



The Portuguese seaport container sector:  
Formulation of a geographical model using linear transportation costs and quality of service

By:  
**Francisco Castelo**

Mentors:  
Professor Fernando Branco  
Professor Manuel Cabugueira

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## **Abstract**

In this investigation, I studied the container market for the Portuguese seaport sector, with a series of modified Hotelling models. I can compare optimal profit expressions from a two-seaport model and a three-seaport model. Furthermore, these models allow to understand how investment in holding several terminals and quality of service is fundamental to block competition, raise prices and obtain higher profits. Quality of service combined with a small number of competitors and the current market structure in Portugal are an attractive combination to improve Port authorities and private terminals payoffs. By doing this I can help explain what is happening in the Portuguese container sector, why there are so few players in the market and who is benefiting with this current market structure.

I derive optimal price, profits and demand functions for the three main container seaports in Portugal: Leixões, Lisbon and Sines. It was important to understand what was the current market structure, who were the main players and what was their relationship.

In the conclusions chapter, I leave some suggestions for the regulators if this market structure is desired, or if planned to change to a more competitive market there is also propositions. Should the regulator believe that no more competition can be allowed for the sector and that consumer well-being is safekept under this market structure, then the real observed prices and demands are optimal and no market power is being exhibited.

## **Síntese**

Nesta investigação analisa-se a situação do mercado de contentores do sector portuário Português, com uma série de modelos de hotelling modificados, desta forma consegue-se comparar expressões de lucro óptimas para um número variado de concorrentes. Adicionalmente, estes modelos permitem analisar a forma como investimento em qualidade de serviço, o aumento de preços por via da obtenção de vários terminais por parte da mesma empresa criando restrições à concorrência do sector por via de limitar o número de lugares que poderiam ser ocupados por novos concorrentes, com o objectivo de obter resultados superiores, resultados esses, impossíveis em concorrência. Desta forma pretende-se explicar como o sector opera dada a estrutura corrente de mercado, a razão pela qual existe um reduzido número de concorrentes e quem é que beneficia destas condições.

Nas demonstrações existe uma formulação das procuras, lucros, preços e funções de utilidade para os três principais portos Nacionais: Leixões, Lisboa e Sines. A análise da estrutura de mercado e o reconhecimento dos principais intervenientes do sector tiveram um papel preponderante em todas as conclusões retiradas.

Nas conclusões, propõe-se algumas sugestões para a regulação do sector, relativamente à importância de se permitir a entrada a novos concorrentes no mercado, restringindo o número de terminais obtidos por cada empresa. Se, por ventura, esta estrutura corrente de mercado for considerada a ideal pela regulação, então esta, sendo regulada, não tem condições para admitir mais concorrentes e os resultados até aqui obtidos pelo sector são eficientes e que o bem-estar do consumidor é salvaguardado.

## Contents

<b>Preface (acknowledgements)</b> .....	5
<b>Introduction/research objective</b> .....	6
<b>Literature Review</b> .....	8
<b>Methodology and limitations/constraints</b> .....	11
<b>Seaport Sector overview</b> .....	12
<b>Relevant factors that facilitate collusion</b> .....	16
<b>Number of firms</b> .....	16
<b>Capital intensive</b> .....	18
<b>Growing demand</b> .....	19
<b>Multi-market contact</b> .....	19
<b>Public procurement process</b> .....	20
<b>Mathematical overview of the main Appendices conclusions</b> .....	21
<b>Location variable relevance</b> .....	22
<b>Number of competitors reduce individual payoffs</b> .....	23
<b>Variable cost limits</b> .....	27
<b>The case of equal locations</b> .....	28
<b>Three-seaport model with non-symmetry cost for the Portuguese sector</b> .....	32
<b>Quality of service dynamics</b> .....	40
<b>Conclusions/propositions</b> .....	42
<b>Appendix</b> .....	44
Appendix 1: Hotelling two-seaport model with symmetric costs.....	44
Appendix 2: Hotelling two-seaport model with local monopolies .....	47
Appendix 3: Cost limits comparison between the two previous models.....	50
Appendix 4: Two-seaport model with non-symmetric costs and quality of service .....	54
Appendix 5: three-seaport model with non-symmetric costs .....	57
<b>References</b> .....	63

## **Tables & graphics index**

<b>Figure 1:</b> Portugal main seaports and International competitors.....	13
<b>Diagram 1:</b> National seaport sector intervenients.....	14
<b>Table 1:</b> Seaport, terminals and company.....	15
<b>Table 2:</b> Seaport, terminals, company and group.....	16
<b>Table 3:</b> Market structure allowing for tacit collusion agreements to be sustained.....	18
<b>Table 4:</b> Port Authority financial ratios for 2012-2013.....	19
<b>Table 5:</b> Price charged by Leixões, Lisbon, Sines and Setúbal container terminals.....	30
<b>Table 6:</b> Demand for Leixões, Lisbon, Sines and Setúbal load/unload container services (in TEU).....	30
<b>Graphic 1:</b> Demand for Leixões, Lisbon, Sines and Setúbal load/unload container services (in TEU).....	31

## **Preface (acknowledgements)**

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My work wouldn't be possible without the help of my good friend António Matos, which provided all the information and contacts from firms and the AMT for me to learn and study the sector. A word of appreciation to Director João Carvalho of AMT for allowing me to visit and discuss my thesis with his team, it proved in the end to be most resourceful for my work developed.

This thesis was not only a personal challenge but also for the ones around me that saw me struggle with it. For them I also want to write a word of acknowledgment and gratitude for all their patience and their kind words along the way in special to my family.

Lastly, a word of gratitude to Director Paulo Gonçalves that was my summer internship supervisor at the Portuguese Competition Authority and the one that proposed this theme as my MSc. Thesis final project.

## **Introduction/research objective**

The Portuguese seaport sector has been a theme with several controversies, on one hand the news showing how the sector has reached a new record of total cargo handled, thus creating an image of improvement of the sector, and on the other hand, there has been a variety of strikes of the Lisbon port workers. It seems that the sector is moving in the right direction but I would like to personally assess the situation under which the seaports operate. It is known that for the containerized cargo the global demand is growing, so it could be a reason, along with the countries getting out of the financial crisis, why Portugal was capable of breaking total handled cargo records in the first semester of 2016, or it could, among several other factors, due to an increase of efficiency levels that made of Portugal a better international competitor. In either way, one cannot ignore the strikes that have been happening in Lisbon and that are hurting the Portuguese economy. For this reason, I believe that Lisbon geographical location and quality of service are a key factor to understand what is happening in the Seaport. As for Leixões and Sines, these two ports are having outstanding performances and are considered the main locomotive for the Portuguese sector success. It is also relevant to understand why are these two seaports having such success and Lisbon been falling behind in the past recent years. Another motive that show some anxieties about the sector is the Portuguese Competition Authority report mentioning some major concerns when it comes to competition issues and the arise of market power from the private entities running public terminals. This issue was already mentioned before by other scholars.

I have developed a series of modified Hotelling models for three purposes; [1] understand the dynamics between competitors, [2] evaluate whether the current market structure can hurt the Portuguese government through a decrease of availability to pay rents over the concession period and lastly, [3] if terminal users are paying higher prices due to the market structure. After answering these three questions, I can say whether the sector has been able to break records due to its own investment and better performance or if there is some other obscure reason behind it that is creating Lisbon workers to schedule successive strikes. Hopefully I will also be capable of better understand why is Leixões and Sines having such outstanding performances when the rest of the sector is falling behind.

This thesis is organized with the following structure, firstly a brief literature review of relevant studies in the area, or similar studies done in other countries as well as their concerns. Secondly some constraints that might influence my results along with the explanation of how

the model was developed. These constraints reduce the explanatory power of the presented models, but cannot make this thesis results invalid.

Thirdly, in the seaport sector overview, I will be presenting [1] the market structure, [2] the political framework, [3] the concessions contract conditions and how this turns out to be an advantage/disadvantage for Portugal as an international competitor. I will start by comparing the sector structure with an article elaborated by Tirole, J., and Ivaldi, M., 2003, for the European Commission where they mention what are the relevant factors of a market structure that create incentives to exist tacit collusion between firms.

Fourthly, there is a brief overview of all the models developed in the appendices and discuss the main conclusions of each one of them. With the conclusions, I then make a comparison with the Portuguese current situation and how the Portuguese Competition Authority arguments can be mathematically sustained.

Lastly, there are presented the main findings, as well as, suggestions to improve and help the AMT with mathematical support for future market structure changes.

## Literature Review

The seaport sector has undergone a series of studies in the last decade. As nations grow and international trading increases, Notteboom, T., (2015) shows that the concentration of terminals and competition on the sector are rising so fast that we might observe a deconcentration in the years to come. Several techniques have been used by researchers to evaluate optimal pricing strategy, efficiency levels, competition and market power for this sector. From DEA analysis, FDI, to geographical models and game theory the literature is uprising. Barros, C.P., Athanasiou, M., (2004) uses DEA analysis to measure efficiency levels for Portugal and Greece, which states that technical efficiency has increased for the Portuguese case in the given period, but, total productivity was not affected by it, leaving room for improvement in the sector. Cullinane, K., Song, DW., Ji, P., Wang, TF., (2004) also uses DEA analysis to measure efficiency for the main seaports in the world, Hamburg, Antwerp, Dubai, New York, Singapore, Hong Kong between others. It concludes that container port efficiency fluctuates over time and that current programming methods are inadequate to capture long-term efficiency and competitiveness that arise from significant investment. Wilmsmeier, G., Sánchez, R., (2009) study the CARICOM countries and analyse the sector situation showing where are the competitiveness bottlenecks of service provision, what are the main reasons of its existence and conclude by making suggestions of what could be the national initiatives to answer these problems. This study is based on Wilmsmeier, G., Hoffmann, J., (2008) previous research of the Caribbean seaports that shows by using an econometric regression that the freight rates and distance travelled are pro-cyclical, the correlation between freight rate and the number of direct service providers are counter-cyclical and lastly, that correlation between freight rate and transit time are pro-cyclical.

