Forecasting Portuguese ports throughput (2021-2030)

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ABSTRACT: Now more than ever, ports require reliable and plausible forecast of the cargo throughput which is likely to be expected for the foreseeable future. The development of any port is tightly linked to its performance, which in turn directly depends on the volume of clients which is able to attract and serve. Port infrastructure and equipment are two of the major costs which are associated to the management process of these ports. The role of cargo throughput forecasts is of extreme importance for appropriately planning the development of the port. A good forecast study can lead to a better performance and readiness in terms of capacity of the port when dealing with future cargo trends and evolutions.

The objective of this thesis is to develop plausible forecasts of cargo throughput in the main Portuguese ports. For this purpose, quantitative techniques such as linear regression and extrapolation of existing trends, as well as qualitative assessments of cargo evolution, are applied. The data concerning cargo throughput, necessary for supporting the analysis, has been gathered from several sources, such as Instituto Nacional de Estatística (INE) and Port Authority's archives. The cargoes are split into different types as well as different ports. Time series have been collected, ranging between 16 and 42 years in length. Gross domestic products (GDP) of relevant nations have also been collected from OECD and the IMF, as required for the regression analyses.

In general, the Portuguese port system has been going through a period of growth in the last two decades, entering a negative trend more recently in 2017. Containerized cargo has been growing until 2018. In turn, general cargo has been relatively stable until 2015 and since then it started to drop in volume handled. The ro-ro cargo sector has been growing at a significant pace since 2013. As for the dry bulk and liquid bulk, both have maintained a constant behaviour over the last three decades.

Linear regression was the main method used to generate forecasts. However as a secondary method, qualitative analyses were carried out with the aid of extrapolations based on certain periods of time in order to create alternative scenarios.

In sum, the cargoes with a positive forecast are the containerized and ro-ro sectors. The cargoes with a negative forecast are the liquid bulk, dry bulk and general cargo. As for the Portuguese port system as a whole, even though the total volume of cargo handled has slowed down since 2017, the resulting linear regression forecast predicts a positive evolution for the next decade given the positive trend seen from 1988 to 2017.

KEYWORDS: Portuguese port system, forecasting techniques, cargo throughput, containerized cargo, bulk cargo, logistics.

1 INTRODUCTION

The exponential growth of population which humanity has been experiencing, has brought along a matching and ever increasing demand for resources and services. Such need is one of the main drivers for technological development of civilization. History has shown that it is inherent to our nature to seek efficiency and evolution.

Proving itself the most cost effective method of transportation of large scale goods, shipping has had a strong presence in society and has been growing worldwide at a fast pace. With globalization causing an overall increase in trade volumes, port authorities and port owners have been actively keeping up by developing and expanding their ports. The main targets are the ones which play crucial nodes in the global transportation network, such as the case of Maaskvale II which has been an essential expansion of the northern giant of shipping that is Rotterdam.

However, more eye-catching investments than expansions of existing ports have emerged. Such is the case of the several planned projects for new building of ports. To mention a few, the Tanzania Trade Hub in Tanzania, the Tema Port in Ghana and the Tianjin Port in China. With the main motivator for such projects being the further development of their respective economic zones and capture the huge market of maritime trading which those regions and the international world.

All these projects are backed up by forecasting studies which have been carried out with years of advance in order to create the most suitable development plan for such tremendous investments. Forecasting techniques of any type require some sort of information as input, and with the revolutionary phenomenon of the Big Data, it is of utmost importance to analyze and develop accurate and powerful forecasting methods with the ability to process a large number of variables.

There is a variety of techniques and methods available to carry out a forecast involving data such as the one presented in this study. One could choose to approach a forecast in a qualitative or quantitative manner. Within quantitative forecasting, time series analysis or causal prediction may be used. Recently, forecasts have been carried out relying on sophisticated techniques such as artificial neural networks. However, for this study in particular, linear regression has been chosen, as it was found to be the most suitable while keeping the problem at a relatively low complexity.

Even though some ports receive support from their countries' respective governments, similarly to other organizations and companies, they are mostly driven and kept running by profits. The revenue originating from the services which their clients receive, such as cargo handling, berthing and storing, must overcome the sum of all expenses the ports undergo, such as the salaries of their employees and the capital costs of the equipment used.

The present thesis is motivated by the crucial need that ports have of knowing as accurately as possible the behaviour and trends of the cargo throughput for short, medium and long terms. Large sums of money are at stake which are directly tied to the ports' efficiency and capacity to respond to the markets and trades in which they participate. Expansions must be carefully planned ahead of time as to maintain a balance between the port's capacity and its demand in terms of cargo handled. An under dimensioned port will suffer due to its inefficiency caused by the large queues of ships, eventually losing the clients' interest to other ports in the proximity with a better efficiency and times. On the other hand, an over dimensioned port's profits will struggle due to its large expenses which may overshadow their revenues.

These type of concerns are also present in the case of Portuguese ports, according to report published by Confederação Empresarial de Portugal (Confederação Empresarial de Portugal, 2015) there are several points regarding the Portuguese logistical network, specifically concerning the road, rails and maritime sectors. With the latter being the most relevant in this study, a few comments and suggestions stand out. The containerized cargo handled in Lisbon shall be shifted from the already crowded area to the port of Setúbal instead, which has the capacity required to host said cargo. Thus leaving Lisbon the room to specialize on the touristic and cultural aspects. In order for this shift to take place, it is also suggested that the administrations of the two ports undertake a process of fusion and collaborate in their management.

Another relevant topic approached in the report is the country's lacking intermodality. Giving emphasis to the issue of the poor rail network, especially when considering the difference between rails types when crossing the Iberian corridor from Portugal to Spain and eventually to France.

All of these topics require forecasting studies to be carried out in order to have a better perception and foundation for their respective development projects.

Another motivator for carrying out forecasting studies is the European Commission (EC) and its plans for improving the trans-European transport network (TEN-T). The EC has provided guidelines in order to further developing the connectivity between the European coastline and the inland hubs. With the intent of boosting growth and competitiveness in Europe's Single Market. In fact, on May 23rd of 2013, the European Commission approved an initiative targeted at optimizing port operations and onward transportation interconnections at the 329 major seaports that make up the trans-European transport network. This project is being implemented in stages using a combination of legislative and non-legislative methods (European Comission, 2015).

1.1 Objectives and Structure

The objectives of this work are the following:

- Complete the cargo handling database in Portuguese ports with data for the periods 1987-2000 and 2015-2018;
- Perform forecast studies for the period 2019-2030;
- Evaluate the results of the forecasts and propose two most likely scenarios, one optimistic and one conservative with an argument for each of them;

This paper is organized in six sections and respective appendices. Chapter 1 presents the topic to be discussed and highlights its relation with the maritime industry as well as its background and importance to the Portuguese port system. The goals and structure of the work are introduced as well. Chapter 2 contains the literature review and state of the art of the subject. A few key studies which are essential for the foundation of this work. Their targeted cargo, location, historical data, methodology and forecasting period also presented. Chapter 3 describes the ports subject of this forecast. It also summarizes their main technical and physical parameters. The major industries which are dependent on the same ports are also described, specifying which cargoes serve as a link between the two points. Chapter 4 presents the yearly cargo handling values in the ports composing the Portuguese port system for the five major types of cargo, both for loading and unloading. The topic of wildcard events is also approached by briefly analyzing the effects of the COVID-19 pandemic. Chapter 5 details the methodology behind the application of the linear and multi linear regression. It also presents the various cases of linear regression forecasts. Then the qualitative forecasting results are described. Chapter 6 compiles the most important results, opinions and a few final conclusions from this thesis. Lastly, a set of recommendations for further work is put forward.

2 LITERATURE REVIEW

A forecasting method is in essence an algorithm which generates a point forecast. That is, a single value which is a prediction of the original value for a certain future period. And a statistical model allows for the stochastic data generating process which may then be used as an input to create a probability distribution for a future time period $n+h$. It is widely accepted that to denote a point forecast of y_{n+h} one can use the notation $\hat{y}_{n+h}$ with the data available for time n.

