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Establishing port container throughput potential; a PLS-SEM approach

Master thesis Urban, Port and Transport economics

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The views stated in this thesis are those of the author and not necessarily those of the supervisor, second assessor, Erasmus School of Economics or Erasmus University Rotterdam.

Preface

This thesis is written for the Master's in science Urban, Port and Transport economics from the Erasmus School of Economics, Erasmus University Rotterdam. In this preface I would like to express my thorough gratitude to the people who aided me during the process. Firstly, I would like to thank my supervisor, Martijn Streng, for his contributions throughout the complete process. His guidance and feedback proved to be very useful and I believe that his insights lifted this thesis to a higher level. Secondly, I would also like to thank my co-reader, Bart Kuipers, for his feedback and his presence during my thesis defence. Lastly, I would like to thank my friends and family who have shown unconditional support throughout my complete study career at the Erasmus University Rotterdam. The past period has been quite special. In the middle of the thesis process, the COVID-19 pandemic came about: no more long days at the university library, no more social events, and no more face-to-face meetings with a thesis supervisor. In the end, everybody found their own way through this, and so did I. The result is a thesis that I am proud of and I truly cherish the desire that the findings will contribute to existing literature.

Abstract

Throughout previous literature there is no general consensus as to what aspects of a port drive its container throughput. Previous research has often resided to using surveys to measure how certain actors in the container supply chain perceive port attractiveness and competitiveness. This paper argues that port attractiveness is a prerequisite for competitiveness and that the two should be combined into one construct, port throughput potential, in order to assess its drivers. This potential is a function of four different clusters of drivers. These encompass the following categories: endogenous endowment (a port's infrastructure and the perceived quality thereof), maritime connectivity, hinterland development, and port performance. Using partial least squares sequential equation modelling, or PLS-SEM, the relative importance of these constructs was measured for 68 container ports over a seven-year period between 2012 and 2018. PLS-SEM is a statistical method that allows for quantitative analysis of latent constructs. A multigroup analysis found that the importance of these clusters differs significantly between geographical region and economy type and hence, four additional models were created. Two for geographical regions (Europe and Asia) and two for different economy types (developed and developing). The new PLS-SEM models indicated that endogenous endowment and maritime connectivity always have a significant impact on container throughput potential. For ports in European and developed countries, focussing on their infrastructure and the perception thereof is key when these ports want to increase their potential. Ports in Asian and developing countries should primarily focus on ensuring that their port is well connected to the global container network. Hinterland development had a significant effect in two out of four models (European and developing model). Port performance did not have a significant effect on port potential in two models. In the other two models, port performance's effect was close to zero. Based on findings in previous literature, where port performance was found to be a significant driver of container throughput, it was inferred that port performance was proxied incorrectly in this research. Using the path loadings from the PLS-SEM models, a Container Throughput Potential Index (CTPI) was calculated. When this index is compared to actual throughput figures, ports were flagged as either under- or outperformers or as performing at their potential. The CTPI was also used to assess on what factors the port of La Spezia (not included in the original sample) should improve in order to boost its container throughput. The port authority should focus on its infrastructure and the perceived quality thereof as the remaining characteristics of the port allow for more throughput.

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Introduction

After the Chinese lockdown at the end of February 2020 due to the spread of COVID-19, container ports worldwide saw tremendous drops in handled cargo volumes. The following worldwide spread of the virus resulted in even lower trade volumes. The CEO of the Port of Rotterdam, Allard Castelein, expects that the port will see a throughput drop up to 20 per cent over 2020 (Mackor, 2020). In times where ports see their throughput figures decline, it could be vital for a port to determine what drives their throughput and what ports themselves can do to let their throughputs flourish again.

Container ports and their operations are a widespread researched subject in literature. They are often regarded as motors of economic regions, operating as gateways to the international maritime transport network. Their container throughput often resembles the wellbeing of its hinterland's economy. Next to that, attracting more container throughput generates revenues for a port via port charges and subsequently generates additional revenues in related industries such as warehousing, hinterland transportation and financial services. This stresses the importance for a port's hinterland for increasing container throughputs. When a port becomes more competitive and as a result attracts more cargo, a complete economic region can benefit from it. Container throughput figures are a function of different aspects of a port and its hinterland; characteristics of an economic region are the reason for container transport demand in the first place, whilst characteristics of a specific port are the reason the aforementioned container transport moves through a certain port. When a port is no longer competitive with nearby ports with overlapping hinterlands, container flows will start moving through those competing ports instead. Thus, remaining competitive and being able to identify what drives a port's throughput is vital for the continuation of a container port.

Port attractiveness and inter port competition are not a new topic at all, they have been around for a long time; studies around the subject remain rather limited (Caschili & Medda, 2015). When it is studied, scholars often reside to surveys in order to rank certain aspects of ports that decision makers find important when choosing a port. Outcomes of these studies vary heavily based on geographical location and surveyed sample (independent shippers, freight forwarders, ocean carriers, port authorities) and, thus, do not provide one uniform ranking of aspects that authorities, investors or any other party can use to assess port attractiveness. This paper tries to identify what factors of a port determine port competitiveness and therewith container throughput and if these factors differ per geographical location or economy type. It is not researched by a survey; researches on port competitiveness based purely on surveys are widespread. Instead, this paper aims to answer the following research question with quantitative factual information collected from copious sources:

What are the main drivers of container throughput?

Container throughput is used as a measure for port competitiveness and attractiveness. It is assumed that when a port becomes more competitive and attractive, more cargo will flow through it. In the next section, the theoretical framework, previous literature is reviewed on their findings and research methods to better identify the current position of literature on the topic.

Theoretical Framework

This section discusses previous literature on the drivers of port competitiveness and shows that there is no consensus on what drives port competitiveness and attractiveness. Before previous literature is discussed, the relationships between different concepts used in this paper is established.

Setting the stage

Port competitiveness is a port's ability to compete with nearby ports. When a port becomes more competitive it is better able to attract cargo flows. As illustrated by Ng (2006), port attractiveness is a prerequisite for port competitiveness. Port attractiveness is based on service level, infrastructure, and efficiency. Port attractiveness will likely attract a certain cargo throughput, but not necessarily at the expense of other ports. Port competitiveness is a more complicated concept as it also dependent on, for example, how such attractiveness is perceived and whether decision makers are free to make the most rational decision. As soon as a port becomes competitive, it will be able to "steal" cargo flows from competing ports. When port competitiveness is established, port decisions by freight forwarders, shippers and carriers will ultimately determine whether cargo will move through a port. In the end, it is expected that the greater a port's competitiveness, the more likely a freight forwarder, shipper or ocean carrier is to decide on using a port, the greater the port's throughput. Port throughput (together with land leases) is what drives a port authority's revenues. Since it is hard to quantitatively measure port competitiveness and attractiveness individually, the two are be combined into one measure: port potential. Port potential is a function of its intrinsic characteristics (attractiveness) and its ability to "steal" cargo flows from other ports (competitiveness). An overview of the concepts is visualized in Figure 1 .

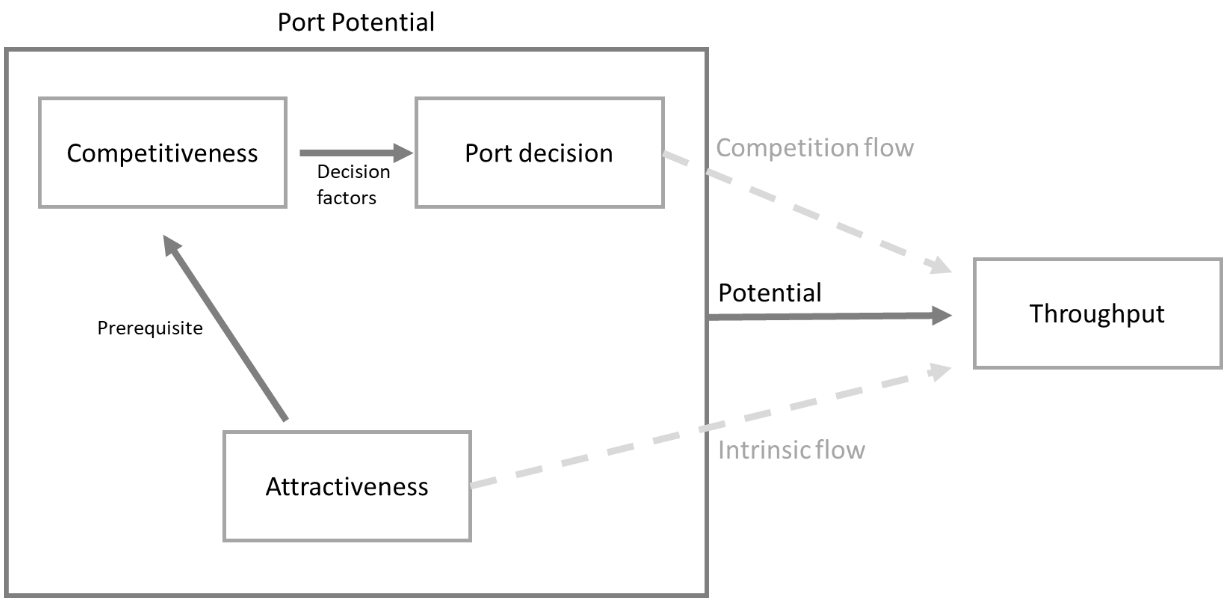

Figure 1: Overview of relationships between key concepts

Literature review

When looking at what previous research has concluded on port competitiveness, attractiveness, and decision factors, it is found that outcomes are widespread and that there is no consensus. For example, Tiwari et al. (2003) found that a higher container throughput in a port leads to the perception of congestion in a port and thus, a less competitive port. However, Song and Yeo (2004) find the complete opposite; higher cargo volumes lead to the perception of more efficient operations and thus, a more competitive port. Both researches were conducted in China around the same time and both researches sampled shippers with a survey. This example stresses the ambiguity found in literature around port competitiveness and decision behaviour.

Even within studies, such as Pires da Cruz et al. (2013), very different perceived preferences can be found. Pires da Cruz et al. found that seaport authorities and terminal operators perceived vessel turnaround times as relatively unimportant (rank 4 out of 5 aspects), whilst ocean carriers perceived vessel turnaround times as the most import aspect for seaport competitiveness. Ultimately, these ocean carriers decide whether they sail to a port. This shows that port authorities and terminal operators struggle to identify what makes them competitive and thus, where they should improve in order to attract more cargo. Murphy et al. (1992) also found that between port authorities, carriers, freight forwarders and shippers, perceptions of important decision factors are widespread. For example, accurate shipment information was perceived by port authorities as relatively unimportant for port decisions (rank 8 out of

9), whilst carriers (rank 5) and shippers (rank 3) perceived those as far more important decision factors. This misconception of the importance of shipment information from port authorities possibly leads to them assigning less resources to improving shipment information, whilst for shippers and carriers this information could prove vital in deciding between competing ports.

Parola et al. (2017) have analysed 46 papers between 1983 and 2014 about the drivers of port competitiveness. They found that in those papers, 39 unique drivers of port competitiveness were identified. Based on the number of papers a certain driver was mentioned in and the number of citations of those papers, they ranked these drivers of port competitiveness. They found that port costs are the most important driver of competitiveness, followed by hinterland proximity, hinterland connectivity, port location, port infrastructure, operational efficiency, port service quality, maritime connectivity, nautical accessibility and port site (e.g. quality of terminal layout). Even though the authors provide a good insight into what has been found to be drivers of competitiveness, the provided ranking is not directly applicable to the real world, since it is merely based on the number of times a certain concept is *mentioned* in such a paper and not the ranking of a concept within one of the sampled papers. It is quite logical that in any analysis of competitiveness, be it neighbouring restaurants, competing clothing brands or in this case, container ports, the price of the product (in the port case: port costs) are taken into consideration. Next to that, even though the samples in the researched papers are geographically and functionally dispersed, they are all combined into one analysis. It could be that, for example, only port authorities identify port costs as an important driver for port competitiveness, whilst shippers and freight forwarders emphasize other factors, such as hinterland connectivity. This would lead port authorities to focus on port costs to drive their competitiveness, even though shippers and freight forwarders do not care as much about costs as long as the hinterland connection is satisfactory. The latter group (together with ocean carriers) ultimately drives container throughput. This mismatch could lead port authorities to unnecessarily cut port dues, leading to lower revenues. The same applies to the geographical dispersion of the papers, port costs may be vital in deciding between Chinese ports but are only a side criterion for the decision between ports in the Hamburg – Le Havre range. Even though the real-world implications for this paper are minimal, the paper provides a good starting point for future research, identifying which factors should be analysed in order to predict container throughput.

Tongzon and Heng (2005) have used a stochastic frontier model to identify a port and terminal competitiveness index that translates itself into container throughput figures. This competitiveness index both encompasses the concepts attractiveness and competitiveness used in this paper. The authors identified eight determinants they intended to use for their index. Due to data availability limitations they only used five and found that efficiency, carriers' and shippers' preferences and landside accessibility were main drivers of port competitiveness. The importance of port efficiency is consistent with other literature (e.g. Ng (2006); Tongzon (2002); Tongzon & Sawant (2007), although only as stated, and not revealed, preference of carriers; Tongzon (2009)). Tongzon and Heng (2005) also used channel depth and the port's ability to changing market conditions as drivers for port competitiveness, but found it to have only a relatively marginal influence. The authors also found that the highest technical efficiency can be achieved within private/public and completely privately owned ports and terminals. The paper fails to take into account some previously identified drivers for port competitiveness, such as port costs (as stressed by e.g. Murphy et al. (1992); Lirn, Thanapoulou and Beynon (2003); Tongzon (2009); Parola et al. (2017)), maritime connectivity (e.g. Caschili and Medda (2015); Lirn, Thanapoulou and Beresford (2003); Lirn, Thanapoulou and Beynon, (2003); Tongzon (2009)) and port service quality (e.g. Caschili and Medda (2015); De Langen (2007); Parola et al. (2017)).

Caschili and Medda (2015) have combined most of the determinants as mentioned by Parola et al. (2017) and grouped them into endogenous, exogenous and subjective variables in order to construct a Port Attractiveness Index using a Sequential Equation Modelling (SEM) technique. Their case study of 41 African ports over a five-year time period leads to an index of the attractiveness of these ports, which can be used by potential investors to create a picture of the attractiveness of a port. Their approach quantitatively combines all factors that drive port competition and attractiveness, unseen in port competition literature before. However, due to their focus at attracting investments (new lessors of port land), they miss out on describing how these factors affect container throughput, which is also a key driver of a port's revenue (through port charges affiliated with container transport). Port charges are usually based on a combination of the ship size and the weight of the containers (Port of Rotterdam, 2020). When container throughput increases, it is very likely that both the total weight of containers and the ship size increase. For ports that have a tool port or public service port ownership model, attracting foreign direct investment is irrelevant. In these ownership models the ports' infrastructure and superstructure are owned and operated by a governing body; a foreign private party cannot invest in these assets. A tool that is aimed at boosting FDI is therefore irrelevant for these types of ports. These ports do however get revenues from port charges. A tool that can be used to get a better insight in what boosts their (container related) port charges could be beneficial for these ports, as well as for ports that have any other ownership structure.

In a broader, more exogenous, context, De Langen (2003) analyses the determinants of container transport demand. The author distuinguishes between two different variables that affect container transport flows; variables that influence the size of trade flows and variables that influence the proportion of containerized cargo. De Langen argues that the total containerized trade volume between two countries is a function of the size of an exporting economy, the openness of that economy, the importance of the importing country as a trade partner and the value density of the trade. Value density is defined as the value/volume ratio. When this value goes up, through more sophisticated production and miniaturisation of components, the container transport demand is expected to go down. Besides that, the author found that GDP, the openness of an exporting country, the containerisable share of trade and the containerisation rate all had a positive relationship with the growth of maritime container transport flows. De Langen also mentions a few additional factors that should be taken into account when forecasting container flows: trends in transhipment and empty container flows, and the competitive position of a port.