Foreign Direct Investment or FDI was used by UNCTAD, (2010) to study the incentives of private firms auctioning for terminals in Nigeria. It advises local competition authorities how to supervise the public procurements where firms auction for more than one terminal in the same hinterland. This study gives an insight on how competition authorities and sector regulators can act to reduce the margin for firms to opt through illegal agreements across competitors to attain a higher level of market power and thus, higher profits.

As for geographical models, one cannot start without mentioning Hotelling, A., (1929), this is along with Salop's circle model, (1979) the foundation of any geographical model. Hotelling, A. (1929) shows that there can be a solution considering Nash equilibrium considering consumer preferences and companies use locations as a strategic variable. Salop,

(1979) is the most famous adaptation of Hotelling model where firms are located in a circle. For the model developed in this thesis, the closer reference and that encouraged the model presented is Zhou, X., (2015) where for a three seaport hoteling model the main conclusions are; (1) seaports that are not located in the centre have incentives to cooperate to capture a higher demand from a centre seaport, (2) centre seaport optimal price is always lower or equal to the other seaports, never higher, and (3) profits will be determined by the investment level in quality of service since locations are fixed. Lastly, it can be seen in Zhou's article as well as in Appendix 5 that although centre seaport benefits from its location, it is also the one that suffers the most when the seaports not located in the centre are close by.

There is also literature that does not use any of the three-research approach mentioned, but they are equally relevant and one could not move forward without mentioning them. These articles are fundamental to understand what are the current issues for the sector and what it is believed to be the reason behind them.

IEVA, (2014) reports that there is a need of investment in the operating system of the terminals for the Portuguese terminals, this means the improvement of transportation in the terminal and the load/unload mechanical arms. It also mentions the need to expand the terminal size to allocate bigger vessels. When it comes to capacity constraints for the container cargo, in 2013 Leixões reached 93% of its capacity, IEVA report suggests to slightly increase the capacity level for this specific type of cargo in the seaport to face the sector rising demand.

Portuguese Competition Authority, (2015) released a report about the sector and raises some concerns at a competition level and conjunctural problems, for instance, Portuguese seaports performance is one of the worst in Europe, concerns arising from the existence of market power originated by the lack of competition and the small amount of private interventions in the sector. This report is also based in IEVA, (2014) suggestions as well as a report called 5+1 from the Portuguese government issued in 2012, that aims to reduce port costs, increase exportations and competitiveness with Spain. Indeed, Marques, R. & Fonseca, A., (2010) criticizes the Portuguese regulation and political system for allowing Mota-Engil to acquire group Tertir calling to attention about an elevated market concentration on a reduced number of firms.

Also, Silva, J., (2013) points out concerns about inter and intra-port competition for the Portuguese seaport sector, suggesting a new tariff model, creation of an independent sector regulator and lastly, the change of the orientation lines of the Port Authorities in which a terminal concession is given to a private operator. It also explains how seaport terminals are a gateway linking two pieces of land, this ideology is also referred in Notteboom, T., (2010)

when it is explained how multi-port gateways are being formed along the coastline of some countries, including Portugal. This is one of the reasons why the sector competition should be rising eventually leading to a deconcentration as stated before, but since operators may exhibit market-power, by controlling more than one terminal this is a strategy that can be used by already installed operators to block the entrance of new competitors.

For the relevance of intra-port competition, Langen, P. & Pallis, A., (2005) conclude that exist social welfare benefits in the existence of intra-port competition, this is confirmed by the AMT to be inexistent for the Portuguese seaport sector. As for the management adopted in Portugal for the seaports, the landlord model, it is shown by Reeve, P., (2010) in a two-seaport model that Nash equilibrium can be achieved when the landlord model is used. It shows that have the best outcomes with or without intra-port competition when compared with other management models, however, this organisational form is not sustainable without regulation because every individual port can obtain a higher profit by separating service provision from port authority. Another conclusion about this article is that when intra-port competition is introduced, the industry profits and prices go down which may create in Port authorities and terminal owners the unwillingness to be opened to such competition.

Lastly, relevant literature about transportation costs, Notteboom, T., (2010), explains that although barriers were abolished in the European continent, this means that cargo can travel free of extra expenses between the European members, there is an inefficiency related to the land transportation when compared with water transportation. This states that water transportation is cheaper than land transportation, resulting in the formation of seaport hinterlands that in part cannot be improved by the sector levels of efficiency of the sector operators. This is the main reason why Portugal can transport cargo that has a final destination of its own jurisdiction territory or to the closest neighbour, Spain. As for the technology advancements of the sector, Marques, R. & Fonseca, A., (2010) mention that the rising demand of the sector, the need to transport bigger volumes and the rise of competition, led to an increase of efficiency in terms of how cargo is loaded/unloaded, an increase of the size of the container vessels and an increase of the bargaining power of each ship. These factors combined are demanding of the terminal operators an intensive capital investment over the last decade to be able to keep up with the market changes and to ensure that the terminal stays attractive to the newest generation of container vessels. As we see an increase of the bargaining power on the side of container vessels, the incentives to form terminal/seaports collusion intensify.

## **Methodology and limitations/constraints**

I develop a series of modified geographical Hotelling models. From the literature explored and practical studies for other countries, along with national reports that have been gone over the sector framework, there was missing a mathematical proof to sustain the findings and some of the arguments made by national institutions. From the appendices, which are a mere attempt to represent the reality, one can take out some important conclusions. How variable costs, the number of competitors, the quality of service differences across competitors, locations and transportations costs interaction, affect prices, demands, profits<sup>1</sup> and incentives to collusion.

In the last chapter of this thesis there is a model with the Portuguese real locations that try to reflect the real prices and demands, where it is projected Lisbon to have higher costs than Leixões and Sines due to inefficiency forcing it to charge price equal to marginal cost and Leixões to act as a monopoly since terminals are in the possession of the same firm. Unfortunately, prices and demands extracted from the model are not in accordance with the real numbers shown, but it was the closest model from reality and some important conclusions can be taken out.

The major limitation for this analysis is the inexistence of a pure variable in any of the demonstrations that aims to grasp the effect of the political framework, therefore, all the conclusions about policy and government welfare will be taken in the following procedure; *“If the private owners in the given structure are capable of achieving higher profits than in any other structure, say perfect competition, then the rent demanded by the Port Authorities will also be higher, making the government better off since Port Authorities are 100% state owned.”*

Lastly, I miss a variable that reflects how demand behaves under situational capacity limits and how this may force temporarily vessels to load/unload in suboptimal terminals. All the results/conclusions assume uniform distribution of consumers.

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<sup>1</sup> By profits I am considering either private owners' profits as well as Port Authorities payoff from rents of the terminals.

## Seaport sector overview

Portugal is in a crossroads of maritime fluxes of ships making it an exceptional player to attract vessels to load/unload that have as destination a variety of countries in the world. As mentioned in Notteboom, T., 2015, Portugal works as a multi-port gateway for the European continent even though this small country in the European tail is capable of loading and unloading vessels that have as destination Portugal, Spain or cargo that temporary stays for transshipment purposes<sup>2</sup>. This is because of the land transportation inefficiency and not due to inefficiency related with the Portuguese terminals capability of handling cargo, as mentioned in Notteboom, T. 2010 sea transportation is cheaper than land transportation. If we could consider that there were no transportation costs and the time value that one container would take to move from departure point to destination point to be insignificant, then all seaports that were connected by land would compete for the same vessels. Since this is not the case, transportation costs and the destination point of each cargo play a role in creating each seaport hinterland, where each seaport market power may arise depending on other seaports locations, capacity constraints and quality of service.

Along the coastline, Portugal have five container seaports, and eleven terminals. Sines, Leixões and Lisbon represent 82% of the total handled cargo in Portugal; 42%, 24% and 16% respectively in 2012. Since these seaports represent over 80% of the total cargo handled, I will be focusing my analysis only in these three. As for the container cargo that is what I am interested in, these are also the ones to represent over 90% of the market with a total of seven terminals, three in Lisbon and two in Sines and Leixões. Over a four-year period, from 2010 to 2013, Sines has seen an increase of 12,8% in total handled cargo volume, Leixões 6,2% and Lisbon 0,9%. It seems that Sines and Leixões are being successful and in the first semester of 2016, the sector has reached a new record of cargo handled, mainly because of Sines and Leixões performances, but also due to a sectorial rising demand, firms starting to export more leaving the economic crisis behind and because of the main international competitor's such as Algeciras in the south of Spain being at capacity limit. The image below shows the geographical locations for the international competitors of Portugal as well as the national locations of the main seaports. From the top to the bottom in figure 1 it can be found Vigo, Leixões, Lisbon, Sines and lastly, Algeciras. Locations are a relevant factor in the decision-

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<sup>2</sup> Sines is the most famous and successful Portuguese seaport for transshipment purposes due to its capability of loading/unloading the last generation of container vessels.

making process in where to load/unload the cargo of a vessel because of the already mentioned land transport inefficiency. For more on this see appendix 1.