This chapter first indicates and describes the existing forecasting methods and showcases a set of typical examples of port throughput forecasting studies. Each of them is backed up by references, explaining their advantages, disadvantages, reliability and possible applications.

Forecasting methods fall in three major groups, causal prediction, qualitative analysis and time series analysis. A description of each of these groups as well as the error assessment processes is given below.

2.1 Causal Methods

In causal methods, one assumes that the dependent variable which is being forecasted is associated and influenced by another variable, called the independent or explanatory variable. There can be more than one independent variables and each of them may have different degrees of impact in the result.

The three main branches of causal methods are segmentation, index method and regression analysis. With the latter, being the most common computable method of causal forecasting.

Regression is a mathematical technique for finding the straight line that best fits values of a linear function. Usually coupled with a plot on a scatter graph of the data points. This line that is obtained, may then be used to predict future values of the dependent variable by simply extending the line itself. Whenever the forecasting model is defined by more than one explanatory variables, the linear regression must be adapted, becoming a multi linear regression.

An example of forecasting study based on a linear regression approach is the one published by William Seabrooke (Seabrooke, 2002) which concluded that a simple linear regression can generate a credible and reliable forecast by correlating the containerized cargo with the GDP of the nation.

First, the qualitative methods were found to be unsuitable as they should be applied in forecasts in cases which historical data isn't easily accessible or is even non-existent. In this study, however, data is generally available and should be used as a foundation, avoiding relying on any subjective opinions when possible. There are however a few cases in which qualitative forecasting will be used, mainly due to sudden events that affect some ports.

The Auto Regressive Integrated Moving Average (ARIMA) was also dismissed as usually it requires over 50 data points according to Box and Jenkins (Box & Jenkins, 1970). For the same reason, Neural Networks Analysis was ruled out as the accuracy of such method heavily depends on the number of data points used. In order to obtain reliable outputs, previous studies (Alwosheel, van Cranenburgh, & Chorus, 2018) advise relying on ANNs only if the number of data points available are at least over 50 times the number of estimated parameters.

Considering, primarily, the availability of data, the linear regression method has been chosen as it is a fairly low complexity method, of easy application and has a relatively low computational time cost, as it revolves around the usage of linear equations. The fitting of the model to the data points was improved by considering multiple explanatory variables, increasing thus the degree of the equations, thus using the multiple linear regression method (MLR).

2.2 Qualitative Methods

When past data is unavailable or impractical to gather, a qualitative approach may be chosen. These methods are essentially subjective opinions of experts. However, such analysis is more complicated as it requires years of accumulated experience and only highly skilled experts may provide a reliably accurate study on the subject.

One of the advantages of these methods is that rare or one-time events may be considered, the so call wild cards which are very difficult to implement in a purely mathematical model. However there is also the real and significant downside of the personal biases which are inherent to such types of studies. For that reason, the Delphi (also known as Estimate-Talk-Estimate or ETE) method may be applied in order to filter and minimize the biased results.

2.3 Time Series Methods

A time series is simply a series of data points ordered in time, where time is usually an independent variable. Time series methods imply that data of historical behaviour needs to be gathered and compiled in order to predict future outcomes based on trends and on the assumption that the future is directly dependent on the past. Particularly in the shipping industry, these time-series methods allow the accounting of seasonality, the well-known shipping cycles as well as world economic oscillations.

These methods are subdivided into three broad classes, the autoregressive (AR) models, the integrated (I) models and the moving average (MA) models. With each of these classes having a linear dependence on past data. Combinations of these models have given birth to other models such as the autoregressive moving average (ARMA), autoregressive integrated moving average (ARIMA) and the autoregressive fractionally integrated moving average (AFIRMA) which generalizes the previous three. These methods are effective whenever one can define the general trends regardless of the variables influencing the projected parameter (Green & Armstrong, 2012). It is worth mentioning, there are also models for a non-linear dependence between the level of the series and the previous data points. Three of the most well-known time series forecasting models are the rule-based models, naïve models and the state space models.

2.4 Forecasting Studies in the port industry

There have been numerous forecasting studies carried out in the port industry. The following ones are some of the ones which consulted for this thesis:

MDS Transmodal has published in 2007 a study targeting bulk fuels such as coal, liquefied gas, oil and petroleum and also roll-on/roll-off cargo as well as port traffic. One of the objectives was to assess the impact of port traffic growth on inland networks. The targeted location was the Great Britain Ports and the historical data used spanned 25 years. The forecast period goes from 2007 up until 2030. The method used was a mix between GDP and the future policy and market trends (Transmodal, MDS, 2007).

UNESCAP published a study targeting the containerized cargo in the Asian region. The historical data period was 1980-2005 and the forecast period was 2005-2015. The method used was through the extrapolation of average growth rate (UNESCAP, 2005).

2.5 Forecasting Inaccuracies

Inherent to their nature, any and all forecasts have a certain degree of inaccuracies and uncertainties attached to them. There have been developed several ways for calculating the error of a certain forecasting method. Typically, for time-series based methods, around 80% of the historical data is used to generate the forecast itself and the remaining 20% serves to test its goodness.

2.6 Choosing a forecasting method

Several methods for forecasting were taken in consideration in the literature review presented in Chapter 2. However, based on the aforementioned Literature Review, it was possible to discard the utilization of most of the forecasting methods presented and discussed in that chapter.

First, the qualitative methods were found to be unsuitable as they should be applied in forecasts in cases which historical data isn't easily accessible or is even non-existent. In this study, however, data is generally available and should be used as a foundation, avoiding relying on any subjective opinions when possible. There are however a few cases in which qualitative forecasting will be used, mainly due to sudden events that affect some ports. The Auto Regressive Integrated Moving Average (ARIMA) was also dismissed as usually it requires over 50 data points according to Box and Jenkins [43]. For the same reason,

Neural Networks Analysis was ruled out as the accuracy of such method heavily depends on the number of data points used. In order to obtain reliable outputs, previous studies [44] advise relying on ANNs only if the number of data points available are at least over 50 times the number of estimated parameters.

Considering, primarily, the availability of data reported in Chapter 4 and summarized, in particular, in Table 4.5, the linear regression method has been chosen as it is a fairly low complexity method, of easy application and has a relatively low computational time cost, as it revolves around the usage of linear equations. The fitting of the model to the data points was improved by considering multiple explanatory variables, thus using the multiple linear regression method (MLR). In essence, linear regression is based on a linear approach to modelling the relation between a scalar response and one or more independent variables. And like all types of regression analysis, the linear regression focuses on the conditional probability distribution of the response given the values of the predictors, instead of on the joint probability distribution of all of the variables.

3 THE PORTUGUESE PORT SYSTEM

3.1 Structure of the Portuguese port system

In this chapter the targeted ports for this study are presented alongside a description of their characteristics such as yearly cargo throughput and their relevant physical dimensions. Figure 3.1 shows the Portuguese port system including all the commercial ports currently in operation. Out of these ports, the most important are Leixões, Aveiro, Lisbon, Setúbal and Sines due to their level of cargo handling, as such they will be analysed in this study.

Figure 3.1 - Commercial ports included in the Portuguese port system

The ports of Leixões, Lisbon, and Sines form part of the European core network, while the ports of Aveiro and Setúbal are part of the comprehensive network as seen in Figure 3.2

Figure 3.2 – Core and Comprehensive Network ports in the Iberian Peninsula

4 CARGO HANDLING IN THE PORTUGUESE PORT SYSTEM: 1990-2020

In this section the evolution of the cargo handling in the most important Portuguese ports is presented and analysed. The objective is to systematize statistical information enabling understanding the reasons behind the observed trends and tendencies. For any forecasting project a strong statistical information foundation is of crucial importance. Independently of the forecasting method chosen, accurate and precise historical data will have a great level of influence over the results obtained. As such, the most trusted sources were consulted, namely the port authorities as well as Instituto Nacional de Estatística. The data was collected from the earliest available archives and processed in order to be easily understood.

