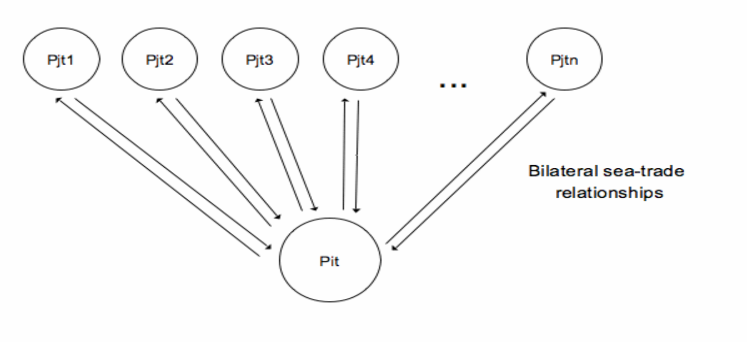
3.2 Port throughput: An alternative definition

Despite the extended use of the existing port throughput definition (section 3.1), the latter may also be seen from a differentiated point of view – one rarely adopted or used as a basis for further analysis. From this perspective, port throughput accounts for the totality of bilateral sea-trade relationships that the focal port i, develops with its trading port partners j (Figure 1). The totality of a country's seaborne trade is facilitated through the sum of its ports. In turn, the majority of cargo that each port accommodates is originated from ports located in foreign counter trading countries[6]. Eventually, the following equation for port throughput is valid:

$$P_{it} = \sum_{j=1}^{n} P_{ijt} = \sum_{j=1}^{n} BSTRP_{jt}$$

where P accounts for the throughput activity of port i at time t , Pij is the throughput of port i contributed by port j and BSTRP are the bilateral sea-trade relations that port i holds with its port trading partners j at time t.

Figure 1: Port throughput from an alternative perspective



Such an alternative port throughput definition places emphasis on the bilateral sea-trade relationships; the more intense the bilateral trade, the greater the extent of sea trade and the higher the throughput associated to the related ports. However, the robustness of this relationship depends on a) the existence of alternative transport systems with adjacent or non adjacent partners, b) the degree of the utilization of these alternatives in the short, medium and the long run and c) a number of idiosyncratic characteristics such as the level of transshipment[7], the eventual formal agreements between any given two ports, the ports technical characteristics etc. Nonetheless, bilateral trade is endogenous to GDP synchronicity (c.f. Frankel and Rose, 1998; Dees and Zorell, 2011) and as such GDP synchronicity is also expected to influence the ports' activities. The present study endorses this "alternative" definition of ports' throughput and focuses on the dyadic relationships developed between given pairs of ports. More specifically, the throughputs of given pairs of ports move in phase (are synchronized) to some extent due to the bilateral sea-trade relationships they maintain. Eventually these relationships allow the "international

[6] This is valid under the assumption that national seaborne cargo movements are limited to some extend and usually accommodated through inland transportation.

[7] In that case port throughput is over estimating trade activities. Thought, the volume of transshipment flows is related to GDP indirectly since it allows the domestic economy to benefit from trade between third countries as a return from appropriate investments.

transmission of idiosyncratic shocks" (Akin, 2006:2) and are directly influenced by the trade intensity between the two countries and the extent of their GDP convergence. Notably, the role of shipping is also of extreme importance and its effect upon ports' throughput is identifiable within such a macro-economic framework. Research efforts that model the association between port activities and shipping developments are relatively limited (Peters, 2001; Notteboom, 2004). More specifically there are no suggested frameworks, which can isolate the role of shipping in affecting port throughput given the international seaborne trade and the growth attitudes of national economies engaged in bilateral trade activities.

3.3 Port throughput determinants

Given the above discussion the present study aims to apply the existing literature of business cycles synchronization on port studies. More specifically, it models the correlation of the port activity between a given pair of ports – where port throughput is considered a suitable measure of port activity and used accordingly - and examines the extent to which the theoretically anticipated variables influence this correlation. The variables in question are 1) the GDP convergence, 2) the bilateral trade of the two countries (as established from a macro perspective), 3) the world maritime fleet development and, 4) the transportation costs occurring between the two ports (including gravity model), stemming from a maritime economics perspective. Additionally, variables capturing structural influences such as 5) the Eurozone relative to EU participation and 6) adjacency, are also taken into account and tested in the model. The remainder of the present section is dedicated to the selection of the variables considered essential to model port throughput synchronicity and the justification of our choices in this respect.