(Figure 1: Portugal main seaports and international competitors)



(Source: Wordpress.com edited by Francisco Castelo)

As it exists seven terminals, with seven different concessions owners operating and always at least two terminals that handle containers in each of the seaports in a small country like Portugal, one can think that competition might be fierce in the container market and that firms would lively compete for each vessel.

My findings show otherwise, firstly (1) during my meeting in AMT<sub>3</sub> I had the opportunity to learn that intra-port competition in Portugal is inexistent because of the asymmetries<sup>4</sup> between terminals, instead, terminal concession owners try to have an efficient distribution between terminals for vessels planning to load/unload. Secondly (2), the sector presents itself under a market structure that combined with specific sectorial features are restrictively reducing competition.

From (1), terminals capable of handling smaller vessels, or in other words outdated terminals, will accommodate smaller vessels and terminals that have been upgraded and can

<sup>3</sup> AMT is an independent organism with administrative, management and financial autonomy responsible to regulate all the transportation sector and safekeeping the public and economic agents interest.

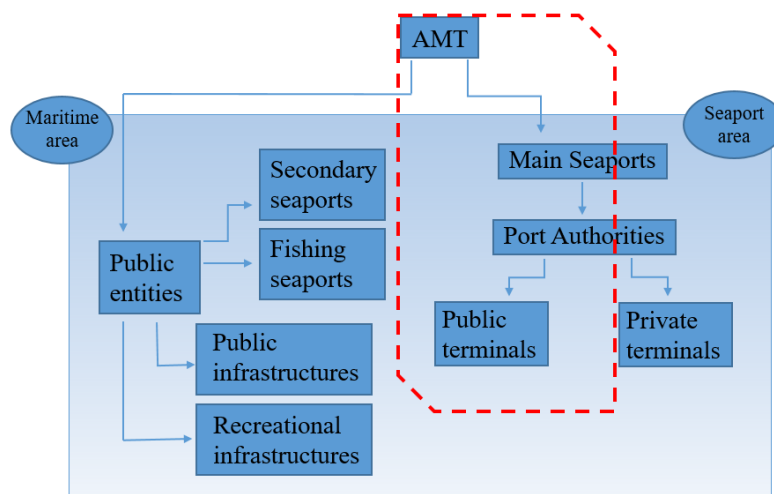
<sup>4</sup> This is a sector that is heavily dependent of investment and terminals stay out-dated fast, they will not be able to operate under the fast innovation of container vessels that require more mechanical arms for load/unload as well as longer and deeper terminals.

load/unload bigger vessels will operate without intra-port competition. Even though, a certain level of market power may arise from the terminal concession owner's side that have an improved terminal, it also might not be an issue if the neighbourhood seaports have a quality of service higher or close to equal and are acknowledged as substitutes. An argument that is commonly used in the European port framework is related with the fact that seaports in Europe are located closer to each other when compared with other regions in the world. By being closer, it means competition is more aggressive and so, it is not needed to have intra-port competition because inter-port competition can generate the same economic outcome benefit for consumers since seaports are closer. This argument could be flawless if not considered that port authorities impose monopoly rents which is a likely assumption for seaports that have only one terminal for each type of cargo creating a local monopoly for each cargo section. By demanding monopolistic rents the Port Authorities can also obtain profits that otherwise would not be possible in any other market structure where firms would lively compete since firms could not pay such a high rent and still be operating, because firm payoffs would not be as high as in a monopoly structured market.

For (2), I will describe the market features and use Tirole, J., Ivaldi, M., 2003 paper as reference to understand whether we are likely to be in the presence of tacit collusions.

To understand which sector players will be relevant for my analysis I created the following diagram highlighting the sector players that onwards I will be addressing as well as the ones I consider to have the biggest impact on the sector performance.

Diagram 1: Seaport sector players



(Source: IEVA report 2014 edited by Francisco Castelo)

<sup>5</sup> I am considering tacit collusion since explicit collusion is banned by antitrust laws, what matters is to check the market structure implemented in the sector and see whether concession owners take some leverage advantage over the consumers and the Port Authorities.

The vertical relevant relation of the sector for my analysis will be between the sector regulator AMT (Autoridade da Mobilidade e dos Transportes), the main seaport authorities and with concession owners operating in public terminals for the container cargo type.

Starting by the number of competitors in this market, as mentioned above for the three seaports that represent over 90% of the container market in Portugal, there are seven terminals, the table below shows the names of concession owners for all the seven terminals:

Table 1: Seaport, terminal and company

Seaport	Terminal	Company
<b>Leixões</b>	North container Terminal	Terminal de contentores de Leixões, S.A.
	South container Terminal	Terminal de contentores de Leixões, S.A.
<b>Lisbon</b>	Container Terminal of Santa Apolónia	SOTAGUS, S.A.
	Multipurpose Terminal	OPERLIS, S.A.
	Container Terminal of Alcantara	LISCONT, S.A.
<b>Sines</b>	Multipurpose Terminal	PORTSINES, S.A.
	Container Terminal	PSA SINES, S.A.

(Source: Port Authorities web domain, edited by Francisco Castelo)

It can be seen by the number of firms operating that competition must be fierce even though in Leixões we have the same firm that is owned by the two national competitors for the two existent terminals. From Tirole, J., Ivaldi, M., 2003, it is known that as the number of competitors increase, the harder it is for the firms to come together and can create an efficient punishing method to keep every agent in line to the collusion agreement. The following argument can be easily understood by looking at the discounted profits expression:

$$\frac{\pi^c}{n} + \delta \frac{\pi^c}{n} + \delta^2 \frac{\pi^c}{n} + \dots = \frac{\pi^c}{n} (1 + \delta + \delta^2 + \dots)$$

The above expression represents the collusive intertemporal profits for firms with the same variable cost and homogeneous goods, where  $\pi^c$  is the collusive profit,  $n$  is the number of firms in the cartel and  $\delta$  the discount factor. If one firms deviate from the collusive agreement it can get:  $\pi^c + \delta \times 0$  where  $\pi^c$  represents the entire collusive profit<sup>6</sup>, and the other firms will answer in the following periods with a price war ( $P_i = c$ ). This means that the cartel

<sup>6</sup> This is only true if variable costs are constant.

must assure that the following expression holds:  $\frac{\pi^c}{n}(1 + \delta + \delta^2 + \dots) \geq \pi^c$  From the left-hand side, where it is represented the intertemporal cartel profit as the number of firms increase, the smaller the left-hand side becomes making it easier for firms to deviate from collusive agreements and initiate price wars since the one-time deviation becomes more attractive. Solving for  $\delta$ :

$$\delta \geq \delta^*(n) \equiv \frac{n-1}{n}$$

When there are more firms in a cartel, the share of each one is smaller, thus, when deviating, the difference between their share and the acquisition of the total cartel profit for a single period is bigger creating more incentives to deviate from the collusive agreement.

Moreover, this is even harder when terminals are structurally different, which is the case from above statement of AMT about the inexistence of intra-port competition. Before moving to the next market feature that facilitates tacit collusion, below I present a new table with more information about the installed firms. By cross referencing the terminal concession owners with a bigger economic group to see if they are indeed all independent, the following table was obtained. Table below shows the firms operating in each terminal as well as the economic group they belong to:

Table 2: Seaports, terminals, company and group

Seaport	Terminal	Company	Group
<b>Leixões</b>	North container Terminal	Terminal contentores de Leixões, S.A.	ETE/YILDIRIM
	South container Terminal	Terminal contentores de Leixões, S.A.	ETE/YILDIRIM
<b>Lisbon</b>	Container Terminal of Santa Apolónia	SOTAGUS, S.A.	YILDIRIM
	Multipurpose Terminal	OPERLIS, S.A.	ETE
	Container Terminal of Alcantara	LISCONT, S.A.	YILDIRIM
<b>Sines</b>	Multipurpose Terminal	PORTSINES, S.A.	ETE
	Container Terminal	PSA SINES, S.A.	PSA SINGAPORE

(Source: ETE and Mota-Engil website, edited by Francisco Castelo)

From table 2, there is a significance change in the competition picture that table 1 was showing. It seems that all the firms except for PSA Sines, S.A. are connected through the same economic groups. From (1) I stated that market power from updated terminals could be controlled by the neighbourhood terminals influence since they were substitutes, but the neighbourhood for all the container terminals is under the same firm's concession allowing terminals to exhibit market power over consumers more easily. From table 1, the decision making of each terminal pricing and investment was linked to the thought process of each individual terminal concession owner and the respective profit maximization under the available resources. In this given structure, each terminal pricing and investment will depend on how the economic group can obtain a higher payoff, independently of what could be the best outcome for each individual terminal. Moreover, we observe an artificial mechanism to attempt to reduce competition by occupying the available terminals<sup>7</sup> in the market, this is a common method of tacit collusion because terminals will not be independently maximizing profits and the group itself will be maximizing the joint profit for all the terminals it possesses.

So far, the market structure presents itself under a fixed number of available terminals for firms to allocate their resources and compete in a regulated market, but the number of competitors is currently being artificially reduced by already installed firms occupying more than one terminal, moreover, the difficulty of seaports to expand and build new terminals give a degree of confidence to installed firms that the probability of a new competitors to enter the market is very small. If a new terminal was to be built, firms would know upfront, due to the nature of the Port authorities being state owned and investments having to be justified which gives time for installed players to either capture the new terminal or accommodate to the new entrant.