In order to better understand the evolution of cargo in the Portuguese port system, Table 4.1 proves to be of critical importance. This will help to point out the main ports which may have a higher influence over the total national cargo handled volumes, leading to finding explanations for periods of growth or decline more easily. The five main Portuguese ports are Sines, Leixões, Lisbon, Setúbal and Aveiro, by this order. Sines is very important on liquid bulks and containerized cargo. Leixões is strong on Ro-Ro and liquid bulks. Lisbon has a strong impact on solid bulks and some control over containerized cargo. Setúbal is specialized mainly on general cargo and ro-ro. Lastly, Aveiro holds great influence over general cargo and at a lower degree over dry bulk.

Table 4.1 - Activity of Portuguese ports in 2017 by type of cargo (Source: AdC)

Porto(s)	Fracionada	Contentorizada	Ro-Ro	Granéis Sólidos	Granéis Líquidos	Total
V. Castelo	5%	0%	0%	0%	0%	0%
Leixões	19%	17%	69%	11%	25%	19%
Aveiro	22%	0%	0%	12%	4%	6%
Fig. Foz	17%	0%	0%	4%	0%	2%
Lisboa	3%	13%	1%	25%	5%	12%
Setúbal	29%	4%	28%	14%	1%	7%
Sines	2%	59%	0%	30%	64%	50%
Continente	**97%**	**94%**	**98%**	**97%**	**98%**	**96%**
RAM	1%	2%	0%	1%	1%	1%
RAA	2%	4%	2%	2%	1%	2%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

This section will now present the general trend in the entire port system for the total cargo, which includes containerized cargo, general cargo, ro-ro, dry bulk and liquid bulk.

To summarize, shown here in Figure 4.1 the entirety of the Portuguese ports system has been stable and rather constant, hovering between the 50 and 60 million tonnes handled prior to 2004. Year in which it is possible to see the beginning of a growth period. However this positive trend was quickly hampered by the world economic crisis of 2007 and 2008. In these years there was stagnation, followed by a couple of years of decline. With the turning of the decade however, the Portuguese ports had a change of pace and resumed their growth. Eventually peaking in the beginning of 2018.

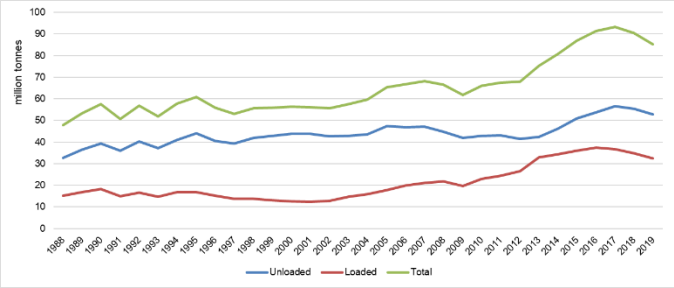

Figure 4.1 - Total cargo handled in all of the Portuguese ports

5 FORECASTING CARGO HANDLING IN THE PORTUGUESE PORT SYSTEM: 2021-2030

General methodology: Linear regression is considered as appropriate for containerized and general cargo and will be used whenever the data allows. Some other types of cargos in specific ports have been considered to be not very significant in terms of the overall cargo throughput in Portuguese ports and the criterion for this categorization was having a low throughput value in 2019 (generally below 300,000 tonnes). Most of the other significant cargos are closely related to specific industries situated around the ports and their behaviour will be forecasted using extrapolations of their trends and qualitative considerations connected with the activity of related industries.

5.1 Linear regression forecasting

One of the most fundamental and widely used method of predictive analysis is the linear regression. The aim of a regression is to look at two things:

- Is it possible to forecast an outcome (dependent) variable using a series of predictor variables?
- Which variables in particular are important predictors of the outcome variable, and how do they influence the outcome variable?

5.1.1 General equations

These regression estimates are used to describe how one dependent variable interacts with one or more independent variables. The formula below is the simplest version of the regression equation with one dependent and one independent variable.

y=b+mx

Where y is the dependent variable, b is the constant intercept (when x=0), m is the regression coefficient and x the score on the independent variable.

5.1.2 Explanatory variables

In order to create a forecast of port throughput with a linear regression, it is necessary to choose a parameter to serve as a foundation. In these forecasting exercises, the GDP has been chosen due its high impact on the nation's consumption behaviour which in turn dictates the level of activity in each of the major ports. On one hand, periods of economic growth lead to higher consumption from the population as these find themselves in a financially advantageous situation. While on the other hand, whenever a nation is going through periods of financial instability or stagnation, the majority of the population - i.e. the middle class - will be more cautious and avoid unplanned spending. Thus leading to a reduction of the cargo volume handled in the nation's ports. This type of events are amplified in extreme conditions such as is the case of world economic crisis of national financial instability during political controversies – e.g. the ongoing crisis seen in Venezuela marked by a mix of hyperinflation, escalating crime, starvation, disease, and mortality rates.

In addition to the Portuguese GDP, it would be interesting to include the GDP of other countries which are directly connected to Portugal via major shipping lines. According to AMT (Autoridade da Mobilidade e dos Transportes, 2018), the most active export destinations are USA, Spain, UK and Netherlands, with the main products being oil products, cement, lime and basic chemicals.

Among the major imported products are crude oil, natural gas, cereal, energy derivatives and coal with main origins in Angola, Nigeria, Ukraine, Spain and Colombia respectively.

With that said, initially the historical GDP data of the following seven nations has been chosen to forecast the cargo throughput in the aforementioned Portuguese ports: Portugal, Italy, Germany, USA, Netherlands, France and Brazil.

5.1.3 Data preparation and evaluation

After gathering all the data for the independent variables as well as the dependent variable, it is important to prepare them before proceeding with the implementation in the model.

The first step is to test for multicollinearity between independent variables. In statistics, independent variables must not be correlated. Otherwise this can undermine the statistical significance of an independent variable, this leading to the introduction of errors in the model and reducing its predicting accuracy. In order to test multicollinearity, one must measure the strength of the correlation between all independent variables by pairs.

Excel's data analysis add-in "t-Test: Paired Two Sample for Means" can be used to obtain the Pearson's correlation coefficient, denoted by "r". This measures the linear correlation between two data sets. It is the covariance of two variables, divided by the product of their standard deviations, thus can be considered a normalized measurement of the covariance, such that the result always has a value between −1 and 1. Pearson coefficient is given by:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - y)}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \qquad 5.1$$

A correlation coefficient above 0.5 can be considered as high, meaning there is a strong correlation (Statistics Solutions, n.d.).

Additionally, one can calculate the variance inflation factor or VIF for short. If the independent variables are correlated, the VIF determines how often the variance of an estimated regression coefficient increases. We're looking for precise

estimates, so more variance is bad. The model will become less accurate as the variance of the coefficients increases. Typically values of VIF above 10 indicate that there may be a problematic case of multicollinearity. Variance inflation factor is given by:

$$VIF = \frac{1}{1 - R^2} \qquad 5.2$$

Where R is the correlation coefficient between two independent variables.

Another parameter to be taken into account in a MLR analysis is the p-value. For each term, the p-value is used to evaluate the null hypothesis that the coefficient is zero (has no effect). The null hypothesis can be dismissed if the p-value is less than 0.05. In other words, since changes in the predictor's value are related to changes in the response variable, a low p-value predictor is likely to be a useful addition to the model. A higher p-value, on the other hand, implies that changes in the predictor are unrelated to changes in the response. In this case the independent variable can be considered insignificant to the model (Minitab, 2013).

5.2 Linear regression applied to containerized cargo

5.2.1 Domestic containerized cargo

With all the data gathered and ordered, it is possible to proceed with the generation of the forecast with the aid of Excel's functions. Although it will be seen that the MLR model is inadequate for this study, it was kept in the first forecast as an example of its issues. Table 5.1 contains the main parameters of the multiple linear regression obtained through the Excel "Data Analysis" add-on.