As shown, current literature lacks a consensus as to what drives container throughput, port decision and competitiveness. It could well be that indeed, decision factors are different over various actors and geographical locations. However, there is no quantitative evidence that the found decision variables actually led to the container throughputs found in reality. The current literature mostly aims to describe port competition based on endogenous and subjective factors that endorse decision criteria for shipping lines (Lirn, Thanapoulou and Beresford (2003); Lirn, Thanapoulou and Beynon (2003); Murphy et al. (1992); Ng (2006); Pires da Cruz et al. (2013); Wiegmans et al. (2008)), freight forwarders (De Langen (2007); Murphy et al. (1992); Tongzon (2009)) and shippers (De Langen (2007); Murphy et al. (1992); Slack (1985)). Most of the current literature uses surveys with relatively small samples sizes as their research method. A data-driven research, without data solely collected via surveys from a specific party involved in container transport, over multiple ports and years lacks in the literature. Most of the current literature does not describe how all these port characteristics, in combination with regional (exogenous) economic factors (e.g. GDP) led to actual container throughput values. The only article, to my best knowledge, that combines endogenous, exogenous and subjective variables in assessing attractiveness of container ports is Caschili and Medda (2015). However, their proposed Port Attractiveness Index (PAI) is used for assessing how foreign direct investments come about in ports. Currently, there is no literature that describes how endogenous, exogenous, and subjective variables together affect container throughput. To that background, this paper tries to combine all these variables into one data driven model that is able to predict container throughput. When combining the PAI as proposed by Caschili & Medda with the

Container Throughput Potential Index (CTPI) proposed in this paper, ports have two powerful tools with which they can assess how their endogenous, exogenous and subjective characteristics affect their level of FDI and container throughput, respectively. The outcome of this research will aid port authorities in deterring from overinvestment in areas where only marginal revenue increases can be achieved. For example, if the hinterland of a port does not allow for big container throughput increases, investing heavily in endogenous variables might lead to financial losses.

In order to answer the main research question, this research is guided using four sub-research questions:

1. How do port competitiveness and attractiveness affect container throughput?
2. Do drivers of container throughput differ per region or economy type?
3. How do we construct the Container Throughput Potential Index?
4. Is the Container Throughput Potential Index suitable to be used as a tool to boost container throughput?

As shown before, there is no consensus in the literature as to how port competitiveness and attractiveness affect throughput. Previous research mostly lacks a quantification of how large the impact of certain drivers is on throughput figures and only resorts to ranking certain drivers. Different researches hardly ever use the exact same drivers when researching how port competitiveness and attractiveness affect port throughput. However, the used criteria can all be grouped into four categories. These categories are the following (the subheadings are examples of indicators that were found to have a significant positive effect on container throughput):

- Port infrastructure (endogenous), such as:
  - Quality of equipment (De Langen, 2007);
  - Basic infrastructure presence (Lirn, Thanapoulou, & Beynon, 2003);
  - Size of marshalling yard (Lirn, Thanopoulou, & Beresford, 2003);
  - Number of berths (Tiwari, Itoh, & Doi, 2003).
- Maritime connectivity, such as:
  - Shipping frequency (Tongzon, 2009);
  - Quality of shipping services (De Langen, 2007);
  - Number of ship calls (Tiwari, Itoh, & Doi, 2003);
  - Closeness to main navigation route (Lirn, Thanapoulou, & Beynon, 2003).

- Hinterland-related, such as:
    - Availability of hinterland connections (Wiegmans, van der Hoest, & Notteboom, 2008);
    - Closeness to import/export area (Lirn, Thanopoulou, & Beresford, 2003);
    - Landside accessibility (Tongzon & Heng, 2005).
- Port performance, such as:
    - Vessel turnaround time (Pires da Cruz, Ferreira, & Garrido Azevedo, 2013);
    - Time efficiency (Ng, 2006);
    - Cargo handling efficiency (Tongzon, 2009).

Previous research has shown that drivers of container throughput vary per geographical location. However, this conclusion can only be drawn when findings from different papers are combined. For example, Lirn, Thanopoulou & Beresford (2003) find different decision variables for ocean carriers for Taiwanese port selection than Pires da Cruz et al. (2013) find for ocean carriers' port selection in the Iberian Peninsula. However, researches that incorporate multiple global geographical regions lack in literature. Previous research mainly focussed on smaller geographical regions and did not compare drivers between geographical regions. A notable exception is Tongzon (2002), where the author established that port attractiveness factors differ between shippers in Thailand and Malaysia. Differences in drivers of port competitiveness and attractiveness between ports in developing and developed countries are not yet researched in previous literature.

For the generation of the Container Throughput Potential Index (CTPI), it was decided to focus on the largest container ports according to Lloyd's List (2019). This decision mainly lies in data availability, it is expected that data is more widespread on these biggest ports than when a specific region with much smaller ports is analysed. Because the largest container ports are spread over the globe, additional insights can be achieved with regards to economical regions. It could be that there are different drivers for container throughput when, for example, North European ports and South-East Asian ports are compared.

This paper will use a statistical method (Partial Least Squares Sequential Equation Modelling; PLS-SEM) that allows for quantitative combination of causal relationships between exogenous, endogenous, and subjective variables. PLS-SEM is a variation on the regular Sequential Equation Modelling (SEM) method used by Caschili and Medda (2015). The benefit of this method lies in its predictive power and ability to model incomparable variables into latent variables and then compare them. Caschili and Medda used SEM in order to have an index as final product, this research takes this method one step further and uses the method to both calculate an index and a container throughput prediction. Where Caschili and Medda grouped their variables into three categories (endogenous, exogenous and subjective), this paper will group variables in the aforementioned four categories: hinterland-related, maritime-related, endogenous (all three consistent with Notteboom (2008) and Parola et al. (2017)) and port performance factors. This last factor encompasses a port's ability to efficiently use its port infrastructure. The subjective side of port potential introduced by Caschili and Medda (2015), will be incorporated within the aforementioned categories where they are applicable. A port's own reputation will be used in the endogenous category, whilst the perception of its hinterland logistic performance will be used in the hinterland-related category. The incorporation of subjective variables is quite rare in current literature, however as shown by previous research (e.g. Caschili and Medda (2015); Lirn, Thanopoulou and Beresford (2003); Ng (2006)), subjective factors also influence port potential and therewith, throughput.

It is important to note that the four aforementioned categories should be regarded as latent variables; it is impossible to say how well developed a port's hinterland related is in one number. Do you measure it in GDP? Number of inhabitants? Number of factories? How well a port's hinterland is developed is a result of numerous variables and cannot be simply calculated as a set factor of each variable (as in a regression). This paper argues that simply increasing a determinant of one of the four latent categories will not directly result in more container throughput, but rather that improving the latent categories will result in higher throughputs. In other words, simply adding berths to a container port will not directly increase container throughput when there is no room for throughput increases based on the other latent constructs. Each port should individually identify on what latent category they under- and outperform similar ports to better identify where improvements need to be made, which will in turn improve throughput.

Methodology

In order to construct the Container Throughput Potential Index, it should first be established how it will be measured. Logically, when the goal is to construct an index for container throughput potential, using actual throughput figures makes sense. Container throughput is defined as the total number of containers (measured in Twenty-foot Equivalent Units (TEUs)) moved through a port in a year, either as transhipment or as origin/destination flow. The Container Throughput Potential Index (CTPI) is then defined as:

A port's potential for container throughput as a function of hinterland, maritime, endogenous and performance related variables.

The higher the index, the greater a port's potential for larger container throughputs.

As also mentioned in the theoretical framework and the CTPI definition, this research will make use of four different types of variables, hinterland-related, maritime-related, endogenous and performance variables. Indicators of these variables are often factual and undisputed (you cannot argue about the number of berths in a port) and can be collected via copious sources online (e.g. WorldBank, UNCTAD). However, incorporating subjectivity in the model required using data that is most often collected via surveys; a research method that is often both costly and time consuming. It was therefore decided to retrieve data from multiple sources that are easily accessed via the internet (such as the Port Quality Index, developed by the WorldBank). This allows us to scale the sample size and time frame of the research. After the data collection, a statistical method should be selected that aids us in constructing the CTPI. Since multiple latent variables need to be connected, causal relationships between incomparable data need to be assessed and container throughputs need to be predicted, the previously mentioned PLS-SEM, as a variation on the SEM-technique used by Caschili & Medda (2015), will be used.

Partial Least Squares Sequential Equation Modelling is a method that is primarily intended for research contexts that are both data rich and theory skeletal (Hair J. , Sarstedt, Hopkins, & Kuppelwieser, 2014). The technique was developed by Wold (1974). It is somewhat similar to multiple regression analysis. However, some of its advantages over multiple regression analysis include the use of latent variables and handling of nonnormal, incomplete data. It is expected that not all data is available for all ports throughout the complete timespan. Model building within PLS-SEM is an evolutionary process; it extracts knowledge from the data and therewith puts flesh on theoretical bones (Lohmöller & Wold, 1980). PLS-SEM is a variation to the more popular Covariance Based Sequential Equation Modelling (CB-SEM). The most prominent justifications in literature for the use of PLS-SEM over CB-SEM are attributed to small sample sizes and nonnormal data. Another advantage of PLS-SEM over CB-SEM is that it easily allows for the use of formative variables, which are different to reflective variables. Formative variables are particularly useful for explaining and predicting constructs for competitive advantage (Albers, 2010). They “form” a certain construct. For example, a person’s physical attributes and personality form a person’s “attractiveness”. Contrary, reflective variables “reflect” how, for example, a person’s morality level leads to certain behaviour. CB-SEM methods do allow for incorporation of formative variables, however, including them deems imposing considerable constraints (Diamantopoulos & Riefler, 2011).

In previous literature, PLS-SEM has been successfully implemented in the following fields: Marketing (204 articles identified by Hair et al. (2011), for example Sattler et al. (2010) and Rapp et al. (2010)), strategic management (e.g. Agarwal et al. (2002); Robins et al. (2002)), management information systems Ringle et al. (2012), productions and operations management (summarized in Peng et al. (2012)), accounting (Lee, Petter, Fayard, & Robinson, 2011). PLS-SEM has hardly been used in the analysis of container ports or maritime transport. To my best knowledge, only Yeo et al. (2015) use PLS-SEM to analyse port service quality and customer satisfaction in Korean container ports. Given this previous work, the Container Throughput Potential Index will be constructed in the next section and therewith answer research question 3: how do we construct the Container Throughput Potential Index?

Mathematical construction of the CTPI

In order to construct the Container Throughput Potential Index, it is assumed that when key constructs go up, the index goes up as well. The key constructs are hinterland-related (H), maritime-related (M), endogenous (E) and performance-related (P). In the model, the four key constructs are latent variables that determine container throughput potential (φ). These are a function of multiple related individual formative variables chosen to determine throughput (e.g. channel depth and berth size for the endogenous key construct). The hinterland-related latent variable H represents the socio-economic quality of a port's hinterland and the port's connection to it. It can be measured on a wide variety of variables, such as economic development, number of internet users and proximity of large import/export areas. Key construct M relates to the maritime side of a container port. When a container port has better maritime connectivity, it is expected to have higher container throughput potential. It can be measured by, for example, its closeness to main navigation routes and the number of weekly liner shipping calls. The endogenous part of the CTPI, key construct E, represents the port's infrastructure and the subjective quality thereof. It can be measured by, for example, channel depth, berth size, container yard area and shipper's quality perception of that infrastructure (Tongzon & Heng, 2005). The last key construct is key construct P, the port's performance. It measures how efficient a port is in using its assets. In short, all formative indicators measure four key constructs, the weighted combination of these four key constructs is the Container Throughput Potential Index, which is reflected in actual container throughput. The proposed model is visualized in Figure 2. The aforementioned key constructs and formative variables are used to construct the Container Throughput Potential Index φ_i^j for port i in the j^{th} year. It can be mathematically written as:

$$\varphi_i^j = \alpha_{HP} * H_i^j + \alpha_{MP} * M_i^j + \alpha_{EP} * E_i^j + \alpha_{RP} * R_i^j \quad (1)$$

Where:

$$\varphi_i^j = \alpha_{PC} * T_i^j$$

$$H_i^j = \sum_{k=1}^{n} \alpha_{h_k} * h_{i,k}^j$$

$$M_i^j = \sum_{k=1}^{n} \alpha_{h_m} * h_{i,m}^j$$

$$E_i^j = \sum_{k=1}^{n} \alpha_{h_e} * h_{i,e}^j$$

$$R_i^j = \sum_{k=1}^{n} \alpha_{h_r} * h_{i,r}^j$$

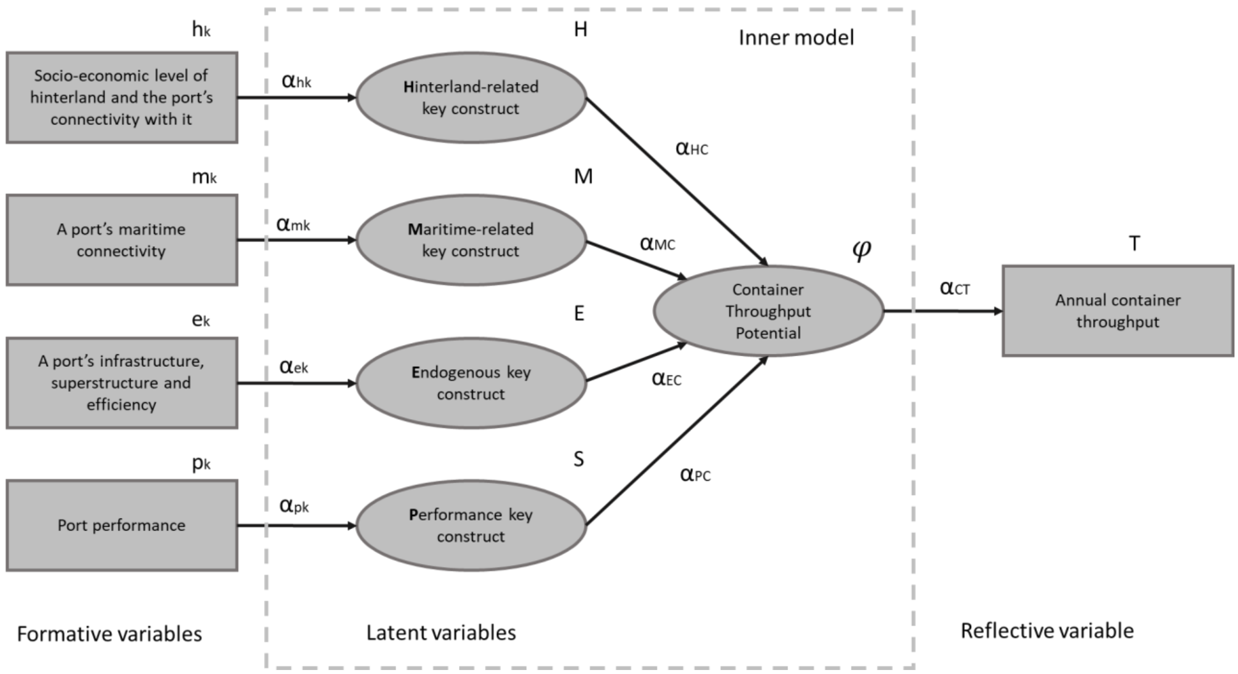

Figure 2: Overview of mathematical model

Path loadings α_{hk}, α_{mk}, α_{ek}, and α_{sk} represent the outer loadings (obtained from the PLS-SEM) of the formative indicators on the key constructs. α_{HC}, α_{MC}, α_{EC} and α_{PC} are the inner weights between the key constructs and the Container Throughput Potential. α_{PC} is the path loading between the Container Throughput Potential and the annual container throughput. $h_{i,k}^j$, $m_{i,k}^j$, $e_{i,k}^j$ and $p_{i,k}^j$ are the kth observed variables for port i in year j. T_j^i represents the container throughput of port i in the jth year. Software for conducting PLS-SEM analysis can be downloaded from SmartPLS (2020).