Another feature of this market is that it is capital intensive and certain levels of investment in quality of service may eliminate the possibility of having new competitors in the market. Not only block the entrance to new competitors but also may kick out of the market installed players in outdated terminals due to the fast innovation process this sector is facing from the demand sides<sup>8</sup>. From Tirole, J., Ivaldi, M., 2003, entry barriers, capital intensive markets allow for tacit collusion agreements to be easier to maintain.

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<sup>7</sup> Seaports have a limited number of terminals that can be auctioned through public procurement processes, from this market feature the number of competitors is already fixed by the number of terminals which allows installed players to predetermine how many competitors they can possibly face and more importantly if collusion is possible and how it will affect payoffs if they were to collude.

<sup>8</sup> Container vessels have been under a variety of technology advancements that require of the terminals a constant update of their infrastructures to accommodate and load/unload bigger vessels.

As mentioned before that this market is facing a growing demand tendency, and this could be one of the reasons why the Portuguese sector reached new records in handled cargo for the first semester of 2016. Growing demand markets allow for tacit collusion agreements to be more easily sustained.

The last market feature I would like to address is the frequency competitors interact. Having the same firms in all the seaports, increases the interaction between them and thus facilitating for illegal agreements to be more easily sustained. Adding to the multimarket contact, these two economic groups have cross-shares for some of the sector firms bringing individual objectives closer. I will present further on another example adding to the Leixões case where these two firms hold shares for the same firms.

Now that I have identified the relevant market structure features that allow for tacit collusion agreements to be more easily sustained for this specific market, there is a clearer understanding why the sector regulator role is fundamental. Some of these features arise naturally from the market specific conditions under which concession owners operate, but for instance, the number of competitors and how frequently they interact can be controlled by the sector regulator.

Table 3: Market structure allowing for tacit collusions agreements to be sustained

<b>Market features</b>		<b>Facilitate collusion</b>
<b>Reduced number of competitors</b>		✓
<b>Rising demand</b>		✓
<b>Multimarket contact</b>		✓
<b>Barriers to entry</b>	Expansion difficulty	✓
	Capital intensive	✓
	Limited nº Terminals	✓

(Source: Edited by Francisco Castelo)

Before Yildirim entered the market, the sector had the same structure where group Mota-Engil through group Tertir was occupying the market along with ETE. Mota-Engil acquired from ETE, SADOPOINT, S.A., one of the concession owners for Setúbal terminals and, Mota-Engil had a 25% share in another Setúbal concession named TERSADO, S.A. that ETE group holds. Markets where the only two competitors share some of the minor terminal operating firms is another way of making competitors walk towards common goals facilitating tacit collusion, therefore it exists at least two cases known in this sector where objectives from competitors walk hand-to-hand in the same road.

Mota-Engil sold group Tertir and their participation in the seaport sector to the Turk group Yildirim that bought this participation through one of the group firm called Yilport. This change has no structure implications since Yildirim didn't have any terminal in Portugal or Spain.

This chapter was started with the mentioning of (1) intra-port competition to be inexistent and that this could be mitigated by the neighbourhood seaports ability to be substitutes and (2) that the market structure implications likelihood to reduce this perspective in (1) from the demand side. Now that the market structure and the market features that allow for tacit collusions agreements to be sustained more easily have been identified it is known that quality of service and price practiced are the main decision factors<sup>9</sup> that drive container vessels to choose where to load/unload their cargo.

Port Authorities are a fundamental variable in the equation to have consumer's interests protected. As the Seaport owners, the Port Authorities are the state organism under which public procurements are runt and the licence to operate in a terminal for a given period can be obtained by private firms. Until now, the most relevant factor that would make Port authorities concede the right to operate in a terminal, would be this firm availability to pay higher rents and invest in their terminal increasing Port Authorities rentability of the terminal. The fact that rents are the decision factor instead of the amount of cargo moved can originate operation problems hard to handle. In the table below there is represented the main financial ratios for the Port Authorities of Leixões, Sines and Lisbon respectively in the year of 2012 and 2013:

Table 4: Port Authority financial ratios for 2012-2013

	APDL		APS		APL	
	2012	2013	2012	2013	2012	2013
Net Earnings	24,6%	20,5%	29,8%	28,3%	6,9%	-2,1%
Financial Autonomy	74%	75%	68%	69%	49%	49,8%
Solvency ratio	2,8	3,03	2,11	2,23	0,96	0,99

(Source: IEVA 2014 report, edited by Francisco Castelo)

In the conclusion chapter, more in this matter to be discussed as I believe this to be a decisive factor for some of the operating problems the sector has been facing.

The last subject I would like to briefly cover in this chapter is the public procurement process and how installed firms have an advantage when compared with firms that are trying

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<sup>9</sup> Appendix 4 for full details.

to enter the market for the first time. There is a passive knowledge obtained by the installed firm allowing it to create a more attractive offer under the spectrum of possible outcomes than other firm trying to get their presence in this sector for the first time. Already installed firms have created during the long concession period, a relationship with some of the frequent consumers, these relations may prove to be relevant when the time comes to re-run for a terminal. This kind of advantage cannot be controlled by the regulator or the state running the public procurement. Although, there are other determinant factors that may influence the attractiveness of an offer and may benefit the installed firm, these may be controlled and eliminated if the procurement process is fair across firms.

Starting off by the installation cost, an already installed firm if not obligated to re-install their working equipment can start in a more favourable situation when presenting a proposal to the state running the public procurement then firms that still must support this cost.

Secondly, an already installed firm already knows the institution running the procurement for several years, may even have close contacts with the procurement committee. These relations cannot interfere with the public procurement process and must be kept aside safeguarding the National interest of a more competitive and efficient sector where market power is diminished and consumer's welfare is protected.

Lastly, if already installed firms are still holding other terminals, it might prudent to carefully analyse their offer, since it is an offer that is not creating more competition, but indeed, artificially reducing the available slots for new firms to compete with the already installed firms. This argument will be discussed along the thesis demonstrations, because it is a fact that this happens in the Portuguese market structure. Also, by allowing this happen, it raises suspicions about the second argument being made about transparency and the safeguard of consumer interests.

## **Mathematical overview of the main Appendices conclusions**

In this chapter I will present the mathematical proofs of all the statements mentioned in the chapter before, being one of them that the profits for each terminal decreases as the number of competitors increase, bringing the price and cost of the service closer, and that the maximum number of competitors is strictly defined by the number of available terminals. Since there is no intra-port competition, one can say that each seaport acts as if they only had one big terminal, which is all the terminals for the same type of cargo organised. Below is the mathematical demonstration of how the seaport terminal concession owners profit decreases, as the number of competitors increase. I slightly changed the numeration for seaports, instead of using seaport 1 and 2, I used seaport 1 and 3 because I intend to add a new seaport on the demonstration after taking the conclusions for the two-seaport model. This change does not affect any outcome and if it wasn't done, would generate some confusion when taking the conclusions for the three-seaport model.

In a standard two competitor Hotelling model with symmetric costs, the optimal profit expressions<sup>10</sup> are given by:

$$\pi_1^* = \frac{t(2 + a_1 + a_3)^2}{18}$$

$\pi_1^*$  represents the optimal profit expression for the seaport 1.

$a_1$  represents the seaport 1 location.

$a_3$  represents the seaport 3 location.

$t$  represents the unitary transportation cost.

$$\pi_3^* = \frac{t(4 - a_1 - a_3)^2}{18}$$

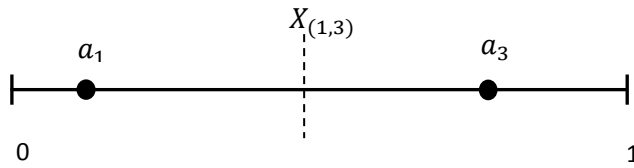
$\pi_3^*$  represents the optimal profit expression for the seaport 3.

These expressions come from finding the indifferent consumer and extracting the true demand function for each seaport. This optimal profit expression is only valid if the indifferent consumer is somewhere between the two seaports meaning, that when the indifferent consumer is no longer in between, further steps need to be taken to find the real demand, prices and profits, this particular case will be shown further on.

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<sup>10</sup> For the whole proof see Appendix 1.

I will assume that  $t = 1$ ,  $a_1 = 0.2$  and  $a_3 = 0.75$ , graphically:



If we use the optimal profit expressions for this case,

$$\pi_1^* = \frac{t(2+0.2+0.75)^2}{18} \text{ and } \pi_3^* = \frac{t(4-0.2-0.75)^2}{18}$$

$$\pi_1^* = \frac{3481}{7200} \text{ and } \pi_3^* = \frac{3721}{7200}$$

For this model, the price and demand expressions are as follows<sup>11</sup>:

$$D_1^* = \frac{P_3^* - P_1^*}{2} + \frac{a_1 + a_3}{2}$$

$$D_3^* = \frac{P_1^* - P_3^*}{2} + \frac{2 - a_1 - a_3}{2}$$

And the respective prices:

$$P_1^* = c + \frac{2 + a_1 + a_3}{3}$$

$$P_3^* = c + \frac{4 - a_1 - a_3}{3}$$

With the  $t = 1$ ,  $a_1 = 0.2$  and  $a_3 = 0.75$  assumption:

$$D_1^* = \frac{59}{120}$$

$$D_3^* = \frac{61}{120}$$

And the respective prices:

$$P_1^* = c + \frac{59}{60}$$

$$P_3^* = c + \frac{61}{60}$$

Looking at the optimal prices, seaport 3 can charge a higher price and still capture a higher demand than seaport 1. This is a result of a better position in the  $[0; 1]$  line than seaport 1, this way it can be seen how locations can be used as a strategic variable when building a new seaport, or how the already built terminals/seaports have an advantage just by being in a

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<sup>11</sup> Full demonstration of the demand and price functions can be seen at Appendix 1.

more favourable location. Now moving on to a three-seaport model, I will introduce a third seaport/terminal in between the seaport at  $a_1$  and  $a_3$  to show how the model dynamics change.