Table 5.1 – Main parameters of the multi linear regression

Regression Statistics	
Multiple R	0.996
R^2	**0.993**
Adjusted R^2	0.991
Standard Error	43971
Observations	46

The first and most important parameter worth being mentioned is the R^2, with a value of 0.993 it gives the model a great fitness. Secondly, the "Significance F" of 2.5E-37 means the group of variables pass the null hypothesis test (p-value<0.05). Even though the MLR model has a great fitness, most of the independent variables have no significance (p-value > 0.05). Meaning that they add no value to the model, only making it more complex and prone to generate inaccurate forecasts due to overfitting.

The values of the VIF parameter between GDPs (e.g. PRT vs ITA) were found to be higher than 10, which also indicates that the MLR is not a suitable method in this case due to multicollinearity. Plotting the results, Figure 5.1 is obtained. The circles represent the historical data of the containers handled in TEUs, the squares demonstrate the trend extrapolated until 2030. The diamond shaped marks are a simple linear regression based only on the Portuguese GDP. Lastly, the triangle markers represent the multi linear regression (MLR) equation until 2020 and the forecast for the period between 2020 and 2030 based on IMF forecasts for economic growth. The MLR equation is based on 8 explanatory variables, being the GDP of Brazil, France, Germany, Italy, Netherlands, Portugal, Great Britain and the USA.

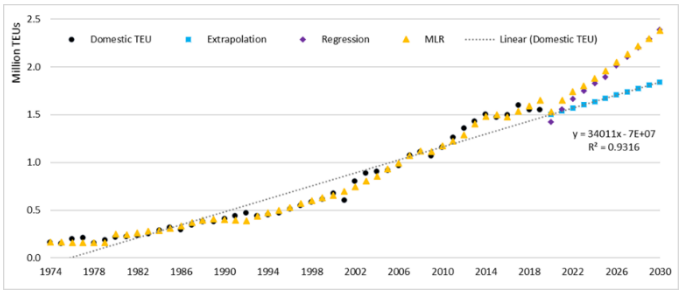

Figure 5.1 - Forecast of the Portuguese domestic TEUs handled

Even though the MLR and the simple linear regression generate similar results, the former breaks a couple of rules of statistics. The first rule is that correlated independent variables shall not be used, the second rule, is that independent variables must be significant, that is, their p-values must be under 0.05.

The simple linear regression model using the Portuguese GDP as the explanatory variable is the better method in this study. Thus it is applied to the remainder of the forecast study whenever possible. Figure 5.2 shows the evolution of the Portuguese GDP as well as a forecast until 2030 according to IMF (International Monetary Fund, n.d.).

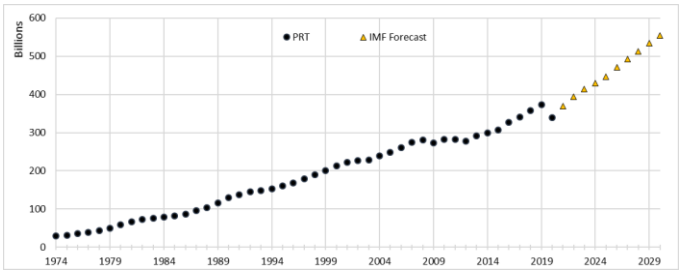

Figure 5.2 - Portuguese GDP and its forecast up to 2030

It is interesting to project an optimistic and conservative scenarios. As such, shows the possible outcomes of the different scenarios regarding the domestic containerized cargo. The optimistic scenario is generated through a linear regression using the Portuguese GDP (as forecasted by IMF) and has very high R coefficient of 0.97. However, this extreme rate of growth is very unlikely when considering the negative effects of the pandemic. The conservative scenario (probably more likely one) is generated by extending the cargo trend seen in the last 4 years. To note that the drop of the linear regression seen in 2020 is due to the fall of the Portuguese GDP for the same year.

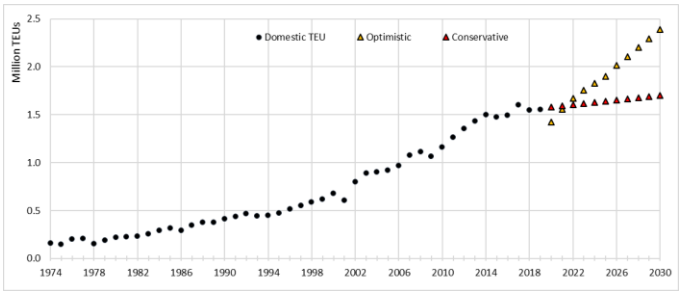

Figure 5.3 - Optimistic and conservative scenarios of the domestic containerized cargo forecast

5.2.2 Containerized transhipment cargo

The objective of the second forecast is to find a correlation between the transhipped containerized cargo in the port of Sines and the world's GDP. Figure 5.4 shows the nearly linear growth of the world GDP and its forecast up to 2030 published by IMF (International Monetary Fund, n.d.).

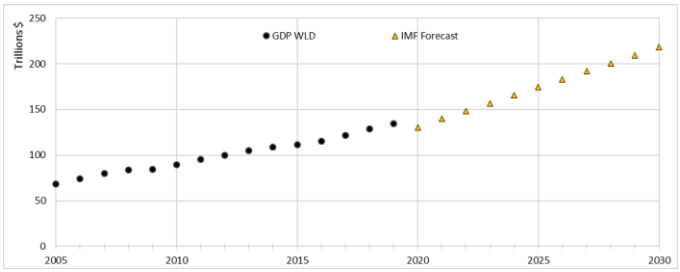

Figure 5.4 – World GDP and its forecast until 2030

Figure 5.5 shows the simple extrapolation of the trend of containerized cargo transhipped in the port of Sines as well as the forecast with a linear regression based on the world's combined GDP. Three cases are presented, a very optimistic case generated by a linear regression with a high R value of 0.94. An optimistic case generated by an extrapolation which extends the trend seen between 2013 and 2019. This scenario could be justified by the ongoing plans of expanding the container terminal as well as the current recovering trend of the global economies. Lastly, a conservative scenario generated by extending the trend seen between 2016 and 2019. An argument for this scenario could be that the Chinese exports will likely begin to slow down in the next years.

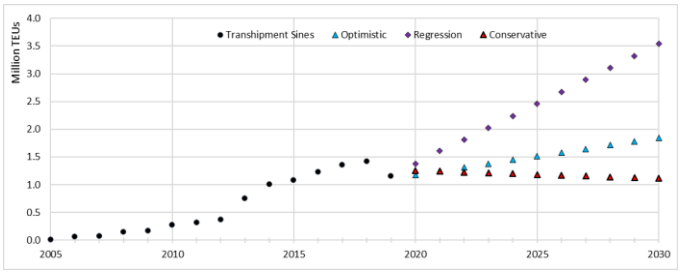

Figure 5.5 - Transshipped containerized cargo in the port of Sines

5.2.3 *Containerized cargo in Leixões*

Using the GDP Portugal as the explanatory variable, the linear regression method was applied to this cargo sector in Leixões. Figure 5.6 shows the resulting values of this forecast. With such a strong correlation coefficient R of 0.95, given the positive upwards trend of the GDP, the unloaded containerized cargo is expected to grow alongside. More recently, there has been a nearly stagnating trend seen since 2012. This is a classical behaviour whenever a port approaches its maximum handling capacity due to the physical restrictions. However, the optimistic case generated by the linear regression is still possible given the ongoing plans of expanding the container handling terminal in the next few years (Lusa, 2021). Otherwise, the cargo handling volume is expected to hover around the levels seen in the most recent years, as shown by the extrapolation. The drop seen in 2020 is partly due to the fall of the Portuguese GDP in that year.

