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Hierarchical Model of Container Ports Throughput

M. Rozmarynowska & L. Smolarek
Gdynia Maritime University, Poland

ABSTRACT: In this article the attempt has been made to construct hierarchical model of container ports throughput development. The presented hierarchical approach uses the relationships of development of global economy and container flows at different geographical levels: global (container throughput in all seaport on the world), regional (container throughput in the Baltic seaports) and national (container throughput in Polish seaports). Model have been evaluated for their fit and usefulness for predictive purposes.

1 INTRODUCTION

Constantly growing global seaborne containerised trade leads to increasing flows of containers in seaports. Increasing number of handled containers is visible at global, regional and national level. Generally speaking, this increasing trend is depended on the economic development, for which the main indicator is Gross Domestic Product (GDP).

In this article the attempt has been made to construct hierarchical model of container ports throughput development. The presented hierarchical approach is based on three models of container ports throughput development at three different geographical levels: global (container throughput in all seaports on the world), regional (container throughput in the Baltic seaports) and national (container throughput in Polish seaports). In this article simultaneously the relationship between global GDP and global container throughput and between container throughput at the different geographical levels: global-regional and regional-national have been illustrated.

The article is divided into three main parts. In the first part the general characteristic of container traffic at the global, Baltic and Polish level has been provided. In the second part the general assumptions to the model have been described, while in the third part the models have been presented and evaluated for their fit and possibility to use for predictive purposes.

2 GENERAL CHARACTERISTICS OF CONTAINER TRAFFIC ON THE WORLD AND IN THE BALTIC AND POLISH SEAPORTS

Nowadays volume of cargo carried in containers constitutes about 16% of global seaborne trade, in 2000 it was 10%, whilst in 1990 only 5.8%. Containerised cargo is the fastest growing cargo segment expanding at an average rate of 8.2% between 1990 and 2010 [3]. These figures show that the role of containerization in maritime transport is constantly growing. The main factors of the increasing share of containerized cargo in total seaborne trade are: the increasing demand for

manufactured goods and growing "containerisation" of bulk and break-bulk cargoes. It is estimated that in 2013 the total volume of containerized cargo loaded achieved a level of about 1.52 bln tonnes, which was 5.5% more than in 2012. If we take into account volumes in TEU, containerised trade reached 159 million TEU in 2013, indicating the 4.6% increase in comparison to 2012 (Fig. 1). The global containerised seaborne trade can be divided into seven geographical categories [2]:

- The Intraregional trade led by intra-Asian trade (28.1%),
- North–South trade (17.0%),
- The trans-Pacific trade (13.6%),
- Far East–Europe trade (13.1%),
- Secondary East–West trade (12.6%),
- South-South trade (11.7%),
- Transatlantic trade (3.9%).

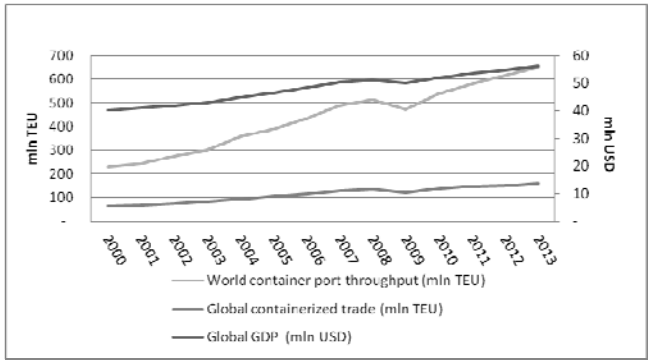

Figure 1. Global containerized trade, world container port throughput and world real GDP in 2000-2013