3.3.1. Basic Macro-economic determinants (economic activity and bilateral trade)

From an empirical perspective, the relation linking the economic activity (measured in GDP) with freight transport has already been well established in the relevant literature (Anderson and Elger; 2007; Ickert *et al.*, 2007; Meersman and Van De Voorde, 2008). However, efforts to empirically establish and quantify the impact of macro-economic determinants on port throughput remain relatively scarce and mainly focus on the relation between port throughput and the GDP of the country where the port is located (Vanoutrive, 2010; Van Dorsser *et al.*, 2011) or international trade (Janssens *et al.*, 2002).

On the other hand and from a theoretical perspective, the relationship between port throughput and economic activity (GDP) is predominant and well established in the relevant literature (Meersman, 2009; Rodrigue, 2010). This relationship stems from the role of trade (as the demand for port services is a derived one) incurred by the exchange of goods, which are consumed at a different location from the one where they were produced. Therefore, "the level of demand for port services is dependent on the level of economic activity within a country and between countries" (Tongzon, 1995:247).

As noted already, the relationship between port throughput and GDP[8] has been tested empirically (Ducruet, 2009; Vanoutrive, 2010; Van Dorsser *et al.*, 2011). More specifically, Vanoutrive (2010) establishes that port throughput is affected not only by the country's GDP, but also by the GDP of neighboring countries. In addition, he reports that different results are obtained for different commodity groups and that a different time lag impact corresponds to each country. The correlation between container traffic and Gross Regional Product (GRP) is also established in the literature whereas port container volumes depend on the degree of the economic or demographic evolution of the port's origin region (Ducruet, 2009). Additionally, Van Dorser *at al.* (2011) justify the causal relation between port throughput and GDP, using various forecasting methods (long and short term).

The relationship between port throughput and bilateral trade is also predominant and established both theoretically (Rodrique, 2009, UNCTAD, 2011) and empirically (Janssens *et al.*, 2002). International trade for instance, greatly influences but cannot fully account for a port's throughput (ibid). The application of appropriate econometric models indicates that port throughput volumes (imports and exports) are influenced by trade to a great extent and factors or forces such as shipping companies alliances, stevedoring companies, intermodal transportation etc, are not negligible either (ibid).

Eventually the relationship between port throughput and bilateral trade is not always positive or straightforward and it is greatly influenced by the ports specialization. Ports may be specialized on single or limited types of cargo. In cases where the bilateral trade between two countries is intense for specific types of goods, different from the ones that the focal port is specialized in, then trade intensity and ports' throughput divergence is to be expected. As a general rule, ports specialization is expected to lead to idiosyncratic cycles allowing for even a negative correlation between bilateral trade and ports throughput intensity. It is worth mentioning that a significant effect of trade intensity on port throughput correlation coupled with a non-significant effect of business cycles correlation on port throughput correlation indicates divergence of trading countries. As a result, cycles can become more idiosyncratic.

3.3.2 Shipping determinants

The maritime trade has a direct and close impact on the ports throughput. What is essential though for the purposes of the present paper is the determination of proper

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[8] For a more holistic approach on the relation between traffic specialization and regional specialization see Ducruet *et a*l. (2012).

variables to model this relationship. In this respect, there is a need to take into account both the supply and the demand side of maritime services. In extent, maritime transportation cost and capacity are considered appropriate variables[9].

Numerous research efforts focus on the impact of transport costs upon the international trade (cf. Hummels, 2007) on the one hand and on the identification of shipping cost determinants (Veenstra, 1999; Strandenes, 1999; Kavoussanos and Alizadeth, 2000; Alizadeth and Talley, 2010) on the other. Transportation costs are directly linked with the transportation distance (Brun *et al.*, 2003; Disdier and Head, 2004), the freight rates and the quality of transport services offered. At the same time, "distance is a time-invariant variable, so the instrument to gauge the contribution of changes in transport costs to changes in trade flows is decidedly blunt" (Jacks and Pendakur, 2008:7). To overcome this constraint, gravity variables[10] should be combined to proxies or indices that account for transportation cost and consequently for freight rates.

However, the question as to whether transportation cost exercises a positive or a negative impact on ports throughput remains an empirical one. An increase of the freight rate can restrict the trade associated to a group of ports. Or, inversely, the increase can lead to an increase of the activities between those ports, which can lessen the total transportation cost by means of comparative advantages. Hence, a freight rate increase that affects the ports throughput in the same (positive or negative) way will result to the increase of the cross-correlation of ports throughput. If however, a freight rate increase affects ports throughput differently (due to ports' differences such as the operating of cost structures for example) then the cross-correlation of ports throughput will decrease.