The path loadings will aid us in answering research question 1: how do port competitiveness and attractiveness affect container throughput? When it is identified that a certain construct has a high path loading, it can be inferred that this construct has a great influence on container throughput potential. These path loadings are theoretically similar to elasticities; when the level of maritime connectivity goes up with a certain percentage, the container throughput potential goes up as well, proportional to the elasticity/path loading.

In order to determine an appropriate sample size, previous literature and recommendations therein should be followed; Caschili and Medda used data for 41 African ports over 5 years in order to come to a

The PLS-SEM Algorithm

When all data is combined and structured in a model, the following steps are taken by the PLS-SEM algorithm, as described by Henseler et al. (2012):

1. Latent variables in PLS are linear combinations of various indicators that are measured in different ways and thus, the latter need to be standardized. This means that they are transformed to have a mean of 0 and a standard deviation of 1.
2. The measured indicator variables are used to create the key construct scores. An iterative process is used, which repeatedly loops through the following four steps:
    i. Latent variables are given initial estimates based on equal indicator weights;
    ii. Initial weights are assigned to the inner paths that connect the latent variables using a regression-based weighting scheme, in order to maximize the R^2-value of each endogenous latent variable (in our case container throughput potential). In other words, using regression, successive iterations adjust structural weights to maximize relation strength of successive latent variable pairs. This maximizes the explained variance of the dependent (container throughput potential);
    iii. The inner weights (between latent variables) are used to adjust the latent variable estimates;
    iv. The outer weights that connect the latent variables to their indicators are estimated based on regression of the latent variables on their indicators.

The iterations stop when there is no significant change in the weights of the indicators. The weights of the indicators in the final iteration are used to compute the final latent variable scores. These final latent variable scores are in turn used in the OLS regressions to calculate the final inner weights of the model.

sound statistical analysis, totalling in at 165 observations. According to Barclay et al. (1995) and Hair et al. (2014), the sample size for a PLS-SEM analysis should be at least ten times larger than the largest number of formative factors used to measure a construct and at least ten times larger than the largest number of inner model paths going into a particular construct in the inner model. Since four inner model paths are directed into one particular construct in the inner model and it is expected that no more than five formative variables will be used to measure one construct, a sample size of at least 50 observations is needed. However, since some data points can only be aggregated at national levels and not at the port specific level and it is expected that some data points will be missing, it was decided to use 68 ports from the Container Port top 100 from Lloyd's List (2019) and observe them for a seven-year period between 2012 and 2018.

Constructing the CTPI: The Container Port Top 100

As mentioned before, 68 ports from the container port top 100 were used for establishing the Container Throughput Potential Index. Originally, all ports from the ranking were planned to be used. However, due to some ports having very little information about them available online, some were dropped. Besides, due to some indicators being only available on the national level and not on the port-specific level, country specific biases could occur. Countries that are overrepresented in the Container Port top 100 would bias the outcome of the model too much. In order to reduce countries being overrepresented in the sample, the maximum number of ports in a country was set to five. This resulted in the number of Chinese ports being reduced from 21 to 5 and the number of ports in the United Stated being reduced from 9 to 5. For the remaining ports, data was collected over a seven-year period (2012-2018). These ports were geographically dispersed over the globe and grouped in five groups: European, North American, Central & South American, Asian, and Middle Eastern ports. Next to that, the same sample was also split into 2 groups based on their country's economic development; developed and developing economies (IMF, 2020). Some ports did not report their throughput figures over the complete timespan, resulting in a total of 468 observations. An overview of all ports can be found in Annex A.

Container throughput figures were measured in Twenty-foot Equivalent Units and collected via Lloyd's List. The average container throughput in the dataset is 5.9 million TEUs with a standard deviation of 6.7 million TEUs. This indicates that the sample covers a widely dispersed set of port sizes. The smallest throughput figure was found for Sines (2012) with a throughput of 0.55 million TEUs, whilst the maximum throughput was found for Shanghai (2018) with 42 million TEUs. The excess kurtosis of container throughput (9.406) and skewness (2.938) indicate that container throughput is not normally distributed around the mean, justifying the use of PLS-SEM. In the remainder of this section, all key constructs and indicators used in the PLS-SEM model are discussed individually.

Endogenous endowment (key construct E)

The endogenous key construct represents the port's infrastructure and the subjective quality thereof. The assumption is made that more infrastructure and a higher perceived quality lead to more container throughput potential. The following datapoints were collected:

- Number of berths;
- Quay length (in meters);
- Maximum vessel draft (in meters);
- Total container yard area (in hectares); and
- The Port Quality index.

It is important to note that the first three variables were only collected on container related infrastructure. For example, the maximum vessel draft for a tanker vessel in a certain port could be greater than the maximum container vessel draft, however, the latter is used in the model as only the maximum container vessel draft is relevant for container throughput. The port quality index measures the perception of a country's business executives of the quality of port infrastructure on a 1 to 7 scale (1= extremely underdeveloped, 7=well developed). The port quality index is only available per country and is developed by the World Economic Forum and published by the WorldBank (2020). The index was not developed in 2018, so these datapoints are missing. Except for the port quality index (measured every year), it is assumed that the infrastructural characteristics do not change over the observation period. Due to the heterogeneity of accounting standards between port authorities and the lack of one complete source online, port costs were not included in the analysis.

Table 1: Pearson's correlation matrix endogenous indicators

	Number of berths	Quay length	Max. vessel draft	Yard area
Number of berths	1	0.82**	0.28**	0.76**
Quay length		1	0.38**	0.82**
Max. vessel draft			1	0.40**
Yard area				1

** correlation is significant at the 0.01 level

Since the number of berths, quay length, maximum vessel draft and yard area all measure the size of a port's infrastructure, criterion validity should be established. Criterion validity refers to the extent to which indicator scores are correlated with other variables that one would expect them to correlate with. When establishing criterion validity, the criteria that measure a concept (in this case: port size) should correlate with each other. Table 1 shows the Pearson's correlation matrix of the four measures of port infrastructure size. All observed characteristics are linearly correlated at the p = 0.01 level. Number of berths, quay length and yard area are all strongly correlated, whilst the correlation between maximum vessel draft and the other variables is weak. This last finding can be explained by natural ports; when a small port has a large maximum vessel draft simply because the access channel is deep from itself, the correlation between maximum vessel draft and the other indicators weakens. The PLS-SEM algorithm has no problem with handling strongly correlating indicators, as long as they are not perfectly multicollinear, which is not the case here. The reason that the test for criterion validity is not repeated for indicators of other key constructs is that these indicators all measure different aspects of these constructs. The indicators in Table 1 all broadly measure the same aspect of endogenous endowment: port infrastructure size.

Port performance (key construct P)

The port performance key construct represents a port's logistic efficiency. This key construct differs from the endogenous key construct as it depicts how efficient a port ecosystem is in using its port infrastructure. It is assumed that better port performance leads to higher port competitiveness and thus, to higher container throughput. Port performance was measured using two indicators:

- Average time to clear customs; and
- Vessel turnaround ability.

Average time to clear customs data is used as a proxy for port efficiency (as deemed important for port competitiveness by e.g. Tongzon & Heng (2005) and Ugboma et al. (2006)). It is calculated by combining data on custom clearance time from the WorldBank and the Logistic Performance Index (LPI, also collected by the WorldBank). The latter is an index that was generated by surveying logistic operators, assessing the logistic "friendliness" of a country based on six pillars: infrastructure, international shipments, logistic competence, tracking & tracing, timeliness, and customs. Customs is defined as the efficiency of the clearance process (i.e. speed) by border control authorities (WorldBank, 2018). A country's customs score was used in the calculation of the average custom clearance time. It is expected that shorter clearance times reflect more efficient ports and thus, higher container throughputs.

In order to measure how time efficient a port is in mooring, (un) loading cargo and unmooring a container vessel, two datapoints from UNCTAD on port efficiency were combined. Average vessel size (in TEU) and median vessel turnaround time (in days). The median (instead of average) vessel turnaround time was used in order to diminish the effect of idle vessels (due to e.g. maintenance) on turnaround times. This median alone is not enough to reflect port efficiency as a "low" value could both reflect an efficient port and a port that only handles small vessels. In fact, there is a significant weak positive correlation (correlation coefficient = 0.29, p-value < 0.01) between average vessel size and port turnaround time. This would mean that higher port turnaround times could actually result in greater container throughputs. In order to internalize average vessel size in this performance indicator, a new variable is introduced: vessel turnaround ability. This variable reflects the average vessel size (in TEU) a port can handle in exactly one day:

$$Vessel\ turnaround\ ability\ = \frac{Average\ vessel\ size}{Median\ vessel\ turnaround\ time}$$

It is expected that a higher vessel turnaround ability reflects a more efficient port. When the two variables, average custom clearance time and vessel turnaround ability, are combined, an ambiguity is introduced: it is expected that *shorter* custom clearances and *larger* vessel turnaround abilities lead to higher container throughputs. Due to these opposite signs of these variables, it was decided to inverse custom clearance times in order to parallelize the signs.

Maritime connectivity (key construct M)

To capture the effect of a port being better connected to the global shipping network on container throughput, the maritime connectedness should be incorporated. It is expected that a higher maritime connection results into higher container throughput figures. This key construct will be measured using the Port Liner Shipping Connectivity Index (PLSCI). The PLSCI, developed by UNCTAD, measures a port's connectivity to the international container network. It is a further development of the Liner Shipping Connectivity Index which measures a country's connectivity to the global maritime container network. The PLSCI is based on six purely factual parameters:

- Number of scheduled ship calls per week;
- Deployed annual capacity;
- Number of regular shipping services from and to the port;
- Number of liner shipping companies that provide services from and to the port;

- Average size in TEU of the ships deployed by the scheduled service with the largest average vessel size; and
- The number of ports that are connected to the port through direct liner shipping services. A direct service is defined as a regular service between as set of ports. There may be stops in between, but a container should not be transhipped in order to reach the other port.

The index is developed annually and is indexed to Hong Kong in 2006 (=100). Since the index was only published in 2019, applications in the literature remain very limited.

Hinterland development (key construct H)

The last key construct measures the development of a port's hinterland and its connection therewith. It is expected that a more developed hinterland and a better connection with that hinterland results in higher container throughput potential. It is measured using five different variables:

- Level of corruption;
- Lead time between port and warehouse;
- Gross Hinterland Product (GHP);
- Internet usage; and
- Logistics Performance Index.

The level of corruption of a port's hinterland is estimated using the Corruption Perception index, developed by Transparency International. The index measures the level of corruption by aggregating data from various sources that provide corruption perceptions by country experts and business people (Transparency International, 2019). It is published every year. A higher index score represents a country with less corruption. It is expected that ports in less corrupt countries are more attractive for international shippers, freight forwarders and shipping lines and thus, result in higher container throughput figures.

In order to measure how well a port is connected to its hinterland the Domestic Logistic Performance Index, developed by the WorldBank, is used. This index was constructed by surveying logistic professionals on the logistics environment in their own countries. Amongst others, it questions the professionals on the average time it takes for goods being taken from a port to their factory/warehouse (import) or vice versa (export). In order to incorporate both import and export, the average of these two datapoints was used in the model. It is expected that shorter transport times lead to a more competitive port and thus, to higher container throughput. Just as for the customs clearance time, this variable is inversed to parallelize its sign with other variables.

When estimating container throughput figures, the size of the port's hinterland's economy should be incorporated (De Langen, 2003). However, simply using a country's gross domestic product (GDP) would be short-sighted, since this would result in big ports in relatively small countries (Singapore, Antwerp, Rotterdam), having a wrong estimate of the size of their hinterland's economy. The same holds for smaller ports in bigger countries (e.g. Charleston in the United States). A port's hinterland is usually not bounded by provincial or national borders, but rather by, for example, transport time. In order to estimate the size of a port's hinterland's economy, the total gross product within a 250km radius of a port was estimated. For example, when estimating this variable for the Port of Rotterdam, a circle with radius 250km was drawn from the port (see Figure 3). As can be seen from the map, the Port of Rotterdam's hinterland (almost) completely covers the Netherlands, Belgium and partially covers Nord Pas de Calais (NPC; province of France), Nordrhein-Westfalen (NRW; province of Germany) and Luxembourg (LUX). Overseas land (in this case, the east of the United Kingdom) was not incorporated in the calculation of the Gross Hinterland Product.

Figure 3: Visualized area of hinterland approximation for the Port of Rotterdam

In order to calculate the Gross Hinterland Product of the port of Rotterdam, the following formula was used:

$$\begin{aligned} &Gross\ Hinterland\ Product\ Rotterdam \\ &= GDP\ Netherlands + GDP\ Belgium + \frac{NRW\ area\ within\ circle}{total\ area\ NRW} * GRP\ NRW \\ &+ \frac{NPC\ area\ within\ circle}{total\ area\ NPC} * GRP\ NPC + \frac{LUX\ area\ within\ circle}{total\ area\ LUX} * GDP\ LUX \end{aligned}$$

This was repeated for every port in the dataset. I understand that I introduce an ambiguity here, a port's hinterland is often way larger than this 250km radius and is often not a simple circle around the port as well. However, this method does overcome the problem of "random" borders and is thus a better proxy for hinterland economy size than simple provincial or national gross product figures. It is expected that a greater Gross Hinterland Product will positively affect container throughput potential. When calculating a port's potential for container throughput, the size of the economy proximate to the port should be incorporated. Regardless of the actual size of a port and its ability to serve its hinterland, the size of the nearby economy results in a certain *potential* for container throughput. The latter is what the Gross Hinterland Product variable measures, where a larger GHP is expected to result in a greater potential for container throughput.

The percentage of a country's population that has internet access will be used as a proxy for the presence of a middle class. It is hypothesized that a greater presence of a middle class will boost the trade of manufactured goods. These goods are mostly moved via containers.

The Logistics Performance Index (LPI) is an index developed by the WorldBank that assesses the reputation of a country's overall logistic performance. This indicator of hinterland development is a subjective one, as it is merely based on the opinion of parties on the logistic performance of a country. It is constructed by surveying foreign logistic operators on six factors: quality of infrastructure, ease of arranging international shipments, logistic competence, quality of tracking & tracing, timeliness, and ease of customs. However, since the customs-scores were already used for estimating average custom clearance times, only the other five were used in assessing a country's logistic "friendliness". There is a very weak (coefficient = 0.20) correlation between the remaining LPI and the custom clearance times estimates. It is expected that a friendlier country for logistics will attract more container transport.