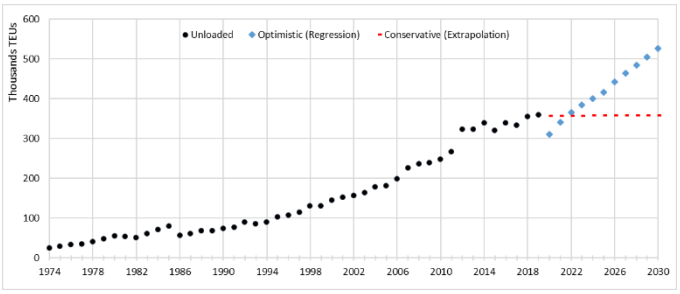

Figure 5.6 - Unloaded containerized cargo in the port of Leixões

5.2.4 *Containerized cargo in Sines*

As for the loaded containerized cargo, near identical results were obtained as seen in Figure 5.7. In an optimistic scenario, a high level of growth is expected for the following 10 years when using the linear regression method which has a high R coefficient of 0.92. Once again, a more realistic and conservative scenario is obtained by extrapolating the trend seen in the last 5 years.

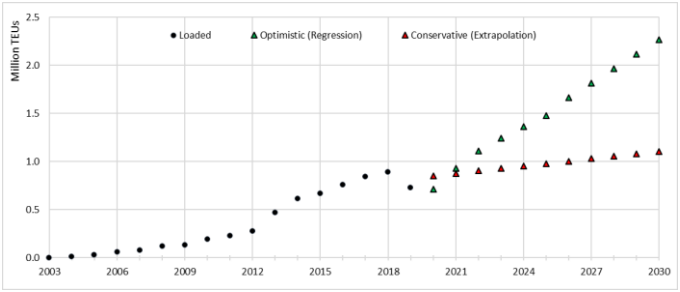

Figure 5.7 - Loaded containerized cargo in the port of Sines

An argument for the optimistic scenario could be made by justifying the growth of the total containerized cargo to 5 million TEUs by 2030 due to the ongoing expansion process of the Terminal XXI. As for the conservative scenario, one could justify it by taking into account that the large majority of this cargo is transshipped, and that the Chinese economy which is one of the main sources of exports has been slowing down, alongside the world GDP in the recent years.

5.2.5 *Containerized cargo in Portugal*

In order to better compare the containerized cargo evolution between the ports being studied, the previous forecasts are grouped into two charts, one for the optimistic scenario and another for the conservative scenario. Figure 5.8 summarizes the performance of the main Portuguese ports in terms of containerized cargo throughput and their respective optimistic forecast. Overall in this forecast, this type of cargo is expected to return to the growth rates seen between 2013 and 2018 if the infrastructure expansion plans of the major ports goes as planned.

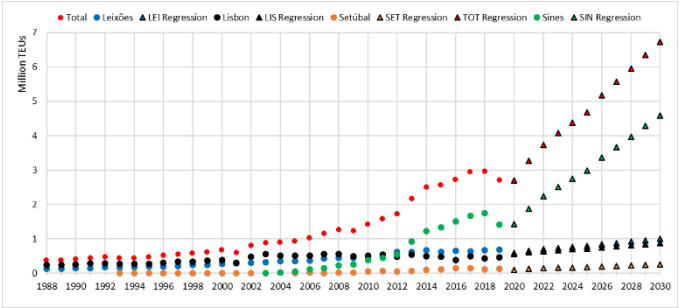

Figure 5.8 - Optimistic scenario of the containerized cargo evolution of main Portuguese ports

Figure 5.9 summarizes the performance of the main Portuguese ports in terms of containerized cargo throughput and their respective conservative forecast. Overall a slight increase is forecasted for this type of cargo in this scenario.

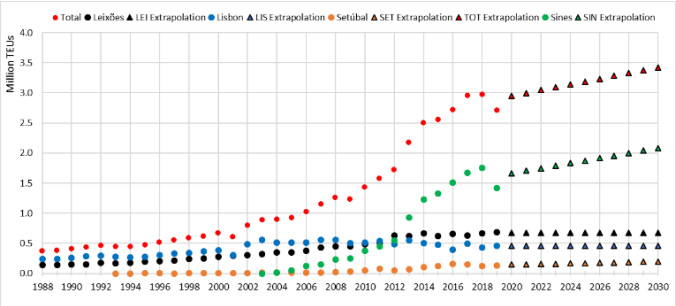

Figure 5.9 – Conservative scenario of the containerized cargo evolution of main Portuguese ports

For 2030, the optimistic scenario forecasts that the Portuguese ports will handle nearly 7 million TEUs, a growth of 200% over what was seen in 2019. This seems unlikely and not realistic, especially when taking into consideration the recent global pandemic. As such, the most likely scenario is the conservative one as it proposes a more reasonable growth rate over the next decade.

5.3 Linear Regression applied to General Cargo

5.3.1 General cargo in Aveiro

The general cargo unloaded in Aveiro has experienced growth from 1988 and peaking in 2004. A downhill trend was seen in the following years, up until the first couple of years of the last decade. Since then there has been once again a trend of growth. Similarly to what was seen in Leixões, a simple extrapolation of the overall generates a more realistic forecast. Figure 5.10 shows the extrapolation as well as an optimistic and a conservative scenarios. Even though highly unlikely, the optimistic takes into account the trend from 2009 to 2019, which may happen if new markets are attracted to the port. The conservative one takes into account the trend from 2001 to 2008, and goes along with the containerization trend.

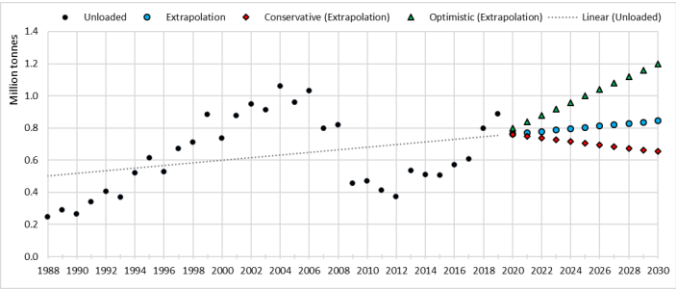

Figure 5.10 - Unloaded general cargo in the port of Aveiro

5.3.2 General cargo in Portugal

In order to better compare the general cargo evolution between the ports being studied, the previous forecasts are grouped into two charts, one for the optimistic scenario and another for the conservative scenario. Figure 5.11 summarizes the performance of the main Portuguese ports in terms of general cargo throughput and their respective optimistic forecast. In this scenario, the cargo is expected to grow slightly as the decade passes, if the economy recovers well from the effects of the COVID-19 pandemic and finds new markets. To note that the total series takes into account the total Portuguese ports general cargo throughput.

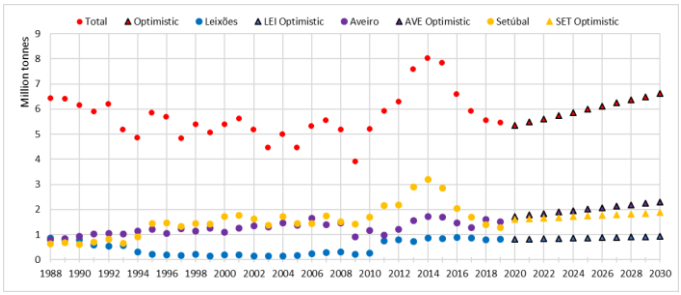

Figure 5.11 - Optimistic scenario of the general cargo evolution of main Portuguese ports

Figure 5.12 summarizes the performance of the main Portuguese ports in terms of general cargo throughput and their respective conservative forecast. In this scenario, the cargo is expected to either stagnate or to go through a slight decrease as the decade passes, following the trend of containerization.

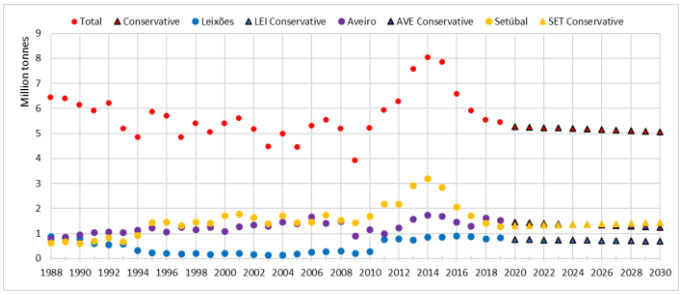

Figure 5.12 – Conservative scenario of the general cargo evolution of main Portuguese ports

Overall, given the global trend of containerization, the conservative scenario is the more likely one.