The extent of supplied international maritime transport services and the associated fleet development in terms of DWT per vessel are also of extreme importance and both influence port throughput directly. After all, the index of fleet development in terms of DWT per vessel reflects the world demand for trade in association to the technological advances in the shipping sector. An increase in available DWT per vessel facilitates sea trade and is expected to have a positive impact on ports throughput. However, the direction of this impact on ports throughput cross correlation is not clear. If two ports' activities are affected by world trade in analogous manners, then an increase of available DWT per vessel will also increase the ports throughput convergence. Inversely, world trade activity can affect the activities of two ports differently.

[9] Given the novelty of the conceptualizations presented and tested in the present study.

[10] "Gravity models" (introduced by Tinbergen, 1962) are intensively used to explain and forecast the growth of trade in order to control exogenous factors, using variables such as the geographical distance between countries and relative country size in terms of population.

This can be imputed to ports' infrastructure constraints that affect differently their capacity to adjust to new build ships berthing requirements. If this is the case, ports throughputs will diverge. Thus, the question whether the actual sign of the DWT per vessel causality on port throughput synchronicity will be positive or negative remains to be answered by the empirical application of the theoretical relation.

3.3.3 Other structural determinants

In the synchronization theory there is a long list of structural variables that are thought of significance in forming probable GDP co-movements. Such variables are inter-alia the degree of financial integration, common currency and currency rules, industrial structure etc. (for an overview of the variables used in business cycle synchronization theory see: Herrero and Ruiz, 2008; Prasad *et al.*, 2004).

4. Theoretical Model

Following the preceded discussion the general model used in the present study in order to explain the synchronization of port activities takes the following form[11]:

$$PT_{ij,t} = a0 \pm a1TI_{ij,t} + a2GDP_{ij,t} \pm a3FD_t \pm a4INDEX_{ij,t} \pm e_{ij,t} \quad (1)$$

Where:

- The subscripts i,j and t denote ports/countries and time, respectively,
- a0 is a constant parameter while t is a time trend,
- PTij,t, is the port throughput cross-correlation index,
- TIij,t is the bilateral trade intensity index,
- GDPij,t is the GDP cross-correlation index, and
- FD t is the log[12] of the average world fleet development in terms of DWT at time t, used as a trend to capture supply of international maritime transport services.
- INDEX ij,t is used as a proxy for transportation cost as formed at time t, and
- eijt is the error term capturing the unobserved variations between ports and overtime.

The present paper adopts and puts to use the type of correlation introduced by Cerqueira and Martins (2009). The significant advantage of such an approach is that, contrary to other models, which examine synchronicity over a time-span (cf. Frankel and Rose, 1998; Calderon et al. 2003), the model in question does capture time variability. This enables the distinction of negative correlations in individual years (clearly portrayed in figures 2 and 3). Moreover, it also captures asynchronous behavior due to structural differences during turbulent times and synchronous

[11] All variables are taken in natural logarithms.
[12] Natural logarithms

behavior over stable time periods. The remainder of the present section provides a detailed analysis of the variables used in regression (1).

4.1. Port throughput cross-correlation index

The port throughput correlation index applied follows Cerqueira and Martins (2009) and takes the following form:

$$r_{ij,t} = 1 - \frac{1}{2}\left[\frac{d_{j,t} - \bar{d}_j}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(d_{j,t} - \bar{d}_j)^2}} - \frac{d_{i,t} - \bar{d}_i}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(d_{i,t} - \bar{d}_i)^2}}\right]^2 \quad (2)$$

Where:

- rij,t are cross-correlations between ports i and j at time t13,
- dj,t and di,t are the port throughput growth rates of ports j and i between t and t-1respectively,
- $\bar{d}_j$ and $\bar{d}_i$ is the average of port throughput growth from t=1 to T (the final year of the entire sample).

4.2 GDP cross-correlation index

The GDP cross-correlation index employs the same formula as depicted in the design of port throughput cross-correlation index:

$$p_{ij,t} = 1 - \frac{1}{2}\left[\frac{z_{j,t} - \bar{z}_j}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(z_{j,t} - \bar{z}_j)^2}} - \frac{z_{i,t} - \bar{z}_i}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(z_{i,t} - \bar{z}_i)^2}}\right]^2 \quad (3)$$

Where:

- pij,t are cross-correlations between countries i and j at time t14,
- zj,t and zi,t are the GDP growth rates of countries i and j between t and t-1 respectively,
- $\bar{z}_j$ and $\bar{z}_i$ are the average of GDP growth from t=1 to T (the final year of the entire sample).