Dataset limitations and discussion

The complete dataset covers a wide scale of variables ranging from throughput figures (measured in TEU), Gross Hinterland Product (in billion USD) and quay lengths (in meters). However, since the PLS algorithm standardizes every indicator, the effect of different measurement methods is diminished. For some ports, the collected information did not cover the complete period (2012-2018). This resulted in a total of 468 observations. According to Barclay et al. (1995), the minimum sample size should be ten times the largest number of formative indicators used to measure one construct. Thus, a sample size of at least 50 observations (five formative indicators for key constructs E and H) is required. Some indicators were only collected for a subset of years in the observation period, resulting in a significant number of missing values for these particular indicators (turnaround ability and lead time between port and warehouse). However, a particular strength of PLS-SEM is its ability to handle missing values. A serious limitation of the used dataset is the fact that some variables were only collected on national levels and not on ports specifically. As a result, port performance is only measured at the national level and can therefore only be used as a proxy for port specific performance. This aggregation of data on only national levels also results in multiple ports in the same country receiving the same data value. Only for 3 out of 13 indicator variables, negative excess kurtosis was found. In combination with the finding that 7 out of 13 indicator variables have absolute skewness higher than 1, the use of PLS-SEM is justified even more; the used data is not normally distributed.

Table 2: Overview of variables and their sources

summarizes all variables and their sources.

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Variable	Source	Variable	Source
Container Throughput	Lloyd's List	*Port Liner Shipping Connectivity Index*	UNCTAD
Number of berths	World Port Source	*Corruption Perception Index*	Transparency International
Quay length	World Port Source	*Lead time between port and warehouse*	WorldBank; domestic LPI
Maximum vessel draft	World Port Source	*Gross Hinterland Product*	Own elaboration on various sources
Total container yard area	World Port Source	*Internet users*	WorldBank
Port quality Index	WorldBank	*Logistic Performance index*	WorldBank; LPI
Customs clearance time	WorldBank; LPI		

Results

The proposed PLS-SEM model was run with 5000 iterations and a stop criterion of 10^{-7}. The outcome of the initial model can be found in Figure 4. The model has an adjusted R^2-value of 0.657, indicating substantial explaining power. The outer loadings show how large the effect of an indicator is on a certain construct. Logically, for the maritime key construct, this loading is 1.00 as PLSCI is the only indicator for this key construct. The inner loadings represent the effect of the key constructs on container throughput potential. The numbers in brackets represent the corresponding p-values for each effect. These p-values were found using a bootstrapping procedure with 5000 subsamples. Some formative indicators have insignificant path loadings, this does not necessarily mean that these are not important for determining the level of a key construct. However, when controlling for all other formative indicators of that key construct they do not significantly influence the construct. According to Hair et al. (2014), dropping insignificant formative indicators should be exception, not rule. Since formative measurement requires full capture of the construct's entire domain, omitting a formative indicator is equal to omitting a part of a construct.

For the first two key constructs, maritime connectivity and endogenous endowment, the path loadings were significant and positive. Since all data is standardized, the results can be interpreted as follows: maritime connectivity is approximately (0.751 / 0.155 =) five times more important for container throughput than endogenous endowment, when the global model is used. From the model it is clear that both hinterland development and port performance do not have a significant effect on container throughput in the whole sample. There could be various reasons for that, but it is likely that it is geographically related. Hinterland related factors being insignificant could well be related to the interchangeability of ports for a certain hinterland (contestable hinterland). This effect would be neglected by the analysis as all data is used together in one analysis. In other words, in the current model, the competition in the Hamburg-Le Havre range is compared with port competition within mainland China. An explanation of the insignificance of port performance could lie in the fact that data on this variable is only collected on the national level. This would result in the port with the smallest container throughput in, for example, China (Fuzhou) being given the exact same value for port performance as the biggest Chinese port (Shanghai). To better analyse what drives container throughput, it should be determined if the drivers of container throughput differ per geographical region and per type of economy (developed versus developing). PLS-SEM software allows for multigroup analysis, which tests whether significant differences exist in path loadings between groups. As mentioned before, the ports are divided in five geographical regions: the Middle East, Europe, Asia, North America, and Central & South America. Because the sample sizes for the Middle-East, North America and Central & South America were too small (according to Barclay et al. (1995)), only new PLS-SEM models were made for Europe and Asia.

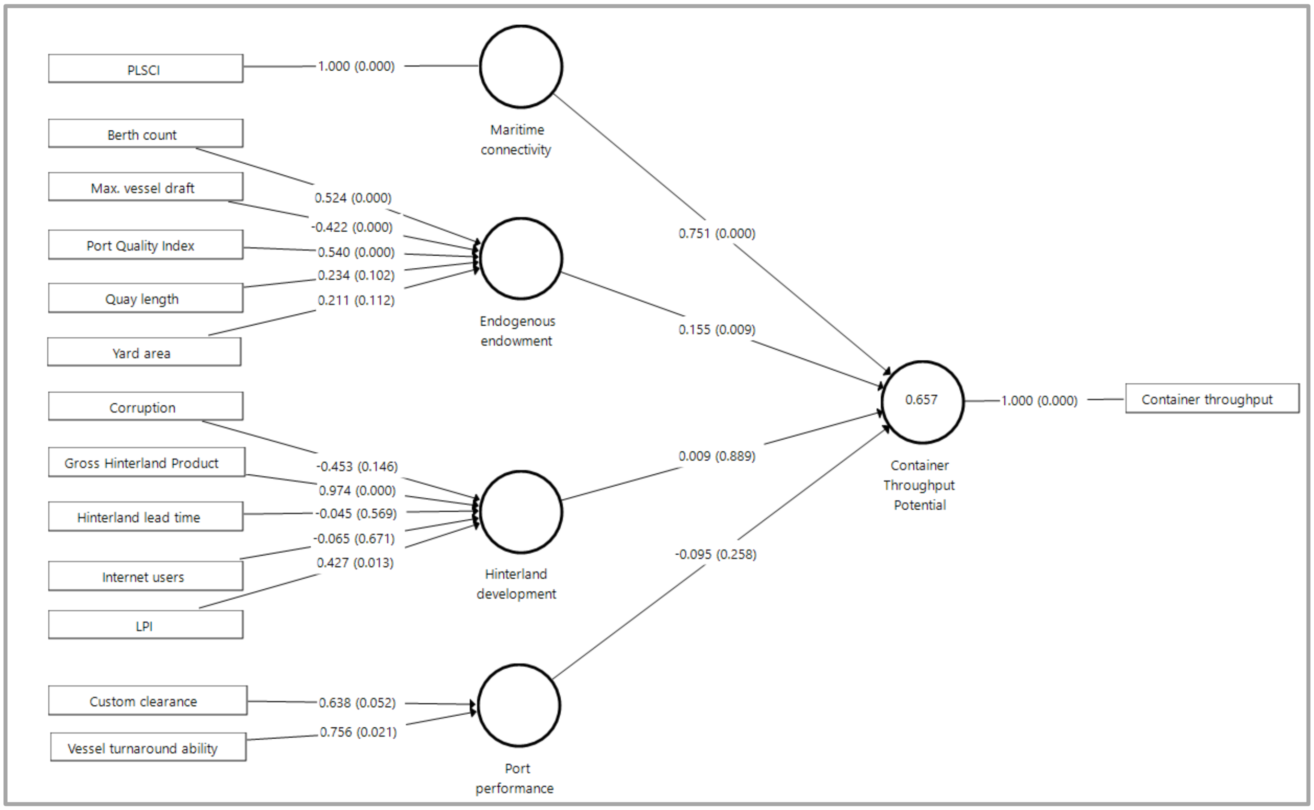

Figure 4: Path loadings and bracketed p-values of the first model

Multigroup analysis: European & Asian ports

To test whether path loadings differ significantly between regions, a multigroup analysis (MGA) was conducted. The method uses t-tests with independent samples to compare paths as proposed by Keil et al. (2000). Before running an MGA, measurement invariance should first be determined. Measurement invariance is tested using the MICOM procedure. Measurement invariance is needed because it should be established that the inner model constructs measure the same concepts between groups. This procedure first tests for compositional invariance and then for scalar invariance. For our MICOM procedure, the test for compositional invariance results indicated that compositional invariance exists for three out of four constructs. Only performance showed composite variance. However, since the indicators for the performance key construct (vessel turnaround ability and average custom clearance time) are all collected from the same source, it can be inferred that the reason for composite variance probably has underlying reasons. In this case, the performance indicators are both measured on national levels (and not port specific). This could also result in composite variance (e.g. all Japanese ports have the same values for both performance indicators). Since all other constructs showed composite invariance, scalar invariance should next be established. According to Steenkamp & Baumgartner (1998), scalar invariance is sufficient if at least two indicators of a construct have equal loadings. For the MICOM procedure at hand, all permutation p-values are insignificant, so scalar invariance is established.

Now that measurement invariance is established, the MGA can be conducted. The MGA tests whether path loadings differ significantly between groups. The outcome of the MGA indicated that three out of four constructs have different path loadings between Asian and European ports. Only performance showed no significant difference in path loadings. Again, the reason for this probably lies in the fact that port performance is only measured on the national level. Since the MGA showed that the other three constructs' path loadings differ significantly between the two regions, two additional models for the specific regions should be developed and the initial model should be disregarded. With the outcome of the MGA the second research question (do drivers of container throughput differ per region and economy type?) has partly been answered; based on the collected data and the multigroup analysis, it can be inferred that the importance of different drivers of container throughput differ significantly between geographical regions. Whether the importance of drivers also differs between economy type will be investigated in the MGA of ports in developing and developed countries. The rest of this section discusses the outcomes of those two specific regions and the Container Throughput Potential Index for all ports in these regions.

European model

When running the model only for European ports, it was found that the model has substantial power in explaining container throughput (adjusted R^2 of 0.901). After conducting a PLSpredict procedure a Q^2-value of 0.891 was found, indicating a high degree of predictive relevance (Hair J. , Sarstedt, Hopkins, & Kuppelwieser, 2014). The found path loadings and p-values can be found in Figure 5. After bootstrapping with 5000 subsamples, it was found that all four key constructs had significant path loadings. However, contrary to the hypothesized outcome, port performance has a negative sign. This indicates that when port performance goes up (i.e. more efficient custom procedures and higher vessel turnaround ability), container throughput goes down. However, since the path loading is very close to zero (-0.074) and the path loading is only significant at the p=0.1 level, it can be inferred that based on the statistical evidence, port performance hardly affects container throughput. This finding is contrary to findings from, for example, Ng (2006) and Tongzon et al. (2007). Next to that, for European ports, endogenous variables (path loading of 0.533) are about twice as important for container throughput than maritime connectivity

Bootstrapping

Bootstrapping is a procedure used for testing significance. It is a common statistical procedure in models where normal distribution of variables cannot be assumed. Since distributional properties of estimates in PLS-SEM are unknown, bootstrapping is appropriate. The procedure takes a large number of “leave one out” samples from the data and then computes a standard deviation. For bootstrapped significance, a probability of 0.05 (p-value) means that there is a one in twenty chance that a similar or stronger absolute result will occur due to random sampling (Garson, 2016).

PLS predict and the Q^2-value

In order to assess the predictive power of a model, PLS-SEM software allows for prediction power analysis. The PLSpredict algorithm uses training and holdout samples. The training samples are used to predict the holdout sample. The result is an Q^2-value, which varies between -1 and +1. The closer to +1, the better the predictive power of the model. If the Q^2-value is positive, the prediction error of PLS-SEM is smaller than the prediction error of simply using means. The procedure was developed by Shmueli et al. (2016).

(0.281) and hinterland related factors (0.243). The Container Throughput Potential Index (CTPI; ϕ) is then calculated using equation 1 for each European port in all years. The results can be found in Figure 6. The displayed indexes are the averages of a port’s index over the complete timespan. These indexes were then compared to the standardized known average container throughputs for each port. This comparison identifies out- and underperforming ports. In the figure, the grey ports are the ports that perform around their potential (difference between CTPI and throughput is less than 0.2 standard deviations of container throughput), the green ports represent ports that outperform their CTPI, whilst the red ports underperform; according to the model, these ports have potential for more throughput than they currently handle. It is remarkable that five out of seven Mediterranean ports outperform their CTPI. This is likely due to these ports being major transhipment hubs (Piraeus, Marsaxlokk, Gioia Tauro). Based purely on their characteristics, they are expected to have less container throughput. However, as this model does not incorporate transhipment possibilities well, ports that have large shares of transhipment in their total throughput usually outperform their CTPI. Next to that, three out of five of the big European ports in the Hamburg - Le Havre range do not reach their full container throughput potential. This is likely due to the fierce competition under these ports, they all compete for roughly the same hinterland. The reason that St. Petersburg outperforms its CTPI likely lies in the way Gross Hinterland Product is measured.

In the measurement, the port's hinterland GDP is a combination of (mainly) the GDP of St. Petersburg and the province Oblast Leningrad. However, the port of St. Petersburg also services the nation's capital Moscow. This part of Russia is not used for calculating the port's hinterland gross product. The CTPI is therefore lower and thus, the port outperforms its CTPI.