5.4 Linear Regression applied to Roll-on/Roll-off Cargo

5.4.1 Unloaded roll-on/roll-off cargo in Setúbal and Lisbon

In this forecast it is of interest to pair the volume of ro-ro cargo imported by the Portugal through its main ports in this sector with the Portuguese GDP, since the main consumers of this cargo is the country's own population. The two important ports for this type of cargo, and for unloading, are Setúbal and, for some years, Lisbon. As seen in Figure 5.13, overall the unloaded roll-on/roll-off cargo in these two ports has been decreasing, with the exception of the last 8 years, where it is seen to have bounced back.

An optimistic scenario is also presented, using only the last 11 years of data in the regression, this case might be justified if the country's demand for vehicles rises. A conservative scenario seen in the same figure is also likely to take place if the markets demand slows down.

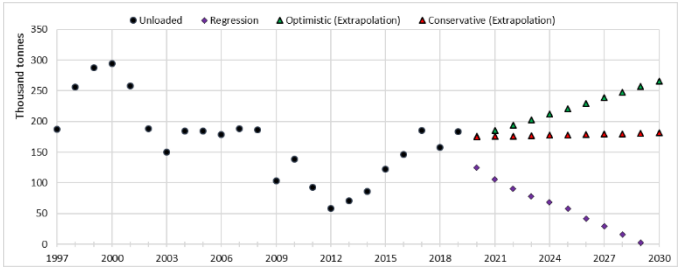

Figure 5.13 - Unloaded Ro-Ro cargo in the ports of Setúbal and Lisbon

The linear regression suggests that these two ports will no longer import roll-on/roll-off cargo starting from mid-2029. This phenomenon has to do with the inverted relation which is seen between the GDP and the unloaded ro-ro cargo, intensified by the increase of the GDP's growth rate in the more recent years. However this doesn't seem realistic, based on the simple logical thought that the Portuguese automotive market will always show some level of demand. In modern days people need vehicles for transportation purposes and industries need them in order to properly function.

Even though the Portuguese GDP is expected to recover in 2022, given the inverted correlation seen between it and the evolution of this cargo, whenever the GDP grows, the linear regression forecasts that the cargo will fall.

5.4.2 Roll-on/Roll-off cargo in Portugal

Between 2005 and 2013 there can be seen a stable output from the ro-ro cargo. Since then however, there has been a substantial, near linear growth. The resulting linear regression for the next 10 years suggest a reasonable rate of growth.

In order to better compare evolution between the ports being studied for this sector, the previous forecasts are grouped into two charts, one for the optimistic scenario and another for the optimistic scenario. Figure 5.14 summarizes the performance of the two main Portuguese ports in terms of ro-ro cargo throughput and their respective optimistic forecast. In this scenario, the cargo is expected to grow at a significant pace as the decade passes, if the economy recovers well from the effects of the COVID-19 pandemic and finds new markets. It is also evident how the operation of a single service (Ro-Ro) changes completely the performance of a port in this specific cargo type.

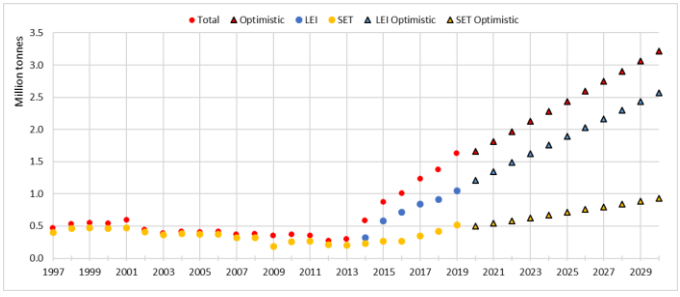

Figure 5.14 - Optimistic scenario of the ro-ro cargo evolution of main Portuguese ports

Figure 5.15 summarizes the performance of the main Portuguese ports in terms of ro-ro cargo throughput and their respective conservative forecast. In this scenario, the cargo is expected to stagnate as the decade passes given the lack of port infrastructure in Leixões.

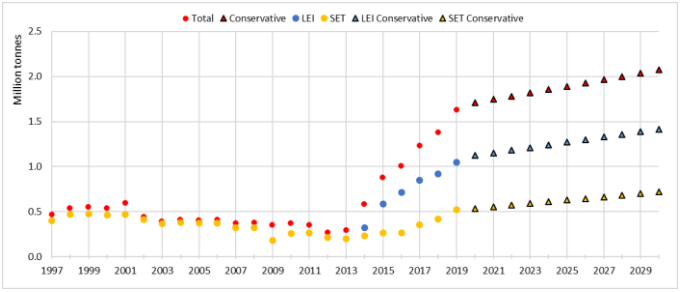

Figure 5.15 - Conservative scenario of the ro-ro cargo evolution of main Portuguese ports

Overall, one could argue the most likely scenario is perhaps the conservative one as the terminals approach their cargo handling capacity.

5.5 Qualitative forecasting applied to Solid and Liquid Bulks

5.5.1 Forecasting of Liquid bulk cargo

As mentioned in Chapter 4, the Galp refineries in Sines and Leixões play an extremely important role in their respective ports. The large volumes of crude oil required by these refineries have granted them a great level of stability along the last decades. However, in December of 2020 Galp announced that it will focus its refining activities and future projects on the Sines complex and discontinue refining in Matosinhos. This means that the port of Leixões is going through a phase where it is looking to attract new clients in order to keep the port running as it was.

With the refinery recently using between 5 and 5.5 million tonnes of crude oil per year (Energia, 2011), the volume of unloaded liquid bulk handled in the port of Leixões is expected to drop near completely from the current 5.2 million tonnes. The crude oil processing capacity is split into three units, the aromatics and solvents unit, lubricants unit and last but not least the main oil factory (Pereira, 2020).

As for the exported liquid bulks, these are also expected to drop nearly entirely from the yearly 2.4 million tonnes when the refinery concludes its shutting down process in the end of 2021. There is a project of using the space of the refinery to install a lithium refinery, idea which is supported by the Minister for the Environment (Silva & Silvares, 2020). However, it has not been established a concrete plan yet. Meaning that any repurposing will take at least a couple of years in order to get approved and executed. If the repurposing plans go through successfully, secondary products present in the lithium refinement process such as hydrochloric acid and hydrogen chloride will be required, meaning they would most likely have to be imported through the port in large volumes.

In Leixões the unloaded liquid bulk is expected to drop nearly entirely as seen in Figure 5.16. This has to do with the fact that the vast majority of this cargo consists of oil products for the refinery, which has recently shutdown. With that said, the linear regression method doesn't generate a realistic forecast. As such, a qualitative analysis is carried out based on the ongoing plans of establishing a lithium extraction and refining operation in the northern region of Portugal. The expected extraction capacity of the mine is of over 20 million tonnes per year and the operating company Savannah Resources plans to refine the ore in China for the initial phase as a safer approach (Holley, 2019). However, in 3 or 4 years, a refinery with a production capacity

of approximately 175 thousand tonnes of lithium concentrate will most likely be built in Matosinhos in order to process the minerals in the same country.

Two scenarios are presented, an optimistic one where the refinery process starts in 2024, with the port handling sulphuric acid as well as other chemicals required for the refining process. As well as a conservative scenario where the refining operation is delayed or cancelled completely.

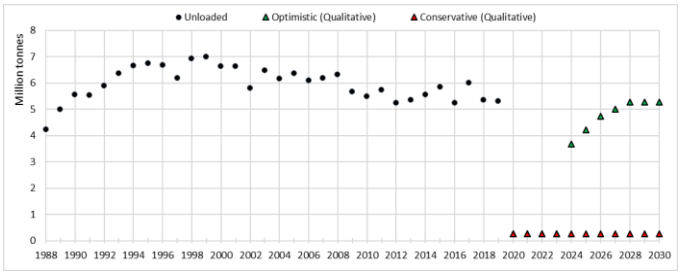

Figure 5.16 - Forecast of unloaded liquid bulk in Leixões

As for the loaded liquid bulk in Leixões, Figure 5.17 suggests it will keep growing, however this sector is also expected to fall as it was heavily dependent on the refinery processed products. Two scenarios are presented, an optimistic one where the refinery process starts in 2024, with the port handling the lithium concentrate and other forms of lithium. As well as a conservative scenario where the refining operation is delayed or cancelled completely.