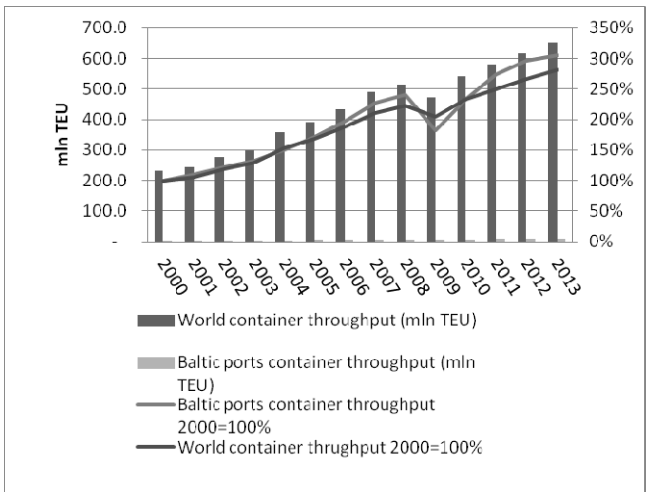

Figure 2. World and Baltic ports container throughput in 2000-2013

The important element in serving containerised trade are seaports. It is estimated that the total world container port throughput grew from 232 mln TEU in 2000 to 651 mln TEU in 2013 (Fig. 2). Comparing these figures with total containerised trade, it can be indicated that on average one TEU is reloaded about 4 times (loaded in the port of origin, unloaded from ocean-going vessel and loaded onto the feeder vessel in container hub port and finally unloaded in port of destination.). Over a half of total world container throughput is taking place in Asia – the manufacturing centre of the world. The Asian and world leader is China, approximately 50% of total Asian ports throughput, and 25% of total world throughput is served by Chinese seaports.

One of the region where there is a fast development of container ports throughput observed is Baltic Sea region (BSR). Baltic Sea region covers nine countries with direct connection to the Baltic Sea: Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, Sweden. All of these countries have at last one port that serve container traffic. Total container throughput in Baltic ports constitute about 1.5% of total world turnover. In 2013 the volumes reloaded in this region were estimated at 9.7 mln TEU. As it can be seen in the Figure 2, the pattern of changes of world and Baltic container turnover is similar. The average tempo of growth of world container throughput in years 2000-2008, was 10.6%, while for the Baltic it was 11.6%.

The crisis year 2009, was much more severe for Baltic ports (-24%). However, since 2010, the higher average annual tempo of growth has been observed for the Baltic traffic than for the total world traffic (+14.8% versus +8.4%).

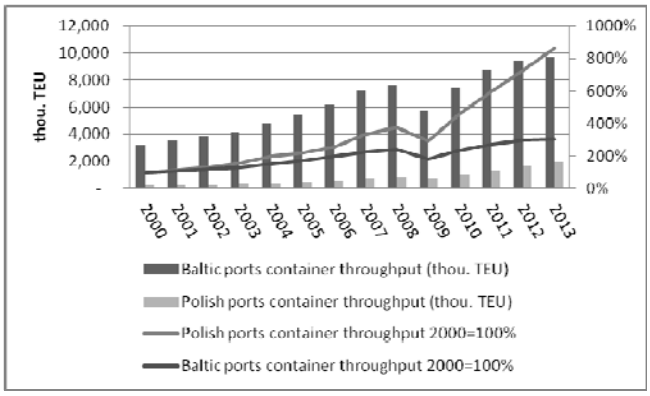

Figure 3. Baltic and Polish ports container throughput in 2000-2013

Over the past dozen years the overall BSR market structure has changed. In 2000 about 72.8% of containers handled by Baltic seaports passed through the three Baltic countries: Finland, Sweden and Denmark. Finland was the leader with the market share of 30.3%, followed by Sweden (26.4%) and Denmark (16.1%). Russian Baltic seaports handled only 10.1% of Baltic container traffic. Polish seaports were on the fifth position handling 7.6% of container traffic, the next positions were held by ports of Baltic States: Latvia, Lithuania and Estonia (6.7%) and German Baltic seaports (2.7%) [3]. However, since several years the Baltic leader is Russia, its share in this segment of Baltic market is estimated at nearly 30%. Since 2012, the second largest container market is Poland. Currently Polish ports handle over 20% of total volumes served by Baltic ports. Since several years Poland has been one of the fastest growing container market within Baltic Sea region. In 2000 Polish ports handled 228 thou. TEU, but since then container traffic in Polish ports increased 8.6 times, while total Baltic market grew only 3 times (Fig.3). Such spectacular increase in Poland was associated not only with the development of domestic market but also with the development of sea transit (from/ to Eastern Baltic region).

In Poland, containers are handled in all major ports, i.e. Gdańsk, Gdynia, Szczecin and Świnoujście. Today the largest Polish container port is Gdańsk, with two terminals: Deepwater Container Terminal (DCT) and Gdańsk Container Terminal (GTK). In the second largest Polish port, Gdynia, there are two container terminals: Baltic Container Terminal (BCT), Gdynia Container Terminal (GCT), but some containers are also reloaded in Baltic General Cargo Terminal (BTDG), In Szczecin containers are handled in DB Port Szczecin. There is also possibility to handle containers in Port Handlowy Świnoujście. The total annual handling capacity of all that terminals is estimated at around 2.7 mln TEU. This means that in 2013 Polish container terminals used around 73% of their handling capacity. It have to be underlined that majority of cargo, over 95% of containers, is handled in three main terminals: DCT, BCT and BCT. The handling capacity of these terminals is estimated at 2.4 mln (in 2013 they used over 77% of their capacity)

Polish ports mainly serve feeder container services. The only Polish terminal that serve ocean connections is DCT Gdańsk. Today DCT serve two such services operated by Maersk Line. The first one ***(AE10 service)*** have been launched in 2010 and connects Gdańsk with Asian container ports. The second one (Service CRX) since May 2014 connects Gdańsk with ports in Mexico, Belize, Panama and Costa Rica.