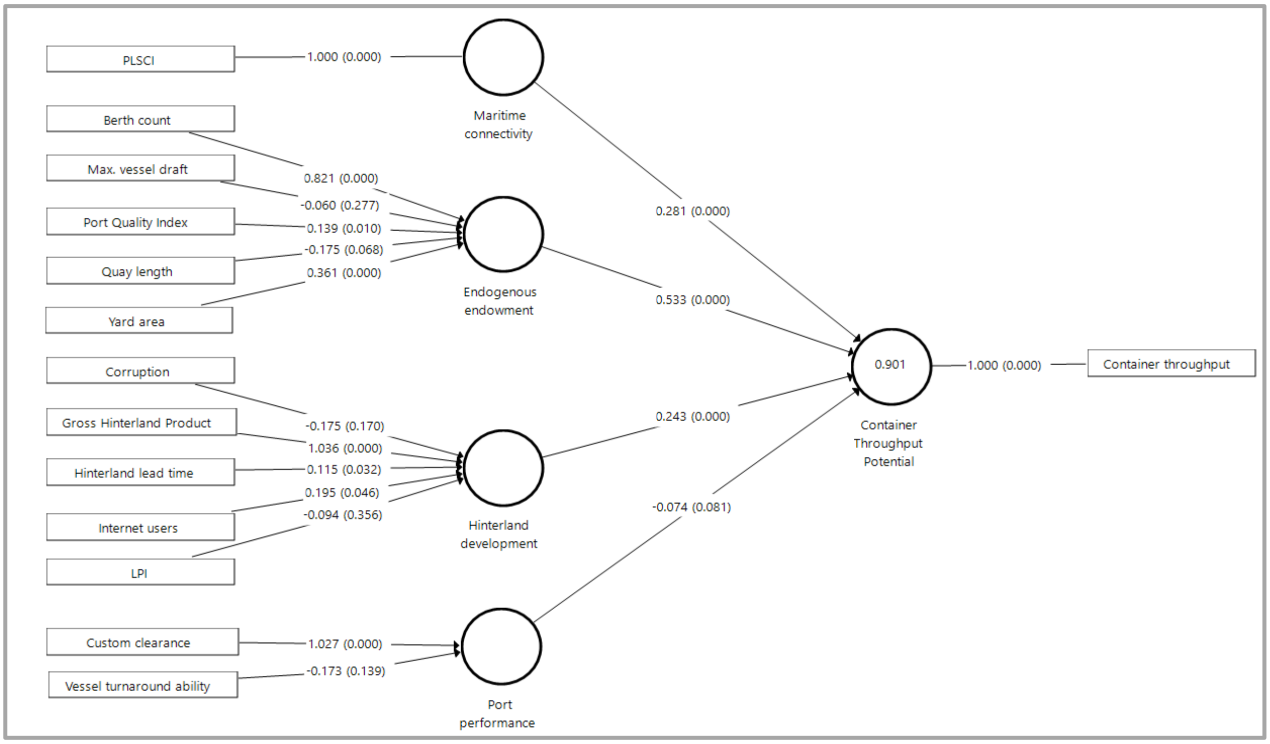

Figure 5: Path loadings and bracketed p-values of the European model

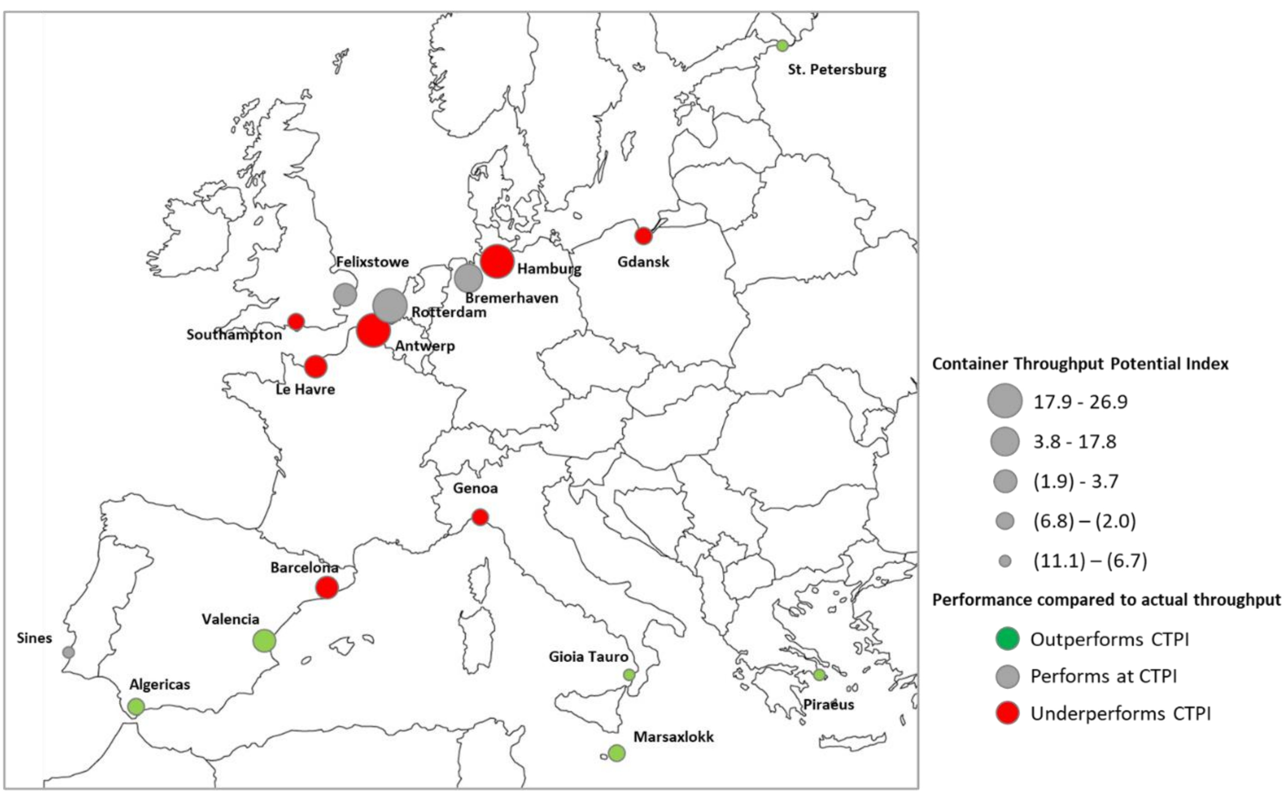

Figure 6: CTPI mapping of all European ports

Interpretation of the Container Throughput Potential Index

The interpretation of the CTPI should be as follows: only within models can CTPIs between ports be compared. This is due to different path loadings and weights between models and the (in) significance of some key constructs and indicators. Insignificant key constructs and indicators are not used for calculating the CTPI. When a formative indicator is found to have an insignificant path loading, it does not necessarily mean that this indicator does not affect container throughput. However, it is, in combination with the other indicators for that same construct, not significant in measuring a key construct.

The CTPI is calculated as a standardized average over multiple years for a certain port. The result of using standardized scores is that some ports have negative CTPIs and some have positive CPTIs. The average CTPI in a model is always 0. In all the legends in this research, bracketed values are negative CTPIs, indicating that these ports have a smaller CTPI than the average port used in the model. Next to that, it was decided to multiply every CTPI with a factor 10 for comprehensibility reasons. When assessing whether or not a port under- or outperforms its CTPI, a threshold of 2 points in CTPI was used; if the difference between a port's CTPI and actual container throughput is larger than 2, it is either flagged as red or green. What this effectively means is that a port's actual throughput differs 0.2 standard deviations (due to the factor 10 multiplication) from its CTPI. A red port has a higher CTPI than its throughput, a green port has a lower CTPI than its actual throughput. The true throughput potential is a function of the standard deviation and the mean CTPI found in each model. For example, if the actual container throughput potential of Rotterdam needs to be determined, the following formula should be used (in the European model):

$$Throughput\ potential\ Rotterdam\ in\ TEU\ =\ mean\ throughput\ of\ EU\ ports\ (in\ TEU) + \frac{CTPI}{10} * STD.DEV.$$

$$Throughput\ potential\ Rotterdam\ in\ TEU\ =\ 4.30\ +\ \frac{26.8}{10} * 3.17\ =\ 12.82\ million\ TEU$$

Both the standard deviation and mean container throughput for each model can be found in Annex B. This throughput potential for the port of Rotterdam is the average potential measured over the seven-year period between 2012 and 2018. The same applies to the CTPI, it is an average of the CTPIs of every year. The average actual throughput of the port of Rotterdam over this seven-year period was 12.66 million TEU. The throughput of the port of Rotterdam was 14.51 million TEU in 2018. The reason that this last datapoint is far higher than the average potential of the port lies in the opening of Maasvlakte 2, which increased the port's capacity significantly somewhere within the studied timespan.

Asian model

The same procedure for the European ports was repeated for the Asian ports. The model again reported substantial explaining power with an adjusted R^2 value of 0.751 and a high degree of predictive relevance (Q^2-value of 0.752). The found path loadings and p-values can be found in Figure 8. After bootstrapping with 5000 subsamples, it was found that for the Asian ports, the hinterland and performance key construct did not have a significant effect on container throughput. Besides, it was found that maritime connectivity (path loading of 0.766) is about four times as important for container throughput as endogenous endowment (0.189).

After running the model and extracting path loadings and the standardized dataset from the software, the Container Throughput Potential Index (CTPI; ϕ) was calculated. The results can be found in Figure 7. The displayed indexes are averages over the complete timespan. This average was also compared to the average standardized container throughput of a port. Just as for the European ports, the red ports underperform, the grey ports perform at their potential and the green ports outperform their potential. It should be noted that, due to the different path loadings found in the model and showed by the multigroup analysis, CTPIs between European and Asian ports cannot be compared.

From Figure 7 it becomes clear that, according to the model, all Japanese ports underperform according to their CTPI. Contrary, all Chinese ports (except for Fuzhou) outperform their CTPI. The reason for this observation probably lies in the difference in type of economy between the two countries; Japan is a developed economy, whilst China is a developing economy (IMF, 2020). In more advanced economies, as expressed by De Langen (2003), the value density of containers tends to go up due to the miniaturisation of components. This results in higher economic value of containers, but less throughput. Being an advanced economy also indicates that the Japanese economy generates more GDP from service-related activities than China. Since services are not transported in containers, Japanese ports have lower throughputs than expected based on the CTPI. Even though the Gross Hinterland Product was not directly used for generating the Asian CTPI, it does correlate positively (and significantly) with the Port Quality Index which quite strongly contributes to the CTPI. It would therefore be interesting to analyse the difference between ports in developing and developed countries and generate the CTPI on the new path loadings for the ports. The next section determines in what type of economy a port is located and reproduces the same procedures used for the Asian and European ports for establishing models for ports in developing and developed countries.

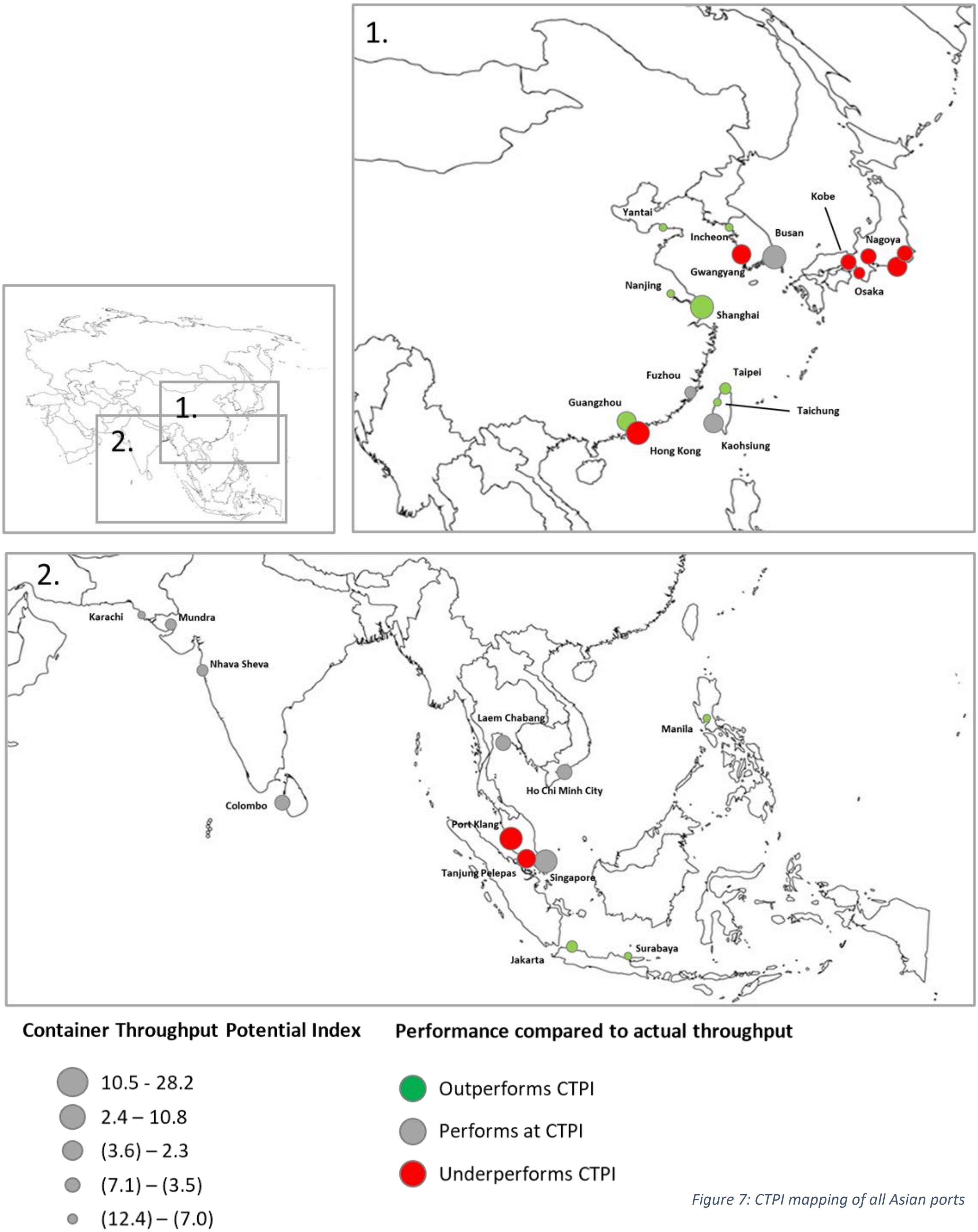

Figure 7: CTPI mapping of all Asian ports

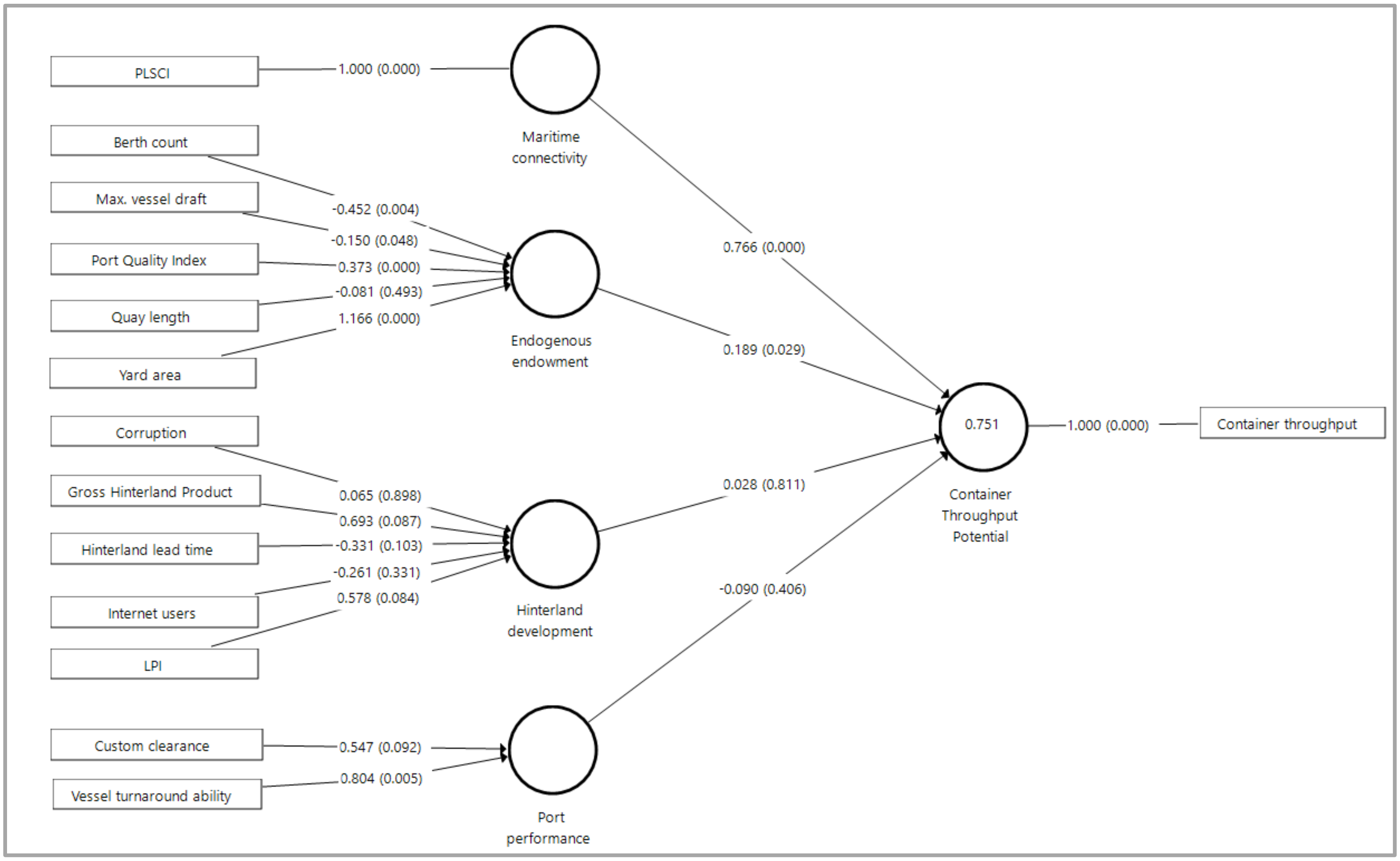

Figure 8: Path loadings and bracketed p-values of the Asian model

Establishing economy type

When looking at what type of economy a port is in, various objective sources exist. The Human Development Index (HDI) developed by the United Nations Development Programme (2019) measures how well income is transformed into health service and education opportunities and therewith into higher human development. It is scaled on a 0 to 1 scale, where a score of over 0.8 is classified as "very high" human development. Apart from the HDI, a countries' membership in the OECD (Organisation for Economic Cooperation and Development) is also a viable option for determining whether a country is a developed or developing economy. However, since the origin of the OECD lies within the "western" world (it was developed after the second world war by the United States and the countries that needed Marshall Aid), using OECD membership might be too short-sighted. Another objective source for determining whether an economy should be classified as developed or developing, is the International Monetary Fund (IMF, 2020). The IMF does not distinguish between advanced and emerging economies based on strict criteria, but it has evolved over time in order to facilitate analysis by providing a reasonable organization of data. Advanced economies are often characterized by high GDP per capita, high industrialization, stable population- and economic growth and investments aimed at improving quality of life. The WorldBank (2020) also distinguishes between high-, upper-middle-, lower-middle- and low income countries. This measure is purely based on Gross National Income (GNI) per capita. The threshold for being classified as a "high-income" country in 2019 was $12,535 GNI per capita (using the Atlas method). There are some minor discrepancies in certain countries' classifications between the different sources. For the countries in the analysis this leads to discrepancies shown in Table 3, where "very high" human development by the UN, a country's membership in the OECD, an "advanced economy" as identified by the IMF and the "high-income" countries as identified by the WorldBank are all marked as developing countries. For all other countries in the analysis, all sources are unanimous on whether a country is a developing or developed country. Ultimately, the classification of the IMF was used for deciding whether a country is developed or developing, as the HDI is too focused on health services and education, OECD membership is originally based on historic events and "high income" is too short-sighted as it does not incorporate how such GNI is generated at all. From the original dataset of 68 ports, 35 lie in developing countries and another 33 lie in developed countries. The next sections discuss the multi group analysis and the two models for ports in developed and developing countries.