According to Cerqueira (2010), the specification of the Cerqueira and Martins (2009) period indices (pijt and rijt), when averaged over the entire sample should be equal to the linear correlation index (pij and rij) and be based on the Euclidean distance between the standardized variables of the two countries at any given date. The main advantage of this index over the correlation index is its ability to distinguish not only negative correlations due to episodes over individual years, but also asynchronous behavior in turbulent times and synchronous behavior over stable periods. Consequently, the applied index captures time variability. A main drawback of the pij and rij combination is their asymmetry and the fact that they deviate

[13] The upper bound of $r_{ij,t}$ is 1 while the lower bound could be less than -1.
[14] The upper bound of $p_{ij,t}$ is 1 while the lower bound could be less than -1.

between 1 and -∞. However, Cerqueira (2010) suggests that this drawback does not affect negatively the statistical validity of the estimated results related to the bounded version of the index that deviates between +1 and -1.

Figure 2 presents the port throughput cross-correlations, capturing the "dot.com" crisis in 2000-2001 and the world financial crisis in 2008, while Figure 3 presents GDP cross-correlations and captures the War in Gulf in 1991 as well as the world financial recession (2009-2010).

Figure 2: Port throughput cross-correlation Index

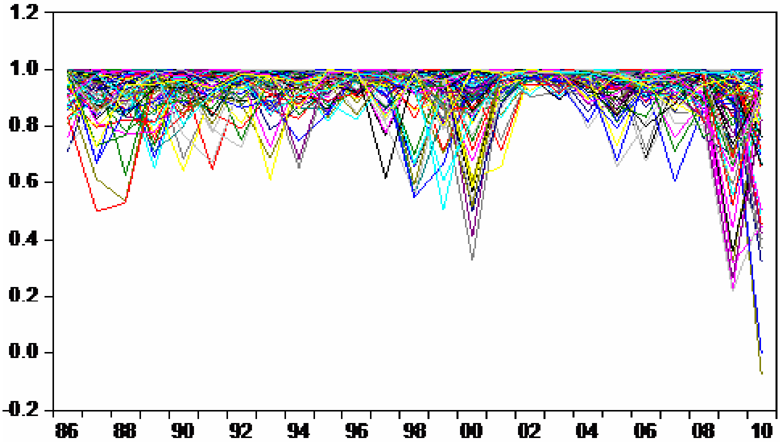
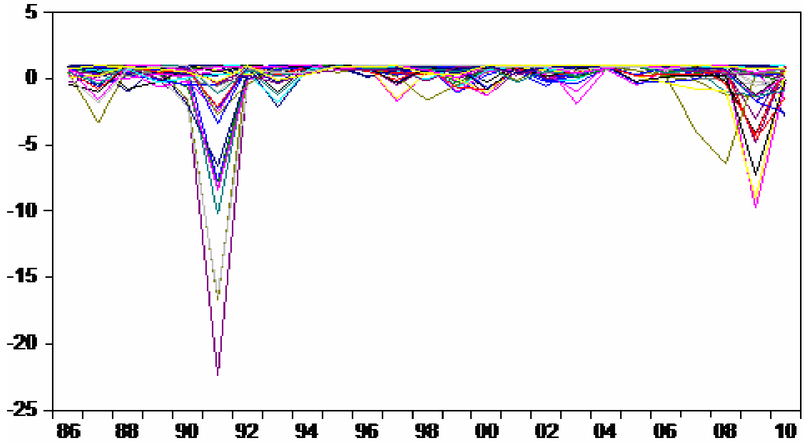


Figure 3: GDP Cross-Correlation Index



From the figures it is obvious that the correlations between pair of ports are strong and positive, indicating ports throughput synchronicity. This similar co-movement is also observed during recessions (2008-2009), because they typically occur simultaneously across countries (Claessens *et al.* 2009; Yetman, 2011). This synchronicity may be the outcome of a common shock (oil price shock) or may be transmitted through trade links and financial integration, which are fundamental contagion mechanisms (Calvo and Reinhart, 1996). The extent to which these channels affect port throughput synchronous co-movement either way remains to be solved empirically.