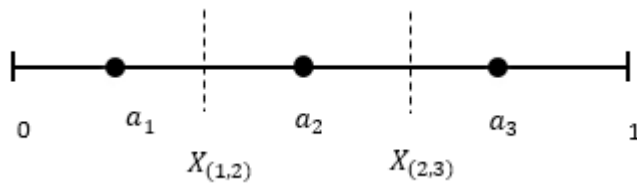
For the three-seaport model with symmetric costs, the optimal profit expressions are given by:

$$\pi_1^* = \frac{t}{288} (2 + 5a_1 + 6a_2 + a_3)^2 \text{ for the seaport located in } a_1.$$

$\pi_2^* = \frac{t}{144} (4 + 2a_3 - 2a_1)^2$  for the seaport located in  $a_2$  that is between the other two seaports.

$$\pi_3^* = \frac{t}{288} (14 - a_1 - 6a_2 - 5a_3)^2 \text{ for the seaport located in } a_3.$$

The optimal profit expression for the already installed seaports in the two-seaport model, have changed because of the introduction of a new competitor, the other assumptions are constant. Graphically:



$\pi_i^*$  represents the optimal profit expression for seaport  $i$ ;

$X_{(1,2)}$  represents the indifferent consumer between seaport 1 and 2;

$X_{(2,3)}$  represents the indifferent consumer between seaport 2 and 3;

By keeping the same assumptions from the first model where;  $t = 1$ ,  $a_1 = 0.2$  and  $a_3 = 0.75$  and adding a location to at the new seaport 2  $a_2 = 0.5$  the new profits for the already installed and the new competitor are:

$$\pi_1^* = \frac{2025}{12800}$$

$$\pi_2^* = \frac{2312}{12800}$$

$$\pi_3^* = \frac{2209}{12800}$$

Under competition, one can conclude that when going from a two-seaport model to a three-seaport model, individual profits greatly reduce. AMT mentioned during my personal interview that intra-port competition is inexistent in Portugal, this may not be an issue if the competition of nearby seaports/terminals of the same type of cargo is significant, especially in the European region where seaports are located closer than in other regions in the world. The Portuguese problem under this market structure is related with the fact that intra-port competition does not exist and the major seaports/terminals that should be perceived as competitors, are run by the same firms in all seaports except for Sines. If terminals are hold by the same firms in every seaport, then how are they really competing? There is the possibility of information share between terminals in different seaports. There is the possibility of vessel rejection in a given seaport, forcing it to load/unload in a more efficient terminal from a close by seaport of the same firm, increasing profits at a zero-risk cost. The optimal demand and price expressions with symmetric costs<sup>12</sup> are as follows:

$$P_1^* = c + \frac{t}{12}(2 + 5a_1 + 6a_2 + a_3)$$

$$P_2^* = c + \frac{t}{12}(4 + 2a_3 - 2a_1)$$

$$P_3^* = c + \frac{t}{12}(14 - 6a_2 - 5a_3 - a_1)$$

And the respective optimal demand expressions:

$$D_1^* = \frac{t}{24}(2 + 5a_1 + 6a_2 + a_3)$$

$$D_2^* = \frac{1}{24}(8 + 4a_3 - 4a_1)$$

$$D_3^* = \frac{4c_2 + c_1 - 5c_3}{24t} + \frac{1}{24}(14 - 5a_3 - 6a_2 - a_1)$$

With  $t = 1$ ,  $a_1 = 0.2$ ,  $a_2 = 0.5$  and  $a_3 = 0.75$  assumptions:

The Optimal prices:

$$P_1^* = c + \frac{45}{80}$$

$$P_2^* = c + \frac{34}{80}$$

$$P_3^* = c + \frac{47}{80}$$

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<sup>12</sup> In Appendix 5 there is the full demonstration with asymmetric costs, for the symmetric, costs I assumed  $c_1 = c_2 = c_3 = c$

The Optimal demands:

$$D_1^* = \frac{45}{160}$$

$$D_2^* = \frac{68}{160}$$

$$D_3^* = \frac{47}{160}$$

From the consumer side, the addition of a third seaport brings a positive impact in the consumer surplus. Not only for those near the new seaport, but also for the consumers that are located the furthest. For those that are located nearby, two positive impacts happen, the first, is the possibility of a lower travel cost to access the same service, the second is related with how a new seaport at a new location creates a pressure on every seaport/terminal price to go down under competition. The furthest consumers from this seaport benefits from this second positive impact, even though they do not access the service on the new seaport/terminal, the already installed firms are forced to lower prices and so, creating a positive impact on the consumer surplus. Below there is a demonstration of this:

Consumer located at 0 buying from  $a_1$ :

$$U_0^*(1) = R - t(a_1 - 0) - P_1^* \leftrightarrow$$

$$\leftrightarrow U_0^*(1) = R - c - \frac{61}{80}$$

Consumer located at 0 buying from  $a_2$ :

$$U_0^*(2) = R - t(a_2 - 0) - P_2^* \leftrightarrow$$

$$\leftrightarrow U_0^*(2) = R - c - \frac{74}{80}$$

The consumer utility at location 0 is higher from buying at 0.2 seaport then buying at 0.5 as previously mentioned;

$$U_0^*(1) > U_0^*(2)$$

Now, comparing the two-seaport utility for the same consumer with the three-seaport model. Consumer at location 0, buying at the 0.2 location in a two-seaport model;

$$U_0^*(1)' = R - t(a_1 - 0) - P_1^* \leftrightarrow$$

$$\leftrightarrow U_0^*(1)' = R - c - \frac{71}{60}$$

There is an increase of utility for this consumer when the market structure went from two competitors to three competitors.

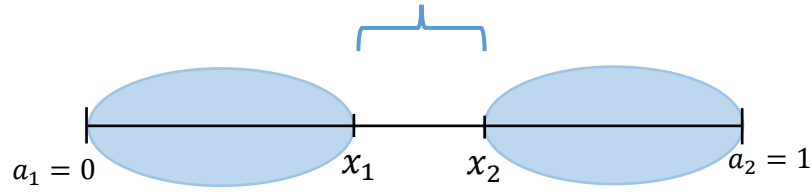
$$U_0^*(1) > U_0^*(1)'$$

Another fact that we can prove in this model is that when increasing the number of competitors and keeping the same geographical area, which for this case the  $[0; 1]$  line, the impact of locations on prices and demands become smaller, this goes hand-to-hand with empirical evidence, meaning that location can be a decisive strategic variable in our equation when choosing where to open a new store, or for this case, when building a terminal/seaport, but as the number of competitors seen as providing a substitute service increase, the impact of our location becomes less relevant.

I have shown mathematically so far that prices go down as the number of competitors goes up and that consumer surplus for every consumer increases when the number of competitors goes up.

Now I will address how the cost limits changes with the market structure. This is relevant to understand why monopoly market structure is inefficient, and why does installed firms have incentives to create conditions, namely acquire several terminals reducing competition, to bring the market acting closer to a monopoly model instead of any kind of competition model. The price range can vary between  $c$  which is the variable cost and  $R$ , which is the reservation price of consumers,  $P \in [c; R]$ . If we consider variable costs to be zero and reservation price to be infinite:  $P \in [0; +\infty]$  bringing the price closer to  $c$  depending on what values it takes, will depend of the competition found, so under perfect competition, one can say that  $P = c$  and under a monopoly model  $P = R$  if unitary transportation costs were to be considered zero ( $t = 0$ ). In the below demonstration, I show how cost limits for installed firms vary depending on the market structure they face. Since variable costs represent the minimum value of the price practiced by the terminal, it is important to understand what are the limits for this variable and how it may impact consumer's surplus.

Consumer's that do not buy



In the figure above, it is represented a monopoly situation, where firms are in the extremes of the line and can only satisfy up to a part of the market due to the consumers exhibiting a small reservation price ( $R$ ), and so, some of the consumers that are further will not buy. This creates a scenario where terminals act as local monopolies with no competition,  $x_1$  and  $x_2$  represents the last consumer that buys.

For this model the  $x_1$  expression is the following<sup>13</sup>:

$$x_1 = \frac{R - P_1^*}{t} + a_1$$

The optimal price expression:

$$P_1^* = \frac{R + c}{2} + \frac{ta_1}{2}$$

And the optimal demand expression:

$$D_1^* = \frac{R - c}{2t} + \frac{1}{2}a_1$$

With the following expressions, I can now find the cost limits for a model with local monopolies and compare them with the first model (Page 23) I presented where terminals would lively compete.

In the monopoly case:

$$c < R - ta_1 - \frac{t}{2}(x_1^* - a_1)$$

Note that  $x_1^* < \frac{1}{2}$ , otherwise we would not be in the presence of local monopolies.