Table 3: Country development assessment of different sources

Country	Very high HDI	OECD membership	Advanced Economy	High Income	Classification
Argentina	Yes	No	No	No	Developing
Colombia	No	Yes	No	No	Developing
Malta	Yes	No	Yes	Yes	Developed
Mexico	No	Yes	No	No	Developing
Poland	Yes	Yes	No	Yes	Developing
Panama	No	No	No	Yes	Developing
Russia	Yes	No	No	No	Developing
Saudi Arabia	Yes	No	No	Yes	Developing
Singapore	Yes	No	Yes	Yes	Developed
United Arabic Emirates	Yes	No	No	Yes	Developing

Multigroup analysis: developed & developing countries

Before the outcomes for the developing and developed countries models can be discussed, it should first be established that the path loadings between the models differ significantly. Again, measurement invariance should be established via the MICOM procedure. From the procedure it was found that composite invariance was present in all four key constructs, indicating that indicators measure the same concepts between groups. Next, scalar invariance was found for two out of four key constructs, which is enough to establish scalar invariance according to Steenkamp & Baumgartner (1998). Since measurement invariance was established, a Multi Group Analysis (MGA) can be conducted. From the MGA, it was found that all path loadings between the four key constructs and container throughput differed significantly between both groups. With the outcome of this second MGA the second research question (do drivers of container throughput differ per region and economy type?) can be completely be answered; based on the collected data and the multigroup analysis, it can be inferred that the importance of different drivers of container throughput differ significantly between geographical regions *and* economy type.

Developed countries model

After running the model with all ports from developed countries (35 ports, 245 observations), an adjusted R^2-value of 0.822 and a Q^2-value of 0.791 were found. This indicates substantial explaining power and a high degree of predictive relevance, respectively. The found path loadings and p-values can be found in Figure 9. Regarding the key constructs, the model showed that for ports in developed countries, endogenous endowment was found to affect container throughput the most (path loading of 0.579), followed by maritime connectivity (0.375). Based on the statistical evidence it was found that port performance and hinterland development do not significantly affect container throughput in ports in developed countries.

With the found path loadings, the CTPI was calculated for all ports in the developed countries over the period 2012 – 2018. The results are presented in Figure 10. Again, the red ports are underperformers, the green are overperformers and the grey perform at their CTPI. As can be seen from the map, four out of five ports in the Hamburg - Le Havre range underperform according to the model. This indicates that these ports have potential to increase their container throughput with their current characteristics. A reason for this finding could be the high level of port competition in this part of Europe. Since there is a finite amount of container transport demand in this region, all relatively proximate ports are competing in the same market. This reduces throughput figures per port and is also the reason that these ports have a lot of growth potential. The same applies to the Japanese ports, where three out of five ports underperform according to the model. On the other hand, the ports that outperform their CTPI are ports with big transhipment percentages of their total container throughput, such as Gioia Tauro, Singapore and Piraeus. Since a port's function as a transhipment hub is not included well in the model, these ports are found to be outperforming their CTPI.

When the ports that are both in the European model and the developed countries model are compared on their performance, discrepancies are found. For example, the port of Rotterdam is flagged as a port that performs at its CTPI in the European model (Figure 6), whilst in the developed countries model (Figure 10) the port is marked red. The underlying reason is the difference in sampled ports. When Rotterdam is compared to other European ports, it performs at its potential. Contrary, when Rotterdam is compared to other ports in developed countries, the port has potential for throughput. In other words, ports with similar characteristics in developed countries have more throughput and thus, the port of Rotterdam has potential for more throughput. The same holds for other ports that appear in both a geographical (Europe or Asia) and an economy type (developed or developing) model.

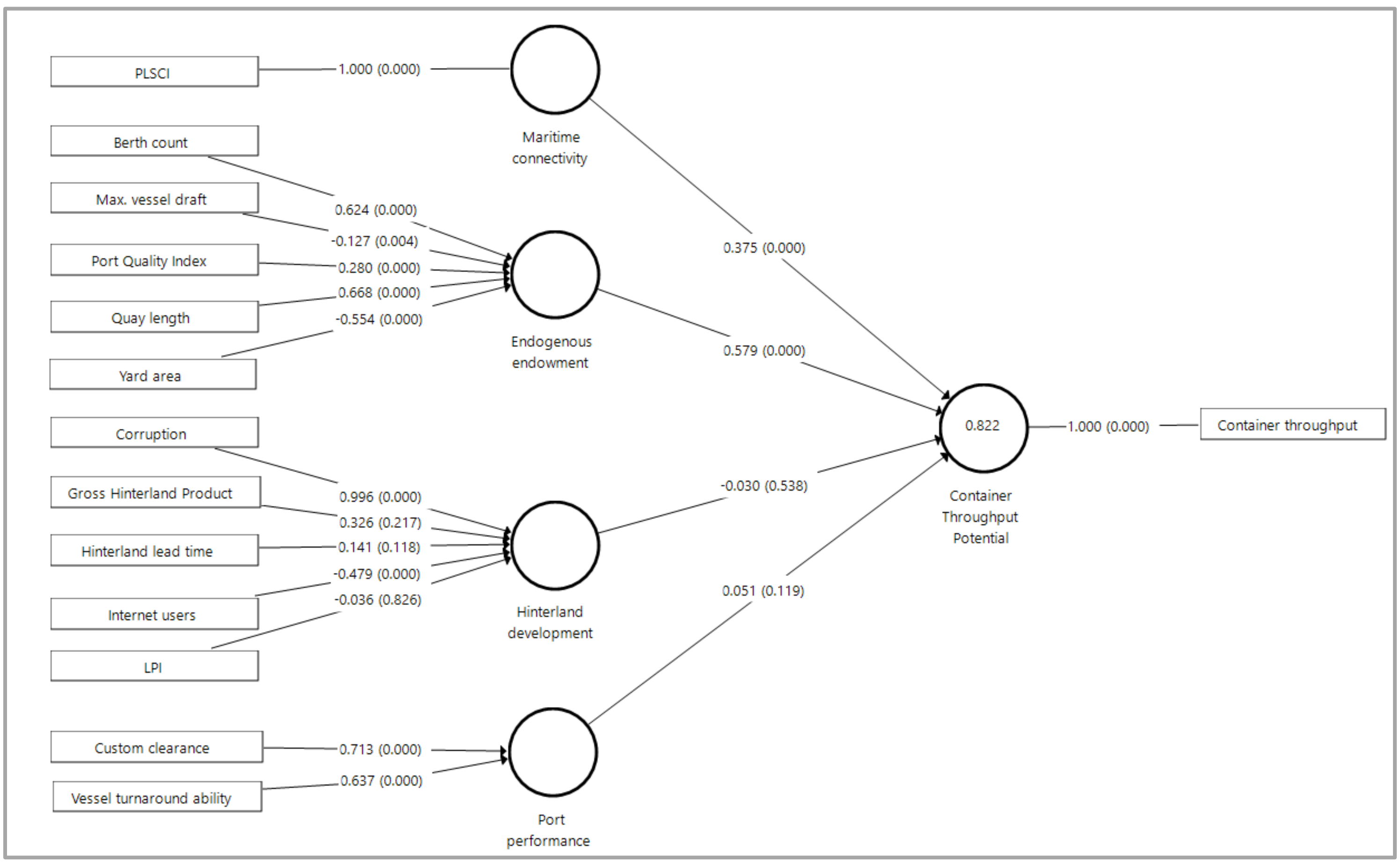

Figure 9: Path loadings and bracketed p-values of the developed countries model

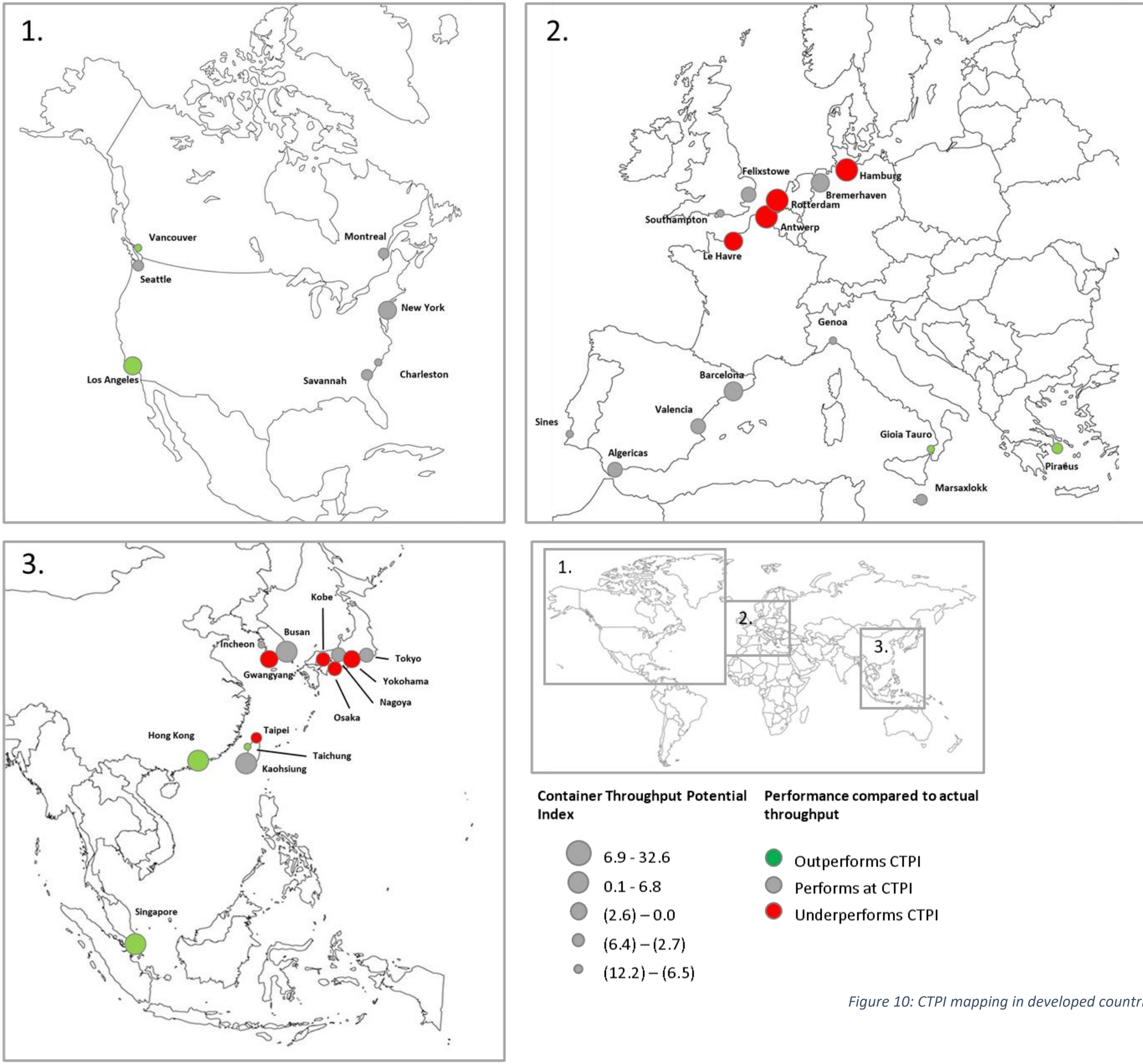

Figure 10: CTPI mapping in developed countries

Developing countries model

When the model was run for solely the ports in developing countries (33 ports, 223 observations), an adjusted R^2-value of 0.924 was found, indicating substantial explaining power. With a Q^2-value of 0.919, the predictive power of the model is very high. The found path loadings and p-values can be found in Figure 111. All paths between the key constructs had significant path loadings. Just as for the European model, port performance was found to have negative effect on container throughput. Since the path loading is again very close to zero (-0.071), it can be inferred that port performance hardly affects container throughput. For the remaining key constructs, maritime connectivity is the most important (path loading of 0.471), followed by endogenous endowment (0.385) and hinterland development (0.276). With all path loadings, the CTPI was calculated for all ports in developing countries. These CTPIs were mapped in Figure 12. Just as for all other maps, after comparing CTPI and actual throughput, the underperformers are coloured red, the overperformers green and the ports that perform at their CTPI grey.