3 GENERAL ASSUMPTIONS TO THE MODEL

The hierarchical approach in this article is based on three models of development of container throughput at three described in the previous chapter geographical levels: global, regional (Baltic Sea region) and national (Poland).

In the first model (development of world container throughput - CP_W) the global Gross Domestic Product (GDP_G) have been used as the explanatory variable. GDP is used because this parameter is commonly regarded as a good explanatory variable for container traffic in seaports. In the world literature the relationship between GDP and seaports throughput (including container throughput) is often used in the context of creating predictive models. Authors of articles usually focus on the relationship between national GDP and turnover of seaports at national or regional levels. Among the publications dealing with this issue are [1],[6],[7],[8]. Author of this article also took on this subject in two publications: [4],[5].

The idea for the two remaining models was to explore the relationship between container throughput on the different geographical levels: global-regional and regional-national. In the second presented in this article model (development of container throughput in Baltic port - CT_B) the world container throughput has been used as the explanatory variable and in the last model (development of container throughput in Polish ports - CT_P), container throughput in Baltic ports has been used as an explanatory variable (Fig. 4).

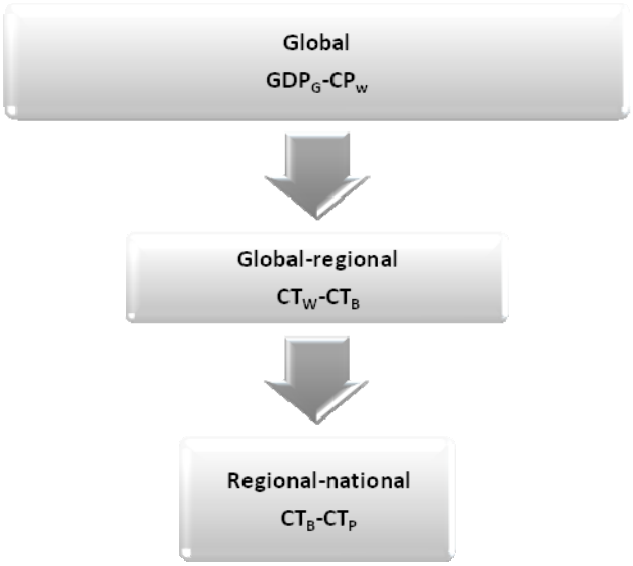

Figure 4. Hierarchical model of ports container throughput

Real world GDP is derived from statistical database of UNCTAD [11], and is expressed in mln USD. Data of world container port throughput are derived from statistical database of UNCTAD [11] and different numbers of publication [2], and are expressed in TEU. In the case of Baltic ports container throughput, data used in the models are cumulated data, which were found for each Baltic country. Data for Russian ports are derived from different sources [10],[13],[15]. Data for Danish ports are derived from Official Danish Statistics website [18], data for Swedish port are derived from the website of Swedish Ports Association [19], data for Finish ports are derived from the website of Finish Port Association [12]. In the case of Germany, data are only for port of Lubeck and are sourced from the port's website [14]. Data for Lithuanian ports are obtained from the website of port of Klaipeda [15], data for Latvia are derived from the website of port of Riga [17], data for Polish ports are derived directly form container terminals (DCT, BCT, GTK, GCT) and Port of Szczecin-Świnoujście. All data of container throughput are annual data for years 2000-2013 and are expressed in TEU.

4 HIERARCHICAL MODEL OF CONTAINER PORTS THROUGHPUT

The first stage of the analysis is the estimation of the trend model for global GDP. This is important from the viewpoint of creating predictive models using GDP as an explanatory variable. Future values of the explanatory variable can be predicted on the basis of the trend model describing the development of the variable over time. Global GDP development trend is described by the squared-Y logarithmic-X model, of the following equation:

$$GDP_G = 10^9 * \sqrt{-1.81139 + 0.238519 * \ln t} \quad (1)$$

where: GDP_G = global Gross Domestic Product in year t

Table 1. Statistical evaluation of global GDP development trend fit

	coefficient of correlation (ϱ)	adjusted coefficient of determination (R^2)	coefficient of random variation (V)
GDP_G	0.990441	97.9388%	1.5%

The probability test is less than 0.05. This factor is highly statistically significant, which means that in the studied phenomenon (growth of global GDP) there is a clear, significant development trend.