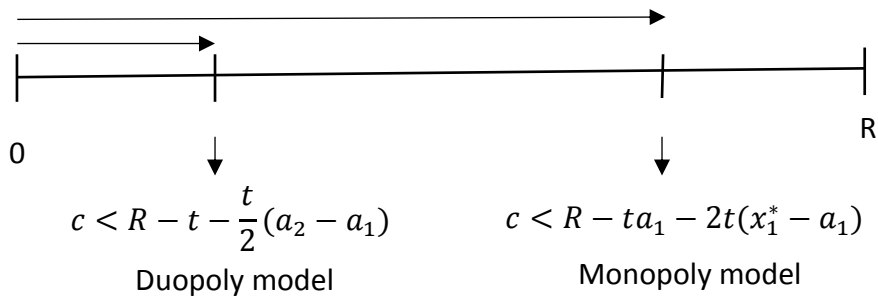
And for the competition case:

$$c < R - t - \frac{t}{2}(a_2 - a_1)$$

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<sup>13</sup> Full demonstration on Appendix 2.

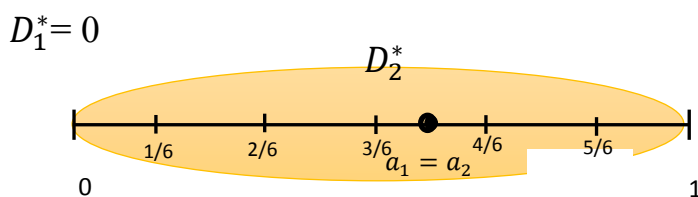
To assist with the analysis, the cost structure can be represented the following way:



It can be seen that local monopolies allow for higher costs and so firms do not need to be efficient. Notice that transportation costs have a big impact in the cost limits, if they were to be zero, consumers would freely travel without any extra cost and both models would generate a  $c < R$  cost expression, making it impossible to observe the cost efficiency gains from having competition. If there is a small positive cost for travelling, which in fact should always be true, since transportation cost can be the sum of a variety of variables, all of them taking positive values, such as the vehicle standard transportation cost, the opportunity cost of the time spent travelling and the risk of an accident, these are plausible positive transportation costs and will most likely never be zero.

Now that the  $c$  value limits are explained and since the reservation price depends of the consumer, when considering locations to be equal ( $a_1 = a_2$ ) and no other terminal to provide the service, for any given consumer, the transportation costs to move to either one of the terminals is the same, being the only decisive factor the price of each terminal. If prices are different, say  $P_1^* > P_2^*$ , the terminal 1, which charges a higher price, will not sell the service and terminal 2 will have the full demand.

Graphically:



This is an important conclusion when analysing intra-port competition where terminals compete for the same type of cargo, my objective with this case is to make a line of reasoning to talk about Lisbon and Setúbal terminals. These two locations are close by and are considered competitors, but Setúbal practices the highest price of service provided for the load/unload of

containers in the whole country and still has a small portion of the total cargo handled in Portugal for the container market.

The small demand can be justified by periods of time where the other seaports were heavily operating creating long waiting periods and so, Setúbal was the only solution for these vessels, now this means that Setúbal operates under residual demands and exhibits monopoly prices; can this be optimal? For a firm looking to establish their own business and position itself as a solution for the majority of the vessels, optimizing individual terminal profits, it is not. However, as a terminal that belongs to the same firm that operates in the other seaports, this can be optimal because as I showed before, prices can go up to  $R$  (Reservation price) when unitary transportation costs are close to zero and there is no competition, the consumer will be forced to load/unload in Setúbal under these conditions. There could be an argument that Setúbal terminals are inefficient and so variable costs are higher, making the terminals operating under higher costs, thus having higher prices. The only problem with this argument would be that since the terminals belong to the same major groups that hold terminals operating in other seaports, information is perfect across terminals of the same firm, as well as the know-how, making the high variable cost argument hardly sustainable, unless there is a high technology asymmetry across terminals, this can be perceived as quality of service and will be shown its impact in equilibrium prices, demands and profits further on this chapter.

In my reasoning, Setúbal is the biggest evidence for the Portuguese Seaport sector that this market structure allows firms to exhibit market power, and if not having intra-port competition is not perceived as a sectorial problem, then having the same major economic groups holding terminals in different seaports should be a major concern when adding to the fact that there is no intra-port competition.

Below I present the prices charged and the demand of the Leixões, Lisbon, Setúbal and Sines seaports.

Table 5: Prices charged by Leixões, Lisbon, Sines and Setúbal container terminals

Seaport	Concessions	Std. Container	Large container
<b>Leixões</b>	TCL	138,19€	138,19€
<b>Lisbon</b>	LISCONT	117,85€	117,85€
	SOTAGUS	110,41€	110,41€
	TSA	108,00€	108,00€
<b>Sines</b>	PSA SINES	122,26€	179,11€
	PORTSINES	112€	112€
<b>Setúbal</b>	TERSADO	158,48€	158,48€
	SADOPORT	151,96€	151,96€

(source: Port authorities' websites, edited by Francisco Castelo)

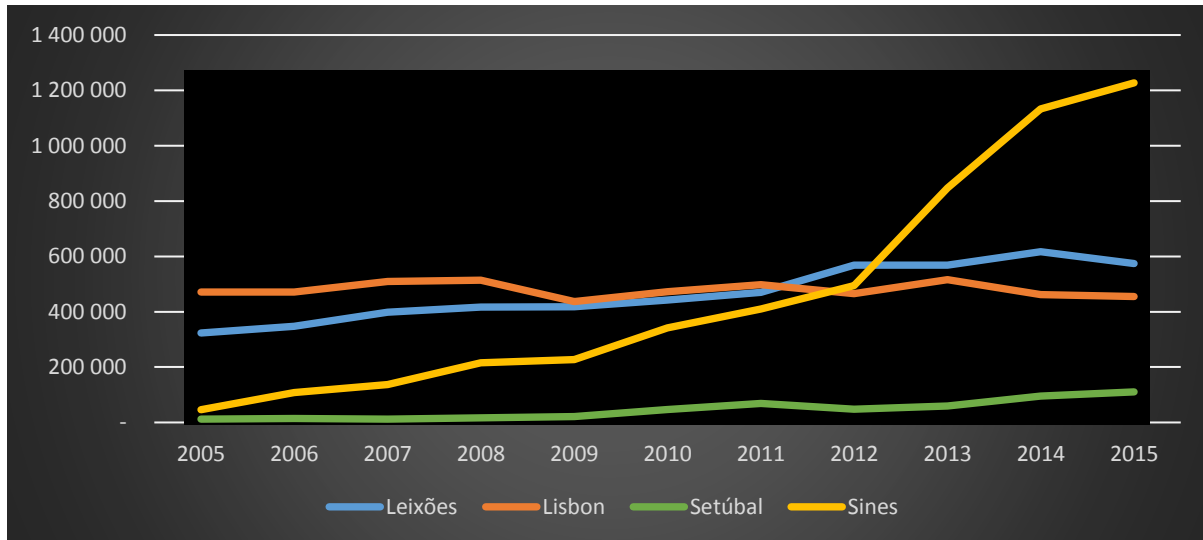
When comparing prices and locations for Lisbon and Setúbal, would be safe to argue that Setúbal only operates when Lisbon is not able to provide the service in the same moment in time.

Table 6: Demand for the Leixões, Lisbon, Sines and Setúbal load/unload container services (in TEU)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
<b>Leixões</b>	323 274	348 003	398 512	417 422	418 266	442 096	469 769	567 958	568 957	616 990	574 421
<b>Lisbon</b>	470 803	471 236	509 387	514 266	436 824	471 897	497 776	464 955	516 026	461 532	455 514
<b>Setúbal</b>	11 996	13 902	12 085	16 150	21 566	46 716	68 321	47 327	59 510	95 862	110 388
<b>Sines</b>	46 063	108 345	136 975	215 481	227 508	341 551	409 758	494 840	847 721	1 133 376	1 227 149

(Source: Autoridade da Mobilidade e dos Transportes – Acompanhamentos dos mercados Portuários, Novembro 2015)

Graphic 1: Demand for the Leixões, Lisbon, Sines and Setúbal load/unload container services



(Source: Autoridade da Mobilidade e dos Transportes – Acompanhamentos dos mercados Portuários, Novembro 2015)

The demand positive evolution in Sines is explained by the entrance of PSA Singapore in 2004 in the Seaport, this firm invested heavily in the container terminal they own and made the Portuguese container market more dynamic and to be a reference for many international firms to load/unload.

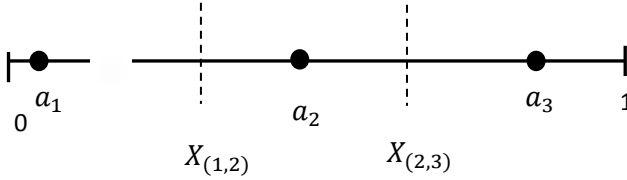
As for Leixões and Lisbon, we observe a swap in the ranking of cargo movement, Lisbon reflects a small negative tendency and at the same time, Leixões shows a positive trend in the total of cargo handled. This goes hand-to-hand with all the arguments made in this thesis about Leixões and Lisbon current situation, it was expected to observe a reduce in total cargo handled in Lisbon when both seaports closer to Lisbon with international influence are being developed, whereas Lisbon stagnated when it comes to terminal and service improvements. The arguments for this dormant situation in Lisbon have already been discussed and have been mathematical proved, as well as severely discussed in other previous articles. This should be perceived as a warning for the Lisbon current situation, when this is a sector of constant innovation from the supply side of containers, more dynamism and transparency need to happen in the Portuguese seaport that can mostly benefit<sup>14</sup> from its geographical location.

I will now present the closest model I could achieve that has results for demands and prices for this sector closer to the reality values. The model had to assume competition restrictions, to bring results closer to the real values.