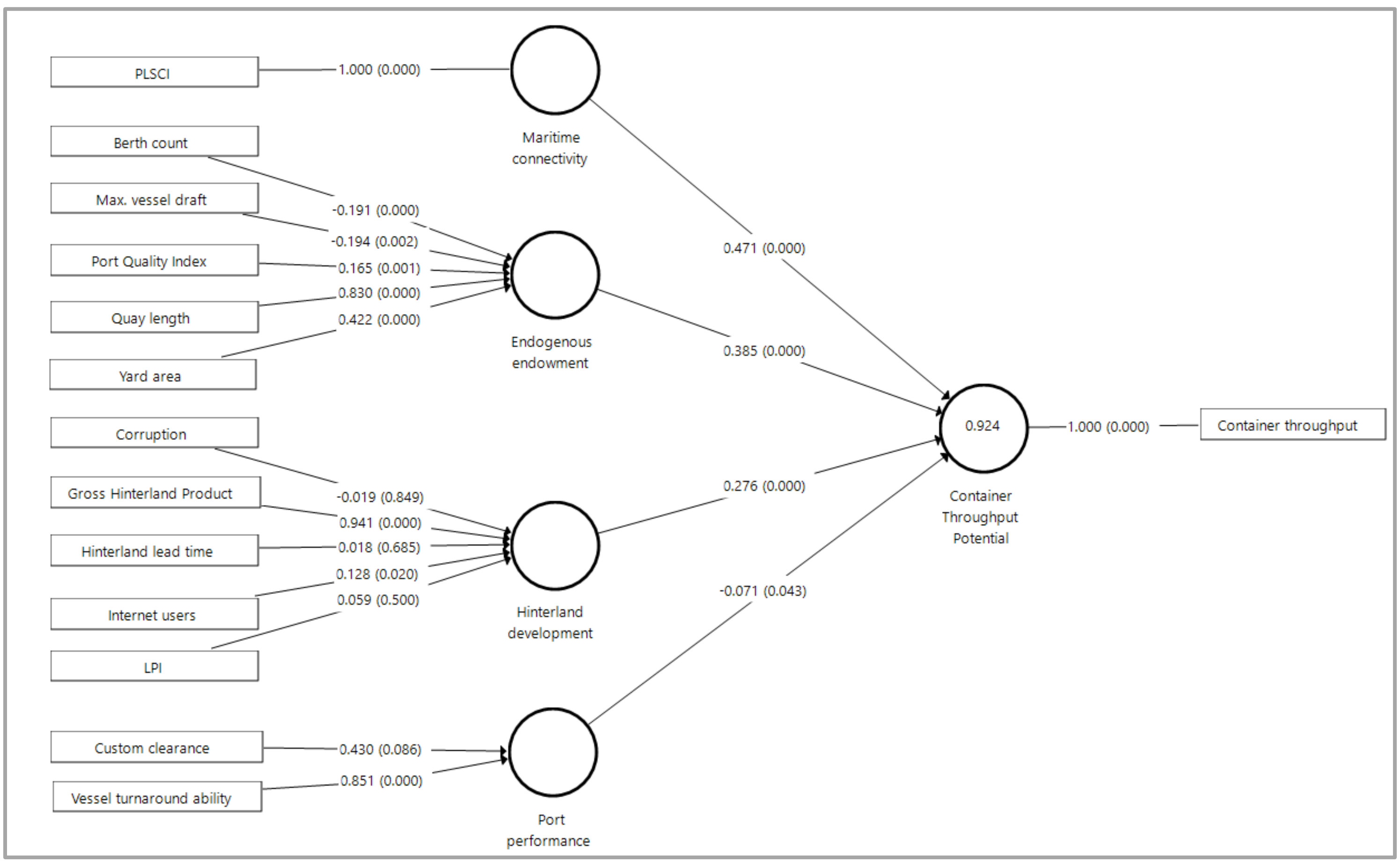

Figure 11: Path loadings and bracketed p-values of the developing countries model

From the mapping it becomes clear that both Malaysian ports (Port Klang and Tanjung Pelepas) underperform according to their CTPI. The reason for this is similar to the underperformance of the ports in the Hamburg – Le Havre range; there is fierce competition for the same hinterland. The two suffer not only from competition between themselves, but also from the world's second biggest container port; Singapore. Something that is also interesting to note is that three out of five ports in Central America outperform their CTPI; Colon, Manzanillo and Cartagena (although not technically in Central America, it does serve the Caribbean Sea). All these ports have relatively limited port infrastructure. However, when these ports are compared to other ports in developing countries, they seem to handle containers quite efficiently. The port of Colon could also benefits from the proximity of the Panama Channel as well; this demands for more transhipment in the area.

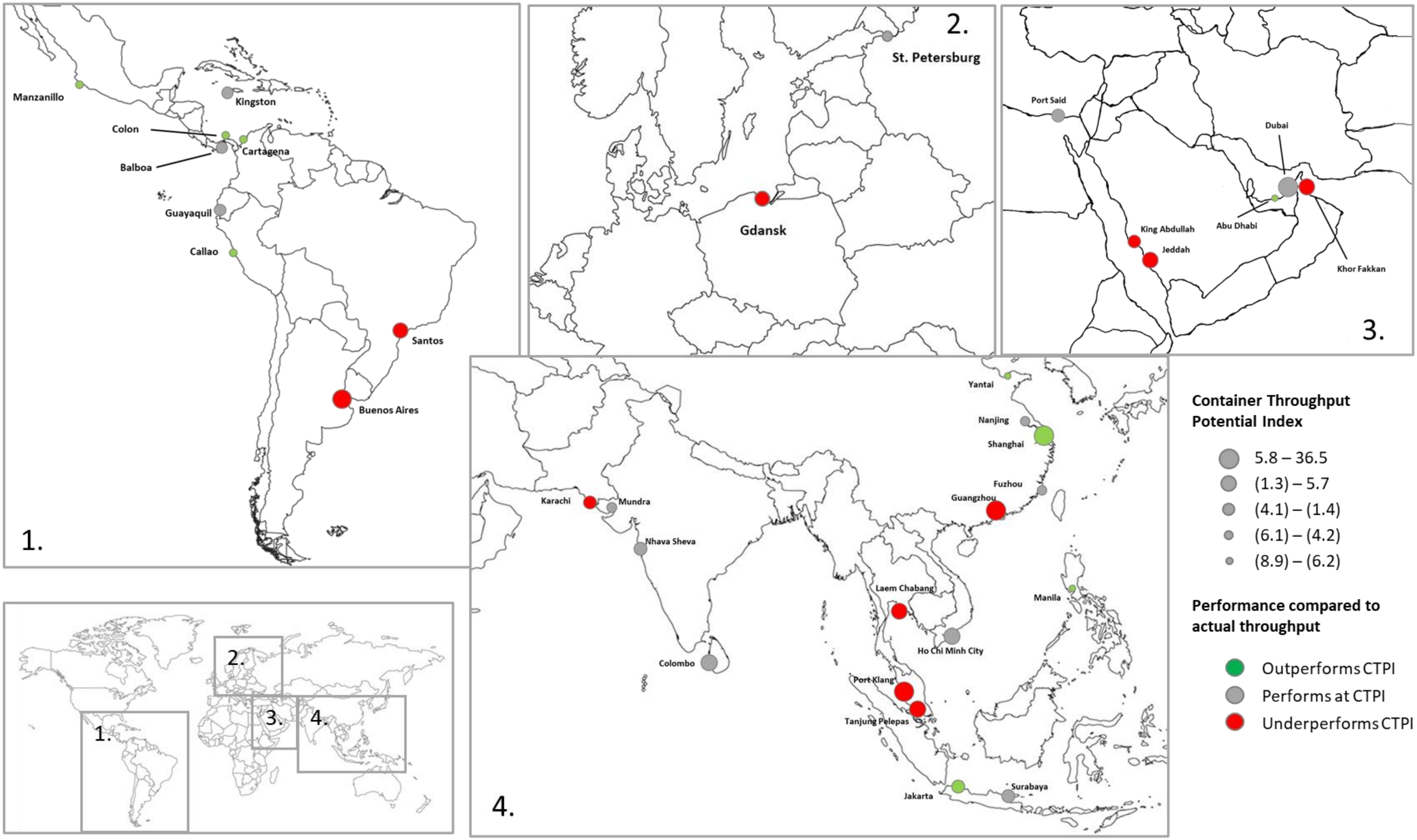

Figure 12: CTPI mapping in developing countries

Overview models and interpretation of results

Table 4 gives an overview of the ranking of the key constructs, their corresponding weights and the top 3 under- and outperforming ports per model. Throughout all models, maritime connectivity and endogenous endowment were always found to have a significant effect on container throughput potential. Maritime connectivity is the most important construct in two out of four models. It was measured with the Port Liner Shipping Connectivity Index. This index measures how well connected a port is connected to the global shipping network based on six variables. Amongst others, these are the number of scheduled ship calls per week and the annual deployed capacity of liner carriers. It could well be that there is a reciprocal relationship between maritime connectivity and container throughput demand and that when a port's hinterland demands more container transport, maritime connectivity follows. In the other two models, endogenous endowment was found to be the most influential cluster of variables for port throughput potential. This construct encompasses port's infrastructure size and the perceived quality thereof.

Table 4: Overview of significant key constructs, corresponding path loadings, under- and outperforming ports of each model

		Europe	W	Asia	W	Developed	W	Developing	W
Ranking of significant key constructs	*1.*	Endogenous endowment	.533	Maritime connectivity	.766	Endogenous Endowment	.579	Maritime connectivity	.471
	2.	Maritime connectivity	.281	Endogenous endowment	.189	Maritime connectivity	.375	Endogenous endowment	.385
	3.	Hinterland development	.234					Hinterland development	.276
	4.	Port Performance	-.074					Port performance	-.071
Top 3 ports	*1.*	Rotterdam		Shanghai		Singapore		Shanghai	
	2.	Antwerp		Singapore		Rotterdam		Busan	
	3.	Hamburg		Hong Kong		Hong Kong		Guangzhou	
Top 3 underperforming ports (red)	*1.*	Barcelona		Gwangyang		Le Havre		Gdansk	
	2.	Le Havre		Yokohama		Hamburg		Buenos Aires	
	3.	Southampton		Port Klang		Rotterdam		Khor Fakkan	
Top 3 outperforming ports (green)	*1.*	Piraeus		Manila		Singapore		Shanghai	
	2.	Algeciras		Yantai		Hong Kong		Colon	
	3.	St. Petersburg		Nanjing		Taichung		Manila	

Hinterland development was significant in two out of four models. In the Asian and developed countries models, hinterland development did not have a significant effect on container throughput. Port performance was only found to have a significant effect in two models (Europe & developing). However, in these models, the path loading of port performance was found to be very close to zero. This could indicate two things: either port performance hardly affects container throughput or the way port performance was measured in the model is not precise enough. If the former is true, ports should focus on creating better infrastructure (more endogenous endowment) and better connectivity to both the maritime network and a port's hinterland. It could also be that the latter is true, since port performance was only measured on the national level and not on ports' specifically. Findings in literature on the positive influence of port performance on container throughput are widespread. For example, cargo handling efficiency was found to be an important determinant of port choice for freight forwarders (Tongzon, 2009) and shippers (Tongzon, 2002). Next to that, vessel turnaround time was found to be the key determinant for port choice by ocean carriers by Pires da Cruz et al. (2013). In fact, Parola et al. (2017) found five other researches where "operational efficiency" was found to positively affect port competitiveness. All these aforementioned terms are clustered under the port performance key construct. To this literature background, I infer that port performance does affect container throughput potential and that it was proxied incorrectly in this research.

When looking at the remaining path loadings, the following results are found. In developing countries, the average PLSCI (41.13; Annex B) is much lower than for ports in European (52.97) or developed countries (51.79). The same goes for the standard deviation. The PLSCI in developing countries is more dispersed (standard deviation of 25.08) than for ports in Europe (18.09) and developed countries (22.85). This shows that, generally, ports in developing countries are less well connected to the global shipping network than other ports worldwide. Ports in those countries that are able to connect well to the maritime shipping network will ensure that they outcompete other ports on connectivity, which is shown by the high path loading of maritime connectivity in the developing countries model (0.471, see Table 4). The finding that maritime connectivity is the most important cluster of drivers is also found by Tongzon (2002) and Tongzon (2009). Both these researches found that shipping frequencies were the second most important driver of port decision (after port efficiency) for shippers and freight forwarders in Malaysia and Thailand. Malaysia and Thailand are both classified as developing countries by the IMF.

Throughout Asia, maritime connectivity in Asia (50.15) is similar to European and developed countries' ports. However, maritime connectivity in Asian ports is more widely dispersed, as shown by the high standard deviation of the PLSCI (30.69). The reason for this high dispersion is likely attributable to the even distribution of ports in Asian developed (13 ports) and developing countries (16). As shown before, ports in developed countries generally have a better connection to the maritime network than ports in developing countries. In European and developed countries, ports are generally all well connected to the maritime shipping network and thus, decision makers will resort to other decision variables; they will base their port decision more on the size of the port and the subjective quality thereof (endogenous endowment). For the decision makers in European and developed countries, the quality of port infrastructure is more important. This is usually associated with less loss and damage of cargo, better track & tracing, and more timely shipments. It seems that as soon as ports have a certain level of maritime connectivity, decision makers reside to other, endogenous, factors to base their port decision on. This is also what Pires da Cruz et al. (2013) found, "seaport facilities & equipment" and "channel depth" are the most important drivers for seaport competitiveness in the Iberian Peninsula. These factors can both be grouped under the endogenous endowment construct. Besides, Murphy et al. (1992) found that, in the United States, for all actors in container shipping, "equipment availability" and "loss and damage of cargo" were consistently the two most important factors for port decision. Both these terms can be clustered under the endogenous endowment construct and since the United States are a developed country, Murphy et al.'s findings are parallel to the findings in this paper; endogenous endowment is the most important driver for container throughput for ports in developed countries.

According to the results, for a port to have a higher throughput potential, in both European and developing countries' ports, having a big hinterland and a good connection therewith is also influential. This finding is similar to that of De Langen (2007), where the author found that the quality of hinterland connections determines shippers' port decision. However, in that same research, the quality of shipping services (maritime connectivity) and the quality of equipment (endogenous endowment) were found to be more important. A good connection with the hinterland can be essential for port decision in manufacturing economies often found in developing countries. When it takes a long time for goods to be transported from a factory to a port, manufacturing companies will relocate their activities to locations with better hinterland connections to decrease their lead times. Next to that, when a port's hinterland has a higher percentage of internet users (which was used as a proxy for the presence of a middle class), the demand for manufactured goods is likely to increase. In developing countries, around 52% of people have internet access, on average. The number of internet users is widely dispersed in developing countries (standard deviation of 22%). In Europe, a larger hinterland economy will result in higher demand for manufactured goods and will thus result in more imports. When it takes a long time to transport goods from a port to a warehouse, it is likely that shippers and freight forwarders will switch to another port with better hinterland connections. The reason that hinterland development was not found to have a significant effect on container throughput potential in both the Asian and developed countries model is probably attributable to the large differences between countries within these models. A good hinterland connection might be something completely different timewise when comparing the hinterlands of Charleston and Singapore (developed model) or Karachi and the Japanese Islands (Asian model). This will result in more regional preferences being neglected by the model and thus lead to insignificant results.

Implementing the CTPI: La Spezia

The goal of this research was to develop a tool with which port authorities could assess whether they have potential to increase their container throughput and if so, on what area they should focus to increase their throughput. Since the container throughput index was calculated with standardized figures, input variables should be transformed to standardized scores before they can be used. These standardized scores should then be used in the PLS-SEM model and be combined with the corresponding path loadings to get to the CTPI. This CTPI should then be compared to actual container throughput to assess whether a port under- or outperforms its CTPI.

To show how a port authority should calculate its CTPI and standardized container throughput, the following section provides an example of the methodology. The port of La Spezia was chosen as an example. This Italian port is the country's third container port in size and lies on the Ligurian coast. The European model will be used to calculate La Spezia's throughput potential. La Spezia was not incorporated in the sample used for the construction of the models.

CTPI calculation

The port has shown tremendous growth in container throughput between 2012 and 2018, growing from 1.18 million TEU in 2012 to 1.65 TEU in 2018 (+39%). To standardize these throughputs, the following formula should be used:

$$Standardized\ container\ throughput = \frac{Container\ throughput - 4.30}{3.17}$$

4.299 is the mean annual throughput (in million TEU) of all ports in the European model, 3.174 is the standard deviation of all these ports' throughput. This information can be extracted from Annex B. The average container throughput over the seven-year period between 2012 and 2018 should then be calculated to obtain the average standardized container throughput of La Spezia. A value of -0.89 was found. After the same procedure is repeated for every significant indicator, all standardized scores can be used to calculate the key construct scores. As an example, for the score on endogenous endowment, the following formula should be used:

$$E_i^j = \alpha_{q_e} * quay\ lengths + \alpha_{y_e} * yard\ area + \alpha_{p_e} * port\ quality\ index + \alpha_{b_e} * berth\ count$$

It should be noted that maximum vessel draft is not used in the calculation for the endogenous endowment score, since its path loading was found to be insignificant in the European model. After all scores for the four key constructs are computed, the CTPI for La Spezia can be computed by multiplying the scores for each key construct with its corresponding weight and then multiplying by ten:

$$CTPI_i^j = \varphi_i^j = (\alpha_{HC} * H_i^j + \alpha_{MC} * M_i^j + \alpha_{EC} * E_i^j + \alpha_{PC} * S_i^j) * 10$$

After the CTPI for every year is computed, the average over the complete timespan should be taken to get the CTPI for La Spezia. For La Spezia, a CTPI of -6.9 was found. When this value is compared with the actual container throughput standardized score (-8.9), it can be inferred that the Port of La Spezia has potential for more container throughput than it currently has (CTPI > actual throughput). When the average weighted scores for every key construct, as shown in Table 5, are examined, it becomes clear that the port of La Spezia has a relatively low score for endogenous endowment. What this means for the port of La Spezia is that, based on the situation they are in, with a well-developed hinterland and a good connection therewith and reasonable maritime connectivity, their endogenous endowment lacks. It could be beneficial for the port to invest in infrastructure or to enhance the general perception of its quality in order to boost throughput figures. This section has shown that the CTPI can indeed be used for as a tool to identify where a port should improve in order boost container throughput, therewith answering research question 4.