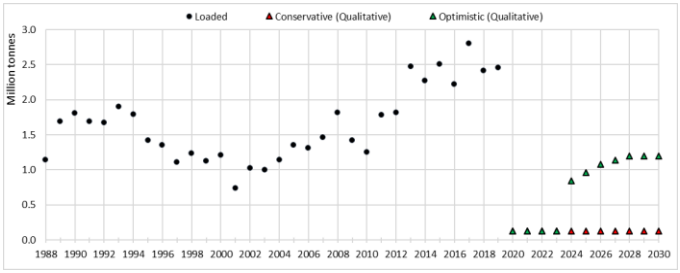

Figure 5.17 – Forecast of loaded liquid bulk in Leixões

In Aveiro the unloaded liquid bulk which consists largely of oil products is expected to have a highly positive evolution over the decade, as suggested by the linear regression forecast in Figure 5.18. The R coefficient for the linear regression is 0.89, a relatively high value. However two points make this forecast unreliable. First, the drop from 2019 and 2020 is too drastic and unlikely, and second, the growth rate is too steep. As such two alternative scenarios are presented. A conservative one which is generated by extrapolating the trend seen between 2011 and 2015. And a more optimistic one which is an extrapolation of the trend seen between 2001 and 2019. It is very likely that the next years will show a growth level somewhere between the optimistic scenario and the conservative one.

A conservative forecast of total liquid bulk handled in Portugal as well as in the five main ports is presented in Figure 5.18. Due to the shutdown of the refinery in Leixões, the total volume handled is expected to drop and stabilize in case if the shift of volumes from Leixões to Sines isn't significant.

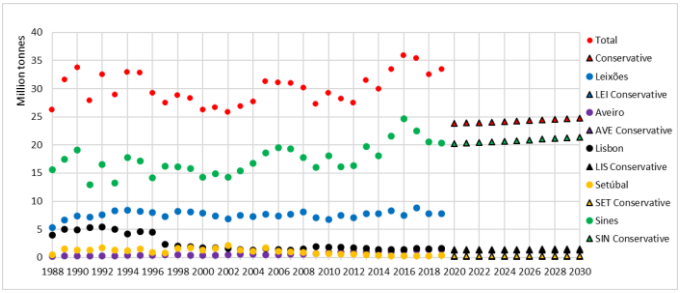

Figure 5.18 – Conservative forecast of total liquid bulk handled in Portugal

An optimistic forecast of total liquid bulk handled in Portugal as well as in the five main ports is presented in Figure 5.19. Due to the shutdown of the refinery in Leixões, the total volume handled is expected to drop but to follow a positive trend which is led by the port of Sines.

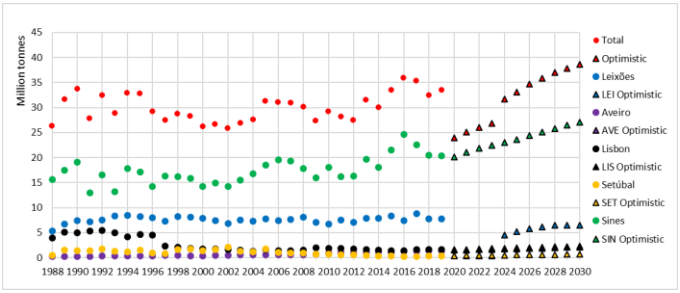

Figure 5.19 - Optimistic forecast of total liquid bulk handled in Portugal

Overall, one could argue the most likely scenario of the two is perhaps the optimistic one given the ongoing plans of establishing different industries in this sector in the country.

5.5.2 Forecasting of Dry bulk cargo

The forecast for the unloaded dry bulk in Sines has a positive trend, as such it would be expected to keep increasing over the next years as well as seen in

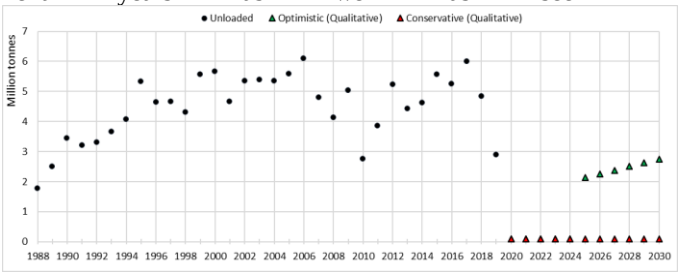

Figure 5.20. However it is known that the large majority – over 97% – of this cargo consists of coal intended to fuel the power plant. And with the shutdown of the power plant this year, the activity of unloading dry bulk in this port will cease. As for a more optimistic scenario, it is somewhat likely for the port to begin handling soya beans in significant quantities in the near future, most likely in the second half of the decade in volumes similar to the ones seen in the port of Lisbon. As for the volumes such cargo, it is too early and there is no sufficient data to attempt a forecast with any reasonable accuracy.

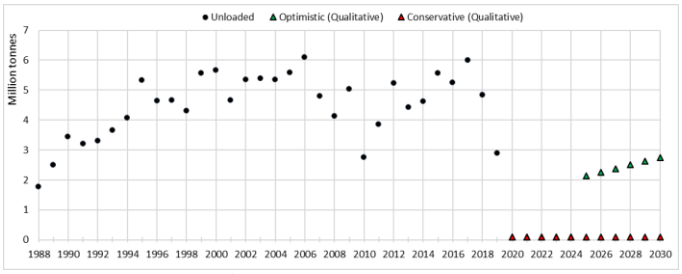

Figure 5.20 - Forecast of unloaded dry bulk in Sines

A conservative forecast of the total dry bulk handled in Portugal as well as in the five main ports is presented Figure 5.21. Due to the shutdown of the power plant in Sines, the total volume handled is expected to drop and stabilize.

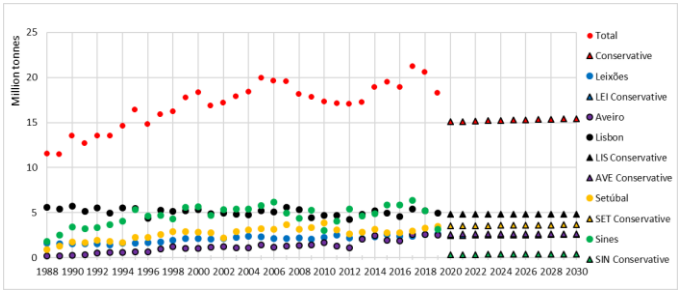

Figure 5.21 - Conservative forecast of dry bulk handled in Portugal

An optimistic forecast of the total dry bulk handled in Portugal as well as in the five main ports is presented in Figure 5.22. Due to the shutdown of the power plant in Sines, the total volume handled is expected to drop. Eventually the total volume is likely to surpass values seen in 2019, especially if an alternative to the coal handled in Sines is found.

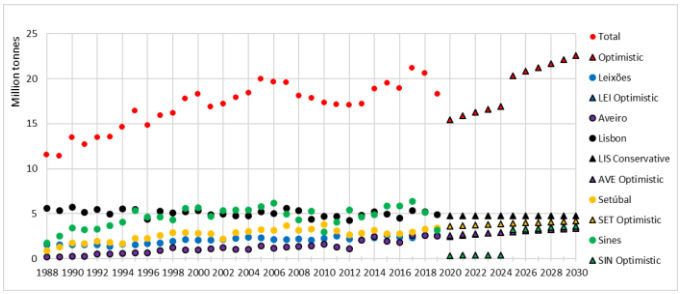

Figure 5.22 – Optimistic forecast of dry bulk handled in Portugal

Overall one could argue the most likely scenario is the optimistic one as it is likely that Sines will find a substitute cargo for the coal in the near future.