4.3 Bilateral trade intensity index[15]

The bilateral trade intensity index follows Deardoff[16] (1998) and indicates trade openess:

$$Bilateral\ \ Trade\ Intensity_{i,j,t} = \frac{Exp_{i,j,t} + Imp_{i,j,t}}{GDP_{i,t}GDP_{j,t}} * \frac{GDP_{w,t}}{2}$$

Where:

- Expij,t and Impij,t17 are the bilateral exports and imports from country i to country j (where the ports are located) at time t respectively,
- GDPi,t and GDPj,tare the countries' i and j GDP at time t,
- GDPw,t is the world's GDP at time t.

4.4 Fleet development and Index

Fleet development indicator (FDt) is defined as the weighted average of the ratios of available DWT per cargo type of vessels with respect to the number of operating vessels in each type. The weights are the percentage of DWT of each cargo type with respect to the total DWT.

INDEX is configured taking the log of Clarksea Index from Clarksons Research Services Limited nominalised by the log of distance in nautical miles between given ports i and j. The Clarksea Index is the only available weekly indicator representing

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[15] A second measure was also used indicating trade intensity, constructed as the ratio of bilateral trade flows between countries i and j divided by the sum of countries i and j's total trade flows. For reasons of space, we have not included these results in the present version. They are qualitatively similar to the results using our other measure and are available upon request.

[16] Deardorff shows that bilateral trade intensity as depicted above equals to 1 if there are no trade barriers and if preferences are homothetic.

[17] Export and import value of goods are deflated with the GDP deflator of the given country exporter and then incorporated to the index.

the earnings[18] (freight rates) of all the main commercial vessels, weighted according to the number of vessels in each fleet sector[19].

5. Sample and methodology

5.1 Sample

Two key driving forces guided the sample selection of the present study. First, based on the more the observations the better the analysis principle, it is obvious that the application of a panel data analysis requires throughput data covering an extended time frame. However, an extended desk research revealed that the number of ports with publicly available throughput data covering a period of more than 20 years on a worldwide basis is quite limited and this in turn limits the analytical capacity of the present study. Second, the analysis deployed in the present paper is quite novel. By this token, a need is felt to make its fundamental characteristics thoroughly understood before moving towards more complex conceptualizations and extended samples (thus guiding future improvements). The sample used in the present study was therefore limited to the throughput volumes of 12 major European ports that publish freely their throughput volumes for an extended period of time (the period 1986-2010[20] is specifically used in the present study). Namely these are the ports of Hamburg, Bremen, Amsterdam, Rotterdam, La Havre, Dunkirk, Ghent, Antwerp, London, Tees and Hartlepool, Piraeus, and Barcelona. Despite the aforementioned restrictions, ports that represent distinct as well as typical market structures and case studies (such as competitive ports of neighboring countries, competitive ports of non-neighboring countries or non-competitive ports) and ones which represent significant geographical areas (North Europe, Mediterranean sea, UK), in other terms ports which may lead to valid conceptualizations have all found their way to the sample composition.

5.2 Methodology

The panel data analysis offers several advantages over the time-series and cross-section techniques. It allows for more efficient parameter estimates (Hsiao *et al.*, 1995), uncovers dynamic relations (Pakes and Griliches, 1984), and identifies relations (by virtue of being a combination of the time-series and the cross-section

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[18] Earnings are estimated as daily time charter equivalents (TCEs) of voyage freight rates, and expressed in $/day on the voyage. In broad terms, earnings for each route are calculated by taking the total revenue, deducting current bunker costs based on prices at representative regional bunker ports (as provided by the Ocean Connect bunker brokering desk) and estimated port costs (after currency adjustments) and then dividing the result by the number of voyage days (Clarksons:2).

[19] The sectors in the Clark-Sea Index are oil tankers (VLCC, Suezmax, Aframax and clean product carriers), dry bulk carriers (Capesize, Panamax, Handymax and Handysize), gas carriers (VLGC) and fully cellular containerships.

[20] The throughput volumes of the ports consisting the database of the present study are freely published on their websites.

techniques) not captured by other models (Griliches and Hausman,1986; Biorn, 1992) such as the analysis of covariance approach.