<sup>14</sup> Appendix 3 and 1, as well as page 20 shows how Lisbon benefit the most from its location, closer to the centre of the [0; 1] line.

### **Three-seaport model with non-symmetry cost for the Portuguese Sector**

After attempting to replicate the demands and prices for the three main seaports in Portugal, Leixões, Lisbon and Sines the closer model from reality I achieved will be presented in this section. I believe that the differences between reality and the modulation made here is related with the fact that my model does not cover waiting periods, quality of service differences and assumes that seaports are competing. Since I was not able to estimate values for the quality of service I did not include it, but I created a two-seaport model with quality of service variable to present the dynamics<sup>15</sup> of this variable. I assumed locations for the three seaports to be fixed, Leixões  $a_1 = 0.1$ , Lisbon  $a_2 = 0.5$  and Sines  $a_3 = 0.7$ , where the  $[0; 1]$  line represents a uniform distribution for the Portuguese inland territory. I assumed Lisbon to be under intense competition and practices a price equal to the variable cost ( $P_2 = c$ ).



Utility expressions for consumers that travel for each seaport:

$$U_{(1)} = R - t(X_{(1,2)} - a_1) - P_1; \text{ Utility from buying at seaport } a_1$$

$$U_{(3)} = R - t(a_3 - X_{(2,3)}) - P_3; \text{ Utility from buying at seaport } a_3$$

$$U_{(2)} \begin{cases} R - t(a_2 - X_{(1,2)}) - P_2 \text{ if } a_2 > X_i; \text{ if consumer is to the left of seaport } a_2 \\ R - t(X_{(2,3)} - a_2) - P_2 \text{ if } a_2 < X_i; \text{ if consumer is to the right of seaport } a_2 \end{cases}$$

#### **Indifferent consumers:**

With  $a_1 = 0,1$ ,  $a_2 = 0,5$  and  $a_3 = 0,7$  and  $t = 1$ ;

$$X_{(1,2)} \leftrightarrow U_{(1)} = U_{(2)} \leftrightarrow$$

$$\leftrightarrow R - (X_{(1,2)} - 0,1) - P_1 = R - (0,5 - X_{(1,2)}) - P_2 \leftrightarrow$$

$$\leftrightarrow X_{(1,2)} = \frac{P_2 - P_1}{2} + \frac{3}{10}$$

<sup>15</sup> The full model demonstration can be found in Appendix 4.

$$X_{(2,3)} \leftrightarrow U_{(2)} = U_{(3)} \leftrightarrow$$

$$\leftrightarrow R - (X_{(2,3)} - 0.5) - P_2 = R - (0.7 - X_{(2,3)}) - P_3 \leftrightarrow$$

$$\leftrightarrow X_{(2,3)} = \frac{P_3 - P_2}{2} + \frac{6}{10}$$

**Demands:**

$$D_1 = \frac{P_2 - P_1}{2t} + \frac{3}{10}$$

$$D_2 = X_{(2,3)} - X_{(1,2)} \leftrightarrow$$

$$\leftrightarrow D_2 = \frac{P_3 - P_2}{2} - \frac{P_2 - P_1}{2} + \frac{3}{10}$$

$$D_3 = 1 - \left[ \frac{P_3 - P_2}{2} + \frac{6}{10} \right] \leftrightarrow$$

$$\leftrightarrow D_3 = \frac{P_2 - P_3}{2} + \frac{4}{10}$$

Taking the first order condition:

$$MAX \pi_1(P_1, P_2, c) = P_1 \left[ \frac{P_2 - P_1}{2} + \frac{3}{10} \right] - c \left[ \frac{P_2 - P_1}{2} + \frac{3}{10} \right] \leftrightarrow$$

$$\leftrightarrow \frac{\partial \pi_1}{\partial P_1} \leftrightarrow \frac{P_2 - 2P_1}{2} + \frac{3}{10} + \frac{c}{2} = 0 \leftrightarrow$$

$$P_1 = \frac{P_2 + c}{2} + \frac{3}{10}$$

Seaport 2 is under intense competition and practice a perfect competition price: ( $P_2^* = c_2$ )

$$MAX \pi_3(P_3, P_2, c) = P_3 \left[ \frac{P_2 - P_3}{2} + \frac{4}{10} \right] - c \left[ \frac{P_2 - P_3}{2} + \frac{4}{10} \right] \leftrightarrow$$

$$\leftrightarrow \frac{\partial \pi_3}{\partial P_3} = 0 \leftrightarrow \frac{P_2 - 2P_3}{2} + \frac{4}{10} + \frac{c_3}{2t} = 0 \leftrightarrow$$

$$\leftrightarrow P_3 = \frac{P_2 + c}{2} + \frac{4}{10}$$

### **Optimal Price:**

$$\begin{cases} P_1^* = \frac{P_2^* + c}{2} + \frac{3}{10} \\ P_2^* = c \\ P_3^* = \frac{P_2^* + c}{2} + \frac{4}{10} \end{cases} \leftrightarrow \begin{cases} P_1^* = c + \frac{3}{10} \\ P_2^* = c \\ P_3^* = c + \frac{4}{10} \end{cases} \leftrightarrow$$

Finding  $X_{(1,2)}$  and  $X_{(2,3)}$

$$X_{(1,2)}^* = \frac{P_2^* - P_1^*}{2} + \frac{3}{10}$$

Replacing optimal prices in the indifferent consumer expression:

$$\begin{aligned} X_{(1,2)}^* &= \frac{c}{2} - \frac{c}{2} - \frac{3}{20} + \frac{3}{10} \leftrightarrow \\ &\leftrightarrow X_{(1,2)}^* = \frac{3}{20} \end{aligned}$$

Consumers from 0 up to 0.15 will buy at seaport located in  $a_1$ .

Testing:

### **Consumer located at 0.15 buying choice**

Cost from buying at seaport located in 0.1:

$$\begin{aligned} R - 1(0.15 - 0.1) - c - 0.3 &= \\ = R - c - \frac{7}{20} \end{aligned}$$

Cost from buying at seaport located at 0.5

$$\begin{aligned} R - 1(0.5 - 0.15) - c &= \\ = R - c - \frac{7}{20} \end{aligned}$$

Any consumer located to the left of  $\frac{3}{20}$  will have a lower cost from buying at seaport located at 0.1. Any consumer located to the right of  $\frac{3}{20}$  will have a lower cost from buying at seaport located at 0.5.

Finding  $X_{(2,3)}^*$

$$X_{(2,3)}^* = \frac{P_3^* - P_2^*}{2} + 0,6 \leftrightarrow$$

$$\leftrightarrow X_{(2,3)}^* = \frac{c}{2} + \frac{4}{20} + \frac{c}{2} + \frac{12}{20} \leftrightarrow$$

$$\leftrightarrow X_{(2,3)}^* = \frac{16}{20}$$

$X_{(2,3)}^*$  is to the right of seaport  $a_2$ , the optimal price given by the optimal price condition is not valid, since for the price  $c + \frac{4}{10}$  consumers are better off buying at the seaport located at 0.5 and therefore, demand for seaport located at 0.7 is zero.

### **Consumer located in 1**

Utility from buying at 0.7:

$$\begin{aligned} R - 1(1 - 0.7) - c - 0.4 &= \\ = R - c - \frac{7}{10} \end{aligned}$$

Utility from buying at 0.5:

$$\begin{aligned} R - c - 1(1 - 0.5) - c &= \\ = R - c - \frac{5}{10} \end{aligned}$$

Consumer at 1 will buy from seaport at 0.5.

### **Consumer located at 0.7**

Utility from buying at 0.7:

$$\begin{aligned} R - 1(0.7 - 0.7) - c - \frac{4}{10} &= \\ = R - c - \frac{4}{10} \end{aligned}$$

Utility from buying at 0.5:

$$\begin{aligned} R - 1(0.7 - 0.5) - c &= \\ = R - c - \frac{2}{10} \end{aligned}$$

There must be a price for seaport 3 that makes consumers to the right of its location indifferent between buying from him or the seaport located at 0.5 and since they are indifferent, they will buy from the closest seaport. Testing for consumer located at 0.7:

$$U_2 = U_3$$

$$R - 1(0.7 - 0.5) - P_2^* = R - 1(0.7 - 0.7) - P_3^* \leftrightarrow$$

$$\leftrightarrow P_3^* = c + \frac{2}{10}$$

Consumer located at 1:

Buying from seaport at 0.5

$$\begin{aligned} R - 1(1 - 0.5) - c \\ = R - c - \frac{5}{10} \end{aligned}$$

Buying from seaport at 0.7:

$$\begin{aligned} R - 1(1 - 0.7) - c - 0.2 \\ = R - c - \frac{5}{10} \end{aligned}$$

For the price ( $P_3^* = c + \frac{2}{10}$ ) all consumers to the right of the seaport located at 0.7 are indifferent between buying from seaport two and seaport three, and will buy from seaport three since it is the closest.