Table 5: Key construct scores for the port of La Spezia

Key construct	**Average score over 2012-2018**
Endogenous endowment	- 0.55
Hinterland development	0.04
Maritime connectivity	- 0.19
Port Performance	0.02
CTPI (sum of weighted key constructs)	**- 0.69**

If we want to calculate what the CTPI translates to actual TEU, the following translation should be used:

$$Actual\ Throughput\ Potential\ =\ Mean\ Container\ throughput\ +CTPI\ *\ STD.DEV.$$

The mean container throughput and standard deviation for each model can be found in Annex B. For La Spezia, the following actual throughput potential was found:

$$4.30\ -\ 0.69\ *\ 3.17\ =\ 2.11\ million\ TEU$$

The reason that the throughput potential of La Spezia is higher than its actual throughput, might be a result of the proximity of the port of Genoa. Genoa is the second biggest Italian container port and lies on 80 kilometres from La Spezia. Genoa therefore competes for the same hinterland as La Spezia.

Conclusion

In order to identify what aspects of a port drive container throughput, this paper used partial least squares sequential equation modelling (PLS-SEM) to measure the influence of four latent constructs in 68 container ports over a seven-year timespan worldwide. The four latent variables comprised the maritime, endogenous, hinterland and performance aspects of a port. From the initial path model, with all ports combined, it was identified that only endogenous endowment and maritime connectivity drive container throughput potential. However, after conducting a multigroup analysis, it was established that path loadings between the key constructs and container throughput potential differ significantly between both geographical region and economy type. This result deems the initial model useless and therefore, four additional models were created. Two of those encompass models for geographical regions, namely Asia and Europe, and two of those were constructed on economy type, namely developed and developing. All these models showed high predictive relevance.

This research has applied a research method that is mostly used in the social sciences to a field where it has never been used, showcasing the power of PLS-SEM. This research suggests that container throughput is not simply a function of, for example, the number of berths in a port, but rather a result of the level and perception of four aggregated constructs. These constructs are clusters of individual drivers of container throughput. For example, the endogenous endowment cluster represents the size of a port's infrastructure and the perceived quality thereof. This research hypothesized that when the level of a key construct increases, a port's potential for more container throughput increases.

Throughout all models, it was found that port performance either did not have a significant impact or a slight significant negative effect on container throughput potential. This is contrary to many findings in the literature (e.g. Ng (2006); Tongzon (2009)), where port performance was found to be a big determinant of port choice and competitiveness, and thus demands for an explanation; in the analysis in this paper, port performance was measured only on the national level and not on the port specific level. The underlying reason for this was data availability. This could result in neglecting port performance differences between ports within countries. Besides, the assumption that national performance measures are a good proxy for port performance is, in hindsight, ambiguous. I tend to believe that port performance was proxied incorrectly and that when a better proxy for port performance was used, it would have resulted in a positive effect on container throughput potential. A better proxy for port performance would have been port specific measures of efficiency, such as average waiting time for trucks or TEUs handled per container crane annually. However, the used proxies in this research, vessel turnaround ability and average time in customs, could also be used as a good proxy in future research when these are collected on the port level.

In both the European and the developed countries model it was found that endogenous endowment is the most important driver for throughput potential. This indicates that ports in these countries should focus on their infrastructure and the perception thereof if they want to improve container throughput. Contrary, for ports in Asian and developing countries, the model finds that maritime connectivity is the most important driver for container throughput. If these ports want to boost their throughput figures, they should focus on connecting their ports more to the global shipping network. Only in the European and developing model it was found that hinterland development and the connection with that hinterland are significant drivers for container throughput. If the characteristics of their hinterland (Gross Hinterland Product, number of internet users, corruption level) allow for container throughput increases, ports in these countries should focus on better connecting to their hinterland.

The latent constructs were formatively measured using 13 indicators. Using these indicators, their outer loadings and inner path loadings, the container throughput potential index (CTPI) was calculated for all ports in the different models. Some interesting findings include; the fierce competition in the Hamburg – Le Havre range results in all these ports not meeting their full container throughput potential and transhipment hubs outperform their throughput potential because of their large transhipment shares in their throughput figures.

If a port authority combines the implied improvement areas of the CTPI with the Port Attractiveness Index suggested by Caschili & Medda (2015), a port authority should be able to identify where they should improve in order to attract more container throughput and foreign direct investment. These two factors are key drivers of a port authority's revenue streams. For the port of La Spezia (not included in the original analysis), the CTPI was computed and it was found that the port lacks on their endogenous endowment.

This indicates that the ports' hinterland development and connection, and its maritime connectivity allow for higher container throughput potential. However, the port's infrastructure or the general perception thereof falls short. If the port wants to attract more container throughput, they should focus on expanding their infrastructure or improve the perception of it.

So, what are the main drivers of container throughput? Well, it depends. In short, this paper shows that container throughput potential, which is defined as the combination of port attractiveness and competitiveness, is a function of multiple clusters of individual drivers of container throughput. The importance of these latent constructs differs per geographical region and economy type. Throughout all models, maritime connectivity and endogenous endowment were always identified as important drivers of container throughput potential. Hinterland development was found to be influential for throughput potential in two out of four models. Even though port performance had a significant effect in two out of four models. The effect was very marginal and negative. It is expected that the measurement method of port performance was wrong and that, based on previous literature, port performance does affect container throughput potential. After establishing how the four construct groups contribute towards throughput potential, a container throughput potential index was constructed. This index can be used to identify what construct cluster a port authority should focus on in order to boost container throughput potential.

Limitations, Discussion and Future Research

Throughout this paper, multiple limitations of the research were discussed. The following section will restate those limitations briefly, discuss the generalizability of the results and give implications for future research.

As discussed extensively, the measurement method of port performance was incorrect. Using a national figure for a port specific attribute lead to insignificant and odd results that are contrary to many findings in literature. Next to that, the fact that endogenous indicators do not change over time (except the Port Quality Index) might result in overattributing increases in container throughput to factors that in reality only had marginal effects. Port costs were not incorporated in the analysis, even though these are also likely to affect container throughput potential. This might result in overattributing throughput increases to other factors, even though they were simply a result of lower prices. In hindsight, conducting an outlier analysis beforehand would have been insightful. For example, in the developing countries model, the enormous ports of Shanghai and Guangzhou boast far greater throughput figures than the other ports in developing countries and therewith press heavily on the analysis. An interesting future analysis would be to compare path loadings between models of different port sizes. For example, comparing path loadings between the top 50 largest container ports and container ports 51 – 100 could provide insights as to whether port authorities should shift their focus when their throughput figures increase.

As shown by the implementation of the Container Throughput Potential Index for the Italian port of La Spezia, the results of this research can also be used for ports outside of the original sample. In fact, the goal of this research was to produce a method with which port authorities worldwide can compare themselves with other competing ports to identify where they could improve in order to boost throughput figures. It can be questioned whether the same path loadings apply for ports that are substantially smaller in size or lie far outside geographical regions (e.g. Africa and Australia) used in this analysis. For these ports, generating a PLS-SEM model that only analyses similar ports (either based on geographical region or port size), might be best practice in order to deflect from incorrectly ranking clusters of throughput drivers. Beyond the analysis of container ports, the used methodology can also be applied to different types of cargo. It is likely that the same path loadings do not apply when analysing, for example, the bulk cargo side of ports. However, the drivers for bulk cargo throughput can also be grouped in the same four clusters used in this research and therefore, the methodology can be generalized beyond the scope of this research.

In general, the outcomes from this research are fairly reliable. Except for the port performance construct, every other construct is believed to encompass the complete concept and be approximated correctly. Of course, since proxies were used to measure, for example, gross hinterland product, the results are not perfect. However, the results provide good insights as to what cluster of drivers ports in certain economies and geographical regions should focus on. Since the same measurement method was used for every indicator in every port in every year, internal consistency can be assumed. Most results match with findings in previous literature, so inter-rater reliability is also established.

Interesting future researches that could build further on this research and its methodology include: the aforementioned analysis between port groups of different sizes, an application on airports and their passenger throughput, a comparison between drivers of container throughput and other types of cargo, and a repetition of this research with a better proxy for port performance. Since it might be hard to accumulate port performance data on port specific levels for some ports, a good future methodology could be to only include ports in countries with one (main) container port. This is the case for most countries in Africa (see Caschili & Medda (2015)), but also in the Caribbean, where most of the islands only have one container port. In this way, indicators that are only available on the national level can be directly translated to the biggest port in that country.

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Annex A: overview of all ports

Port	Country	Region	Development
Abu Dhabi	UAE	Middle East	Developing
Algeciras	Spain	Europe	Developed
Antwerp	Belgium	Europe	Developed
Balboa	Panama	Central & South America	Developing
Barcelona	Spain	Europe	Developed
Bremen/Bremerhaven	Germany	Europe	Developed
Buenos Aires	Argentina	Central & South America	Developing
Busan	South Korea	Asia	Developed
Callao	Peru	Central & South America	Developing
Cartagena	Colombia	Central & South America	Developing
Charleston	United States	North America	Developed
Colombo	Sri Lanka	Asia	Developing
Colon	Panama	Central & South America	Developing
Dubai	UAE	Middle East	Developing
Felixstowe	United Kingdom	Europe	Developed
Fuzhou	China	Asia	Developing
Gdansk	Poland	Europe	Developing
Genoa	Italy	Europe	Developed
Gioia Tauro	Italy	Europe	Developed
Guangzhou	China	Asia	Developing
Guayaquil	Ecuador	Central & South America	Developing
Hamburg	Germany	Europe	Developed
Ho Chi Minh City	Vietnam	Asia	Developing
Hong Kong	Hong Kong	Asia	Developed
Incheon	South Korea	Asia	Developed
Jakarta	Indonesia	Asia	Developing
Jeddah	Saudi Arabia	Middle East	Developing
Kaohsiung	Taiwan	Asia	Developed
Karachi	Pakistan	Asia	Developing
Khor Fakkan	UAE	Asia	Developing
King Abdullah	Saudi Arabia	Middle East	Developing
Kingston	Jamaica	Central & South America	Developing
Kobe	Japan	Asia	Developed
Laem Chabang	Thailand	Asia	Developing

Port	Country	Region	Development
Le Havre	France	Europe	Developed
Los Angeles	United States	North America	Developed
Manila	Philippines	Asia	Developing
Manzanillo	Mexico	Central & South America	Developing
Marsaxlokk	Malta	Europe	Developed
Montreal	Canada	North America	Developed
Mundra	India	Asia	Developing
Nagoya	Japan	Asia	Developed
Nanjing	China	Asia	Developing
New York/New Jersey	United States	North America	Developed
Nhava Sheva	India	Asia	Developing
Osaka	Japan	Asia	Developed
Piraeus	Greece	Europe	Developed
Port Klang	Malaysia	Asia	Developing
Port Said	Egypt	Middle East	Developing
Rotterdam	Netherlands	Europe	Developed
Santos	Brazil	Central & South America	Developing
Savannah	United States	North America	Developed
Seattle-Tacoma	United States	North America	Developed
Shanghai	China	Asia	Developing
Sines	Portugal	Europe	Developed
Singapore	Singapore	Asia	Developed
Southampton	United Kingdom	Europe	Developed
St Petersburg	Russia	Europe	Developing
Surabaya	Indonesia	Asia	Developing
Taichung	Taiwan	Asia	Developed
Taipei	Taiwan	Asia	Developed
Tanjung Pelepas	Malaysia	Asia	Developing
Tokyo	Japan	Asia	Developed
Valencia	Spain	Europe	Developed
Vancouver	Canada	North America	Developed
Yantai	China	Asia	Developing
Yeosu Gwangyang	South Korea	Asia	Developed
Yokohama	Japan	Asia	Developed

Annex B: path loadings of the four models

It should be noted that for each model, only the significant indicators and key constructs are reported.

				EUROPEAN			ASIAN		
	VARIABLE NAME	Measured in	Key construct	Mean	Std. dev	Path loading/weight	Mean	Std. dev	Path loading/weight
THROUGHPUT	*Container throughput*	Million TEU	-	4.30	3.17	-	8.08	9.09	-
KEY CONSTRUCTS	*Maritime connectivity*	-	-	-	-	0.28	-	-	0.77
	Endogenous endowment	-	-	-	-	0.53	-	-	0.19
	Hinterland development	-	-	-	-	0.24	-	-	-
	Performance	-	-	-	-	-0.07	-	-	-
INDICATORS	*PLSCI*	index	M	52.97	18.09	1.00	50.15	30.69	1.00
	Berth count	number	E	14.24	10.84	0.82	19.55	13.14	0.45
	Quay length	meters	E	4747.9	3713.5	-0.18			
	Yard area	hectares	E	233.8	196.0	0.36	172.47	147.25	1.17
	Max. vessel draft	meters	E				15.38	1.79	0.15
	Port quality index	index	E	5.28	0.79	0.14	4.80	0.77	0.37
	Internet	percentage	H	77.68	11.12	0.20			
	Gross Hinterland Product	billion USD	H	664.51	650.98	1.04			
	Corruption Perception	index	H						
	Hinterland lead time	days	H	-2.45	0.97	0.12			
	Logistic Performance Index	index	H						
	Custom Clearance	days	P	-3.65	1.12	1.03			
	Vessel turnaround ability	TEU	P						

	VARIABLE NAME	Measured in	Key construct	DEVELOPED Mean	Std. dev	Path loading/weight	DEVELOPING Mean	Std. dev	Path loading/weight
THROUGHPUT	*Container throughput*	Million TEU	-	5.54	6.30	-	6.10	7.19	-
KEY CONSTRUCTS	*Maritime connectivity*	-	-	-	-	0.38	-	-	0.47
	Endogenous endowment	-	-	-	-	0.58	-	-	0.39
	Hinterland development	-	-	-	-	-	-	-	0.28
	Performance	-	-	-	-	-	-	-	-0.07
INDICATORS	*PLSCI*	index	M	51.79	22.85	1.00	41.13	25.08	1.00
	Berth count	number	E	17.13	11.31	0.62	15.70	13.49	-0.19
	Quay length	meters	E	5121.96	3679.24	0.67	3424.78	2690.30	0.83
	Yard area	hectares	E	234.96	191.64	-0.55	137.25	141.93	0.42
	Max. vessel draft	meters	E	15.72	2.24	-0.13	15.29	1.91	-0.19
	Port quality index	index	E	5.47	0.60	0.28	4.55	0.96	0.17
	Internet	percentage	H				52.18	22.44	0.13
	Gross Hinterland Product	billion USD	H				286.25	366.85	0.94
	Corruption Perception	index	H						
	Hinterland lead time	days	H						
	Logistic Performance Index	index	H						
	Custom Clearance	days	P						
	Vessel turnaround ability	TEU	P				5006.04	2220.72	0.85