The main objective of the present empirical study is to test the effect of the GDP convergence, the trade intensity and other shipping and port variables on the port throughput (a) synchronicity. The association in question does not necessary imply that causality is of one direction only (section 3) To overcome such a constraint, we use the dynamic panel Generalized Methods of Moments (GMM) estimator developed by Blundell and Bond (1998). The GMM improves the performance over ordinary least squares or two stage least squares in the presence of heteroskedasticity of unknown form (Hansen, 1982; Gragg, 1983; White, 1984; Newy and West, 1987) or neglected serial correlation (Wooldridge, 2001). Thus GMM weighting matrix is expected to account for unknown endogeneity and unobserved heterogeneity problems. In our model the explanatory variables are treated as endogenous, since it is accepted that past values of the error term have an impact on their future realizations. A maximum of two lags is included to retain a sufficient number of observations, which is necessary to derive reliable conclusions.

Regression (1) is augmented with binary pair-wise variables, in order to capture possible different behaviors between groups of ports. In the present study, the ports that deserve extra attention and a more detailed analysis are the ones being confronted with intensive competitive forces. The Northern European (“NE”) range (also referred as the Le Havre-Hamburg range) is being widely acknowledged as the region where the inter-port competition stands at high levels, thus considered adequate for further analysis. The “NE” subsample includes the following ports: Hamburg, Bremen, Amsterdam, Rotterdam, La Havre, Dunkirk, Ghent, Antwerp and an adjacency dummy is used, taking unity otherwise zero. Finally, regressions are performed using an unbalanced-panel dataset consisting of 61 port pairs (61*25=1525 observations).

6. Estimation and results

6.1 Descriptive statistics

Applying the Im, Pesharan and Shin (1997), Fisher-Augmented Dickey Fuller (ADF) and the Philips Perron (PP) unit root tests for stationarity, our indexes of the port throughput activity, the cross-country GDP and INDEX are found I(0) in levels, while the bilateral trade intensity and fleet development are I(1) in levels and I(0) in first differences[21]. Table 1 presents the descriptive statistics on the variables of the GMM. The Jarque-Bera (1980) statistic is distributed as $\chi 2$ with 2 degrees of freedom to test for normality. The reported probability is the probability that a Jarque-Bera statistic exceeds the observed value under the null hypothesis (in

[21] Results of unit root tests are available from the authors.

absolute value). Here, the hypothesis of normal distribution at the 5% level is rejected. Finally, Table 2 illustrates the variables' covariance.

Table 1: Descriptive statistics

	PT	GDP	BT	FD	INDEX
Mean	0.937546	0.369754	0.009287	6.428004	1.680089
Median	0.974480	0.804131	0.008569	6.445704	1.356825
Maximum	1.000000	0.999999	0.040216	6.999039	5.407639
Minimum	-0.075802	-22.40584	0.000000	6.074541	-0.140387
Std. Dev.	0.099540	1.633462	0.003877	0.280190	1.263202
Skewness	-3.633225	-7.512098	3.013084	0.397795	0.768589
Kurtosis	22.26649	76.76541	19.12075	2.050740	2.825607
Jarque-Bera	37983.23	507674.3	26533.98	137.4260	75.78871
Probability	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	2015.723	794.9721	19.96783	13820.21	1276.868
Sum Sq. Dev.	21.29289	5733.956	0.032300	168.7109	1211.121

Table 2: Covariance Analysis

	PT	GDP	BT	FD	INDEX
PORTACT	0.009904	0.011303	-5.25E-06	-0.004186	0.000587
GDP	0.011303	2.666956	-0.000216	0.004242	-0.277769
BTRADE	-5.25E-06	-0.000216	1.50E-05	0.000173	0.348241
FL	-0.004186	0.004242	0.000173	0.078470	0.008236
INDEX	0.004966	-0.049881	0.001511	0.061363	1.640267

6.2 Estimation

A GMM methodology has been applied with the ports synchronization index as the dependent variable. All non-stationary series were adjusted accordingly. In order to examine the long-run and short-run effects (dynamic) that variables may have on the correlation of throughput activity between certain pair of ports we first proceed to the estimation of a general-unrestricted model. The results denote that any increases of the time lags and thus of the dynamic representation of our model are not adding more information. With the short run dynamics being impoverished by the long run effects we proceeded to the estimation of a second "restricted" model (Table 3). Thus, the general model is "restricted" by the removal of variables and the testing with an F test for linear restrictions. At the 5% significance level we accept the restricted "EU" model with critical value F (5, +∞)=2.21.