### **Identifying the demands:**

$$D_1^* = \frac{P_2^* - P_1^*}{2} + \frac{3}{10} \leftrightarrow$$

$$\leftrightarrow D_1^* = \frac{3}{20}$$

$$D_2^* = \frac{P_3^* - P_2^*}{2} - \frac{P_2^* - P_1^*}{2} + \frac{3}{10} \leftrightarrow$$

$$\leftrightarrow D_2^* = \frac{11}{20}$$

$$D_3^* = \frac{P_2^* - P_3^*}{2} + \frac{4}{10} \leftrightarrow$$

$$\leftrightarrow D_3^* = \frac{c}{2} - \frac{c}{2} - \frac{1}{10} + \frac{4}{10} \leftrightarrow$$

$$\leftrightarrow D_3^* = \frac{6}{20}$$

### **Optimal Profit expression:**

$$\pi_1^* = P_1^*[D_1^*] - c[D_1^*] \leftrightarrow$$

$$\leftrightarrow \pi_1^* = \left[ c + \frac{3}{10} \right] \times \frac{3}{20} - \left[ c \times \frac{3}{20} \right] \leftrightarrow$$

$$\leftrightarrow \pi_1^* = \frac{9}{200}$$

$$\pi_2^* = P_2^*[D_2^*] - c[D_2^*] \leftrightarrow$$

$$\leftrightarrow \pi_2^* = c[D_2^*] - c[D_2^*] \leftrightarrow$$

$$\leftrightarrow \pi_2^* = 0$$

$$\pi_3^* = P_3^*[D_3^*] - c[D_3^*] \leftrightarrow$$

$$\leftrightarrow \pi_3^* = \left[ c + \frac{2}{10} \right] \times \frac{3}{10} - \left[ c \times \frac{3}{10} \right] \leftrightarrow$$

$$\leftrightarrow \pi_3^* = \frac{12}{200}$$

Since Prices, demands and profits estimated are further apart from reality, I will introduce cost asymmetry, assuming Lisbon to have a higher variable cost than the other seaports  $c_2 > c_1, c_3$  and the variable costs for Leixões and Sines to be equal  $c_1 = c_3 = c$

### **Optimal price:**

$$\begin{cases} P_1^* = \frac{P_2^* + c}{2} + \frac{3}{10} \\ P_2^* = c_2 \\ P_3^* = \frac{P_2^* + c}{2} + \frac{4}{10} \end{cases} \leftrightarrow \begin{cases} P_1^* = \frac{c + c_2}{2} + \frac{3}{10} \\ P_2^* = c_2 \\ P_3^* = \frac{c + c_2}{2} + \frac{4}{10} \end{cases}$$

### **Check for indifferent consumer's:**

$$X_{(1,2)}^* = \frac{P_2^* - P_1^*}{2} + \frac{3}{10}$$

Replacing optimal prices:

$$X_{(1,2)}^* = \frac{c_2}{4} - \frac{c}{4} + \frac{3}{20}$$

$$X_{(2,3)}^* = \frac{P_3^* - P_2^*}{2} + \frac{6}{10} \leftrightarrow$$

$$\leftrightarrow X_{(2,3)}^* = \frac{c}{4} - \frac{c_2}{4} + \frac{8}{10}$$

If  $c_2 = 1$  and  $c_1 = c_3 = 0.5$

$$X_{(1,2)}^* = 0.275$$

$$X_{(2,3)}^* = 0.675$$

$$D_1^* = \frac{11}{40}$$

$$D_2^* = \frac{16}{40}$$

$$D_3^* = \frac{13}{40}$$

**Optimal Profit expression:**

$$\pi_1^* = P_1^*[D_1^*] - c[D_1^*] \leftrightarrow$$

$$\leftrightarrow \pi_1^* = \left[ \frac{c + c_2}{2} + \frac{3}{10} \right] \times \left[ \frac{11}{40} \right] - \left[ c \times \frac{11}{40} \right] \leftrightarrow$$

$$\leftrightarrow \pi_1^* = \left[ \frac{3}{10} \times \frac{11}{40} \right] + \left[ \frac{5}{10} \times \frac{11}{40} \right] + \left[ \frac{3}{10} \times \frac{11}{40} \right] - \left[ \frac{5}{10} \times \frac{11}{40} \right] \leftrightarrow$$

$$\leftrightarrow \pi_1^* = \frac{121}{800}$$

$$\pi_2^* = P_2^*[D_2^*] - c[D_2^*] \leftrightarrow$$

$$\leftrightarrow \pi_2^* = c[D_2^*] - c[D_2^*] \leftrightarrow$$

$$\leftrightarrow \pi_2^* = 0$$

$$\pi_3^* = \left[ \frac{c + c_2}{2} + \frac{4}{10} \right] \left[ \frac{13}{40} \right] - c \left[ \frac{13}{40} \right] \leftrightarrow$$

$$\leftrightarrow \pi_3^* = \left[ \frac{4}{10} \times \frac{13}{40} \right] + \left[ \frac{5}{10} \times \frac{13}{40} \right] + \left[ \frac{4}{10} \times \frac{13}{40} \right] - \left[ \frac{5}{10} \times \frac{13}{40} \right] \leftrightarrow$$

$$\leftrightarrow \pi_3^* = \frac{169}{800}$$

When cost asymmetry exists, seaports with lower costs can obtain higher profits than in a scenario where seaports have symmetric costs.

Does seaport three have incentives to reduce price to increase profits?

By using the previous price for ( $P_3^* = \frac{c+c_2}{2} + \frac{2}{10}$ ):

$$D_3^* = \frac{c_2}{4} - \frac{c}{4} - \frac{1}{10} + \frac{4}{10} \leftrightarrow$$

$$\leftrightarrow D_3^* = \frac{17}{40}$$

$$\pi_3^* = \left[ \frac{c+c_2}{2} + \frac{2}{10} \right] \left[ \frac{17}{40} \right] - c \left[ \frac{17}{40} \right] \leftrightarrow$$

$$\leftrightarrow \pi_3^* = \left[ \frac{1}{4} \times \frac{17}{40} \right] + \left[ \frac{5}{10} \times \frac{17}{40} \right] + \left[ \frac{2}{10} \times \frac{17}{40} \right] - \left[ \frac{5}{10} \times \frac{17}{40} \right] \leftrightarrow$$

$$\leftrightarrow \pi_3^* = \frac{153}{800}$$

Sines (seaport in location 3) has no incentives to reduce prices under cost asymmetry of seaports. It seems that models where monopolistic competition exists brings the results closer to the reality values, in this case, collusion in Leixões, Lisbon operating under higher costs, forcing it to practice  $P_2^* = c_2$  and Sines with monopolistic competition. Furthermore, Leixões has been heavily developed by the installed firms, leaving Lisbon with no technology improvements, this is another fact that could be different if Lisbon was operating under the terminals ownership of a different firm from the ones operating in Leixões. This differences in quality of service may also be the reason why Lisbon is operating under higher costs<sup>16</sup>, the lack of innovation and investment in more efficient technology. If differences in quality of service are introduced in the first model I've discussed in the chapter, it can be seen how the new dynamics from differences in quality of service allow firms to exhibit higher prices when there these are acknowledged by the consumer. This might indicate that Lisbon is being used by the firms to allow Leixões to be developed creating better conditions to compete with the only foreigner firm installed in Portugal, more accurately, in Sines, and at the same time assuring that no competition arises in Lisbon from a competitor to invest in Lisbon terminals, since these are owned by the same firms. This argument makes sense with the declining demand seen in the past years for the Lisbon seaport, the current successive strikes, as well as with the

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<sup>16</sup> I mentioned in page 26 that under the influence of the same firm in different terminals that variable costs should be equal across terminals from different seaports, what I didn't mention, since no differences in quality of service were assumed in that model, was that investment in quality of service may also reduce variable costs creating non-symmetric variable costs across the sector.

Port Authority financial results for the Lisbon seaport being the only one presenting positive results close to zero and in some years even negative.

If quality of service is introduced<sup>17</sup> and variable costs non-symmetry in the first two-seaport model, the new expressions are as follows:

Optimal prices:

$$P_1^* = \frac{\gamma(s_1 - s_2) + 2c_1 + c_2 + t(2 + a_1 + a_2)}{3}$$

$$P_2^* = \frac{\gamma(s_2 - s_1) + 2c_2 + c_1 + t(4 - a_1 - a_2)}{3}$$

Optimal demands:

$$D_1^* = \frac{\gamma(s_1 - s_2) - c_1 + c_2 + t(2 + a_1 + a_2)}{6t}$$

$$D_2^* = \frac{\gamma(s_2 - s_1) - c_2 + c_1 + t(4 - a_1 - a_2)}{6t}$$

As the optimal price expression shows, the own quality of service increases the own price and the competitor quality of service reduces own optimal price.

As the optimal demand expression shows, the own quality of service increases the own demand and the competitor quality of service reduces own optimal demand.

This differences in quality of service may create differences in prices, just like we observe but notice that these differences need to be perceived for the consumer and have an impact of  $\gamma$  per unit of quality of service differences, and  $\gamma$  should take values between 0 and 1. In some cases it can be seen a huge difference in prices being practiced in Portugal for the same type of service which cannot be fully sustained by differences in quality of service.

Optimal profits:

$$\pi_1^* = \frac{\gamma^2(s_1 - s_2)^2 + t^2(2 + a_1 + a_2)^2 + \gamma(s_1 - s_2)t(2 + a_1 + a_2)}{18t} + \frac{2c_2t(2 + a_1 + a_2) - 2c_1t(2 + a_1 + a_2) + c_1^2}{18t} + \frac{c_2^2 - 2c_1c_2 + c_2\gamma(s_1 - s_2) - c_1\gamma(s_1 - s_2)}{18t}$$

$$\pi_2^* = \frac{\gamma^2(s_2 - s_1)^2 + t^2(4 - a_1 - a_2)^2 + \gamma(s_2 - s_1)t(4 - a_1 - a_2)}{18t} +$$

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<sup>17</sup> For the full demonstration see