To evaluate the goodness of fit of the model adjusted coefficient of determination has been used (R^2). In this case coefficient of determination shows that the model explains 97.9388% of global GDP volatility (Tab. 1), this value indicates a good fit of the model. As can be seen in the Figure 5, the model pretty well describes the development of phenomenon over time. In addition to the clear trend, cyclical fluctuations are visible, as well as the collapse of the world economy, especially felt in the year 2009. When it comes to assessing the suitability of the model as a prognostic tool on the basis of the level of random variation coefficient (which tells us of how many percent on average, the theoretical values obtained from the model are different from the actual values), the model can be considered as a very useful. The coefficient of random variation reached a low level of 1.5%, which reflects small differences between the theoretical and actual values.

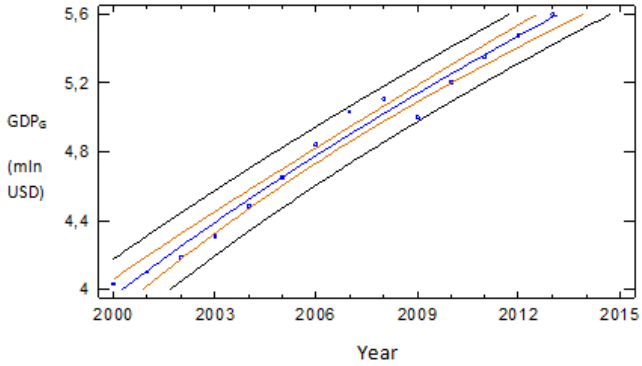

Figure 5. Trend model of global GDP [mln USD]

Below the models of development of container throughput are presented at three levels: global, Baltic and Polish. In this part the relationship between global GDP and world container throughput, between world container throughput and Baltic container throughput and between Baltic container throughput and Polish container throughput has been examined. All these relationships are described by the following equations:

$$CT_W = 10^8 * -8.35419 + 26.3974 * GDP_G \quad (2)$$

$$CT_B = \frac{1}{10^{-9} * -6.72195 + \frac{73.6431}{CT_w}} \quad (3)$$

$$CT_P = \frac{1}{10^{-6} * -1.32584 + \frac{17.9321}{CT_B}} \quad (4)$$

where: CT_W = world container throughput; CT_B = container throughput in Baltic seaports; CT_P = container throughput in Polish seaports

Table 2. Statistical evaluation of models fit

	coefficient of correlation (ϱ)	adjusted coefficient of determination (R^2)	coefficient of random variation (V)
GDP_G-CT_W	0.999029	99.7896%	1.5%
CT_W-CT_B	0.992884	98.4637%	6.0%
CT_B-CT_P	0.994293	98.7669%	9.4%

In all cases, the P value is less than 0.05, which means that there is a statistically significant relationship between the variables at the 95.0% confidence level. The correlation coefficient in all cases exceeds 0.99, indicating a strong relationship between the variables (Tab. 2).

The relationship between GDP_G and CT_W is described by a linear model. The model can be considered as well matched. For this model, a very high coefficient of determination has been obtained, which indicates that the model explains 99.7896% of the variability in CTw. There is also a very satisfactory value of coefficient of random variation, which indicates that the theoretical values obtained from the model differ from the actual values by only 1.5% at average, which is a very good result. It can therefore be concluded that described model may be useful for predicting the development of world container throughput.

The second analysed relationship (global container throughput and container throughput in Baltic seaports) is described by the double reciprocal model. In this case, there is also quite high value of the coefficient of determination, indicating that model explains 98.463% of the variation in CT_B. However, for this model, the worse coefficient of random variation have been obtained, the theoretical values differ from the empirical by 6% on average. Nevertheless this level can be regarded as admissible. The analysis of ex-post errors indicates that in the analysed period (2000-2013) the theoretical values deviate from the actual values from 0.3% to 6%, except from crisis year 2009, when the difference was significant (data from the model are significantly overvalued in relation to empirical data), and exceeded 15%.

The last analyzed model shows relationship between container turnover in Baltic ports and container turnover in Polish ports. This relationship is described by a double reciprocal model. The adjusted coefficient of determination indicates that the model as fitted explains 98.8618% of the variability in CT_P, which is a satisfactory value. However, not very satisfactory is the level of coefficient of random variation, which reached 9.4%. It can be indicated that the theoretical results differ from the empirical especially in years 2006-2010. The ex-post errors in these years are at the level of 10.8%,

11.07%, 13.5% 15.8%, 13.2%, respectively. The lower errors are in the years 2011-2013: 0.2%, 3.1%, 3.5%, respectively. As it can be indicated, the model is well-fitted especially for the last three years. In last three years the tempo of growth in Polish ports was much higher than in total Baltic sea region, by 1.7, 2.8, 5.9, respectively.