The set of moment restrictions is rejected by the Hansen test (1982) for over-identifying restrictions in all cases. This implies that some instruments should be added to the existing regressors, which is equivalent to the enrichment of the dynamics of the empirical relations. The tests for serial correlation are consistent with the maintained assumption of no serial correlation of uijt only in the second order serial correlation[22]. For the first-order serial correlation, a formal Wald test rejects the null hypothesis that the original idiosyncratic errors are serially uncorrelated (Wooldridge, 2002)[23].

Table 3: Panel results 1986-2010-Restricted model

	Generalized Methods of Moments Restricted Model	
	EU Ports	NE Ports
PT(-2)	-0.117 (0.005)	-0.17 (0.00)
GDP	0.007 (0.05)	0.003 (0.97)
ΔTI	-2.10 (0.02)	-6.10 (0.003)
ΔFD	-0.092 (0.00)	-0.04 (0.02)
INDEX	0.06 (0.00)	0.08 (0.00)
AR(1)	-0.54 (0.00)	-0.57 (0.00)
AR(2)	-0.02 (0.44)	0.07 (0.02)
Hansen test	484.3 (0.00)	720.9 (0.00)

[22] Arellano and Bond (1991) estimates are based on the assumption that there should not be second-order serial correlation in the residuals of the first-difference equation.
[23] Wooldridge (2002) observe that if the residuals are serially uncorrelated, then Corr (Δεit, Δεit)=-0.05. The same procedure is followed for the within-panel correlation.

Notes:
1. Dependent variable pair-wise port throughput activity between ports i and j (i,j=1.....61) in period t (t=1986,.....,2010).
3. Numbers in curved brackets are p-values.
4. AR(1) and AR(2) are tests for first order and second order serial correlation in the first-differenced residuals asymptotically distributed as N(0,1) under the null of no serial correlation.
5. The Hansen test is a test of the over-identifying restrictions, asymptotically distributed as χ^2 , under the null of instrument validity.
5. Dependent variable lagged 2 periods and all explanatory variables lagged 1 to 4 periods were used as instruments in each equation.
6. Δ indicates the first difference of the variable that was applied for stationarity.

6.3 Results

From the results obtained in table 4 we get a positive relation between port throughput and GDP synchronicity in the general "EU" model, which is becoming statistically non-significant for the "NE" subsample. The trade intensity (TI) and shipping variables (FD, INDEX) have statistically significant effects on all tested samples. The rate of change of trade intensity though, has a negative sign in all equations. This means that higher trade intensity (TI) decreases the ports throughput cross correlation index thus leading to lower convergence of the trading countries' port activities. This is mainly due to the fact that ports circulate different kinds of cargo, so an increase of the bilateral trade between countries doesn't necessary incur a parallel increase in the activities of ports of their origin, as each port has its specialties (specialization effect cf. Hintjens *et al.*, 2012). In extent, specialization is causing the industrial structure of trading countries to diverge, weakens global linkages and is associated to more idiosyncratic business cycles of trading countries (Kenen, 1969; Eichengreen, 1992; Krugman, 1993). This view is also expressed in a different way by Coeck *et al.*, (1997), where it is stated that the competitive advantage of a port could also be expressed by different types and amounts of cargoes. However, this is roughly the case as far as EU countries are concerned and even less so as far as the "NE" countries (France, Belgium, Netherlands, and Germany) are concerned. In this case, both intra and inter industry trade are taking place and both common and country specific shocks are expected to affect the countries' economies (Kose and Yi, 2001). Thus, our findings point out the fact that, in all probability, in the "NE" countries subsample, land borders allowing for the substitution of maritime trade by other transportation systems (rail and road) dampen the effect of GDP convergence on port throughput synchronization.

The rate of change of the average DWT of world fleet development (FD) variable has a negative impact on the port throughput cross correlation index leading to lower ports throughput synchronicity and convergence in all equations. Thus the higher the rate of change of the average DWT supplied to serve maritime trade the lower the synchronicity between ports throughput. The world shipping developments do not affect ports in the same manner since the ports' infrastructure does not adjust symmetrically to meet the requirements of newly built sizeable ships of advanced technology. On the other hand, the divergence of ports throughput synchronicity due to an increase of the worlds' DWT per vessel is also associated to ports capacity constraints. In more detail, the total capacity of a given pair of ports of the present study is given for a short to medium time frame. In cases where their capacity is fully utilized, cargo will be directed towards other ports that are not found in our sample. Thus, this will cause a divergence of the ports throughputs found in our sample. Notwithstanding, ports are being confronted with capacity constraints as the supply for maritime trade is intensified (also expressed through an increase of the world's average DWT). Finally, the more efficient ports (which is the case of the ports of our sample) are the ones confronted with capacity issues more frequently as their use is favorable by shipping companies.