5.6 Aggregation of forecasts for the Portuguese port system

As for the Portuguese port system as one, the aggregated total volume of cargo handled in the next years is expected to grow at a significant pace according to the optimistic scenario generated by the linear regression forecast seen in Figure 5.23. The R coefficient for the linear regression is 0.88. One could argue this is too optimistic given the negative trend that the country has entered in 2017 and to add up, the negative effects of the most recent global pandemic of COVID-19. As such, a more conservative and more likely scenario is presented. This one was generated by extrapolating the trend seen between 2014 and 2019 and it forecasts a less steep rate of growth for the cargo handled in Portugal for the next decade.

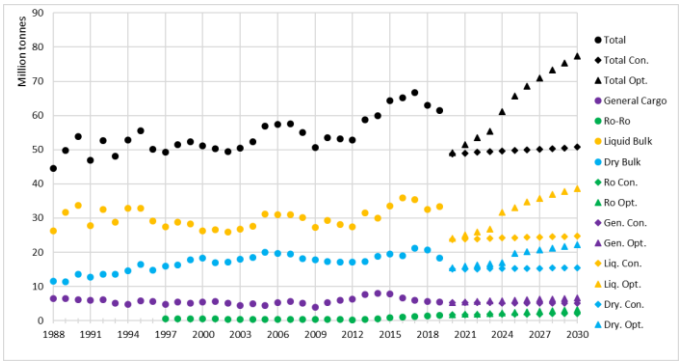

Figure 5.23 - Forecast of the total cargo handled in the Portuguese port system

Overall the results are fairly reasonable, generating forecasts with likely and realistic outcomes. In some cases the extrapolation method proved to be more suitable in detriment to the linear regression due to high variability or lack of data points. The optimistic and conservative scenarios generated are in some cases subjective, as these were created based on the trends in which the cargo were found to be growing or receding at a more reasonable rate. These are to be interpreted with care, and are meant to serve as a general set of guidelines in terms of the most likely upper and lower boundaries for each of the cargoes' throughput evolution. One could argue that the most likely scenario is the optimistic one given the ongoing structural expansions which will increase the handling capacity of cargo and also due to the recovery which is expected from the global economies.

It is also worth mentioning that in many of the ports, one cargo takes a large share of the volumes handled in the terminals. Leaving the ports vulnerable to significant changes whenever the company responsible for that one cargo moves or shuts down operation.

To finalize, it is important to take any forecast as general guideline, taking into consideration the most likely lower and upper boundaries but not discarding completely the more extreme cases. One example of an unfulfilled forecast is one made by the Portuguese Minister of the Sea (Palma-Ferreira, 2017) stated that the Portuguese port system was expected to grow and surpass the 100M tonnes of cargo handled in 2018. However such growth didn't take place, in fact, the opposite happened. As seen in the statistics, the total cargo entered a period of decline in 2018 and even more in 2019.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

One of the main contributions of this thesis has been the presentation of a detailed review of the development of cargo handling in the major Portuguese ports. Statistical data has been collected covering extensive periods of time, for the various types of cargo. Containerized cargo is now available for the period between 1974 and 2019. General cargo, liquid bulk and dry bulk is available between 1988 and 2019. Ro-Ro cargo is available for the period between 1997 and 2019. This statistical data updated the time series previously available in the work of Mainardi (Mainardi, 2016) and largely expanded the initial period of 2001-2014 both to previous years and by updating the database for recent years.

The analysis of the data gathered on port cargo handling allows the conclusions that over the past three decades the Portuguese port system has been evolving with a positive trend. The volume of most of the cargo types handled have been increasing from year to year, especially in the containerized sector. A few exceptions are the unloaded liquid bulks in Leixões, Lisbon and Setúbal, as well as the unloaded dry bulk in Lisbon which have been experiencing a downhill trend.

The forecasts are an attempt at predicting the cargo throughput in the main Portuguese ports for the 2020-2030 period using mostly linear regressions but also extrapolations when the former don't generate reasonable results. The main drivers of the Portuguese economy are led by the agro-alimentary industry as well as industries which highly rely on imported raw goods. These are mainly the productions of cement, steel, paper, as well as chemical and oil products. The country is a highly open economy and this means that the country is easily influenced by global trends and crises. This translates into a more complex problem as the forecasts can be invalidated by wildcard events. Also, events such as the world crisis of 2008, the acquisition of the main Portuguese container handling terminals by the YILPORT, a container terminal managing giant or the current pandemic, have significant consequences in the forecasting exercises. Overall, port forecasting remains a very hazardous task especially in today's world.

The GDP of Portuguese nation used as a basis for the majority of the forecasts has had a fairly stable growth period over the last decades. As such, this trend tends to positively predict most of the different types of cargoes analyzed in this study.

One important outtake from this study is that the non-containerized cargoes alike liquid bulk or dry bulk are tightly interlinked with the evolution of industries related to the respective products. Meaning that extrapolation method of the trends of their evolution is more adequate when predicting their future. Another important conclusion is that multiple linear regressions aren't always the best forecasting method due to multicollinearity which are inevitable when using data points such as the GDP of various nations. In those cases the simpler method of linear regression can be used. With that said, one must still be critical and analytical regarding the results which are generated, as these may in some cases create forecasts which could be either too conservative or too optimistic. As is the case of the containerized cargo. It could be argued that due to the nature of the linear regression, there is a tendency to over accentuate the causal relation between the independent variable which is the GDP and the dependent variable which is the volume of containerized cargo.

One other challenge in using linear regression as a forecasting method is dealing with highly variable data sets such as the case of the general cargo. The method attempts to find mirroring trends between the two variables, however one can quickly understand that due to the erratic distribution of data points over the years it is highly difficult to find one. As such alternative methods alike extrapolation of trends must be used in order to filter out and simplify the high level of variability.

The cargoes where the linear regression proved to generate more realistic results were the dry and liquid bulks. Given the stable evolution of the volumes handled each year, it was possible to more easily create likely scenarios.

As for the roll-on and roll-off cargo, the Setúbal and Lisbon ports had a somewhat unstable distribution of points which made the forecasting process more difficult. Regarding the remaining ports, due to the relative short number of data points, the resulting forecasts must be taken lightly even though the trend was found to be nearly linear, thus generated quite realistic results given the conditions.

In terms of extreme or wildcard events, the recent shutdown of both the fuel refinery in Leixões and the thermoelectric plant in Sines have caused a severe loss in terms of cargoes handled in both ports. In Leixões nearly 7.5 million tonnes of liquid bulk will no longer be transported through the port in the next few years. In optimistic circumstances, if the lithium refining process is started successfully, the port may slowly once again begin to see more activity in this sector. In the case of Sines, nearly 5 million tonnes of coal are no longer being imported to fuel the shutdown of the thermoelectric plant. However there may be some alternative dry bulk contenders which may replace the coal such as soya intended for food processing or consumption.

Overall the Portuguese port system has shown a promising growing trend up until 2017. The years of 2018 and 2019 showed already some worrying trends and this was further complicated by COVID pandemic. However, as the economies begin to recover and return to normality, the years following the COVID-19 global pandemic will most likely give place to a boom in investments of industries which will lead the global shipping to bounce back and grow ever stronger and more active. As decade unfolds, the previous target set by the Minister of Sea for the national port system to reach the 100M tonnes of total cargo handled may well be achieved by 2030 given the conservative forecast predicting 80M tonnes and the optimistic forecast predicting 140M tonnes.

6.2 Recommendations for future work

One of the perhaps most interesting recommendations for future studies would be the application of more complex methods of forecasting. Methods such as Artificial Neural Networks may generate more plausible results, provided that enough data points are available in order to train and test the network with a satisfactory level of accuracy. In order to obtain such high number of data points, one could attempt to collect statistics with a shorter interval of time. Using quarterly or even monthly values for example, instead of yearly cargo throughputs in any given port. Another recommendation is to develop or research a forecasting model for the Portuguese main manufacturing and production industries. And then attempt to use its results as foundation for a hypothetical linear regression model which would substitute the forecasts of GDP in Portugal as a basis for forecasting exercises for some types of cargo.

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