The high tempo of growth in Polish ports in years 2010-2013 was most likely connected with the development of transhipment traffic in port of Gdańsk, the largest Polish container port. By 2010, container cargo handled in Polish ports was destined to or come almost exclusively from domestic market. However, since 2010, when the first direct ocean service from Asia to Port of Gdańsk have been launched, we have been dealing with a new phenomenon. Since 2010, one of the Polish port have been becoming growing hub port for containerized cargo going to or coming from the East-Baltic markets (mostly to / from Russia). This means that containers delivered to the hub port by ocean vessel from the exporting country are reloaded in the port to smaller ship and transported to the importing country. Unfortunately, the data on the volume of containers handled in sea transit are not disclosed, so it cannot be fully specified what is the share of sea transit cargo in the total container traffic handled in Polish ports. However, according to the opinion of some representatives from maritime sector, such traffic increases. And, generally, it can be assumed that the hub role of Gdańsk will evolve in the nearest future.

All three models described in previous paragraphs have been illustrated in the Figure 6. From that figure we can simultaneously read how the global economy influence the world container throughput and what is relationship between global, Baltic and Polish container throughput. The presented hierarchical model is quite useful to analyse the past trends and relationships and can be use as a prognostic tool.

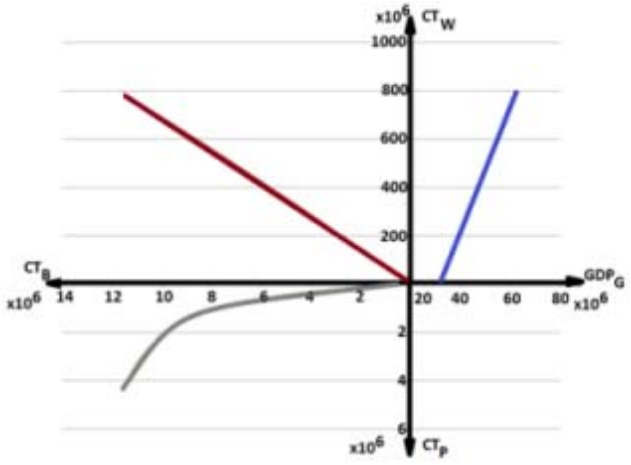

Figure 6. Hierarchical model of container throughput (global, Baltic and Polish level)

However, it have to be underlined that the third presented model (relationship between Baltic and Polish throughput) will not be adequate in long term. According to this model (see Fig. 6) if the whole Baltic container market will continue to grow the share of the Polish ports in total Baltic container market increase and finally exceed 100% which is not true, as the Polish ports constitute the part of the whole Baltic market. To conclude, this model may be adequate maximum for several years and most likely for 2-3 years. The presented model has been adjusted to the increasing share of Polish ports in total Baltic container throughput. Such situation had place during the last years. However, this will not be everlasting trend. The share will reach some level and probably will be more or less stable or in some future will decline (such situation may occur for example if there will be some change in Baltic container market and the other hub in the Baltic will appear, that will compete with Polish ports). The presented model shows the accelerated tempo of increase of Polish ports share in total Baltic throughput, however this many not be true. The increasing role of Polish ports is much likely, but probably not in such rapid peace as it is indicated by model.

On the other hand, if the tempo of growth of container throughput in Polish ports will remain at a high level and assuming that there will be a similar pattern to this observed today or there will be a growth in development in other Baltic container markets and additionally the pattern of development of world container traffic will be consistent with a first presented model (relationship between GDP_G and CT_W), it can occur that second model (relationship between (CT_W and CT_B) will not be adequate any more, and will have to be adapted to the changing Baltic market.

5 CONCLUSION

The presented hierarchical model illustrates simultaneously the relationships of container throughput development at different geographical levels: global, Baltic and Polish. It is quite useful to analyse the past trends and relationships. However, some errors of estimates are visible, which could be corrected by some correction factors. The whole model can also fulfil some prognostic role, and deliver the forecast of the container throughput at global, Baltic and Polish level. But most probably the hierarchical model as a whole, will not be adequate for long term, it could fulfil its prognostic role only for the next several years at most. Then its components will have to be adapted to the changing circumstances especially in the Baltic sea region.

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