An increased transportation cost[24] (Index) can result in a higher port throughput cross correlation index, increasing synchronicity and convergence of the activities of trading ports in the "EU" and "NE" samples. This stands true as the maritime companies, in their attempts to reduce the increased travel cost, a) aim to further exploit economies of scale, and b) make extensive use of more efficient ports with a better combination of cost and service level. Shipping companies aim to make even better use of their vessel's capacity in order to realize higher marginal profits (especially in cases when the total transportation cost is increased). This is in line with the fact that the average DWT is increasing in line with the transportation cost[25].Thus, a trade concentration may be related to the higher efficiency of ports in use. On the other hand a trade concentration may be related to the higher efficiency offered by some ports as opposed to others and the need to counterbalance the losses associated to higher freight rates. These findings can also be attributed to the fact that the ports of our sample are ranked among the most efficient ports of the world. Hence, the observed synchronicity can also be a direct consequence of this qualitative characteristic of the sample composition.

Lastly, from the unrestricted model we note that all dynamic variables have the opposite sign of the one preceding their long-term effects, while in numbers the estimated variables are close. Thus, we may infer that the timing of the exogenous effects might be varying. However, even if we allowed for past values of the exogenous variables to affect ports throughput synchronicity, the form of long-term relation would be left unchanged.

[24] Concerning the construction of the variable, authors used also the bunker cost as a proxy for the transportation cost, but due to the high correlation across the two variables (0.99), the Clark Sea index nominalised by distance was preferred.

[25] Results are available from the authors under request.

7. Conclusions

In this paper we redefined port throughput as the sum of throughput associated to bilateral sea trade relationships of the focal port with its trading patterns. This approach led to the concept's macro modeling. Such a modeling opens the road to the identification of shipping effects on ports throughputs at given GDP and trade intensity developments. Thus, it concludes on a framework for modeling the relationship between ports and shipping activities.

The model was tested using panel data consisting of 61 pairs of ports (located in Europe, the Mediterranean Sea, and the UK) with the following as explanatory variables: GDP, bilateral trade relations, shipping related variables (fleet development, seaborne transportation cost) as well as a dummy variable (adjacency). The results signal the statistical significant and positive role of GDP synchronicity on ports throughput convergence, which is weaker in the case of NE countries where inter-port competition prevails. An increased trade intensity leads to port throughput divergence due to a) the specialization of ports in dealing with specific trading volumes, b) the concentration of maritime trade to more technologically advanced ports, and c) the fact that ports capacity cannot be increased in short periods of time. Increased world fleet supply in terms of DWT per vessel result unequivocally to port throughput divergence. Freight rates increases result to the convergence of ports throughput thus counterbalancing the losses imposed by the higher sea transport charges. All the tested effects were found to exercise long run impact on port throughput convergence. Overall the findings underline the role of specialization and technical features of ports in forming their placement in the international ports and maritime networks.

The suggested method can be further tested with the use of panel data from an extended sample of ports and countries. Moreover, the model can be enriched with qualitative ports' characteristics, such as concessions and infrastructure developments or macroeconomic variables capturing the financial conditions and the industrial structure of the countries in question.

In addition, the suggested model can form the foundation for micro studies relating a port i throughput associated to specific country j to the general trade intensity and GDP convergence variables that refer to the countries i and j. This allows for the application of forecasting techniques in order to estimate the throughput volumes of port i that are expected from country j. Moreover it allows for the identification of the role of key shipping factors, which influence a port's throughput, facilitating investment planning and decision-making towards increasing the port's attractiveness. Overall, the model allows a port authority to mark its performance against the dynamics of economic convergence and trade intensity of the country of origin with counterpart countries and in relation to the eventual changes in the shipping sector.

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Data Appendix

For the purpose of this study, yearly data were collected for four distinct variables for the years 1986-2010. The data on port throughput (in million metric tons) are collected wherever possible from sources such as specific ports' annual reports, Drewry reports, and countries' central banks. GDP (index=2005) and Bilateral Trade (US dollars) data come from OECD database and IMF Direction of Trade Statistics. Statistics concerning fleet development (dwt) and the Clarksea Index ($/day) are from Clarksons Reasearch Services Limited. Distance (nm) is obtained from sea distance-voyage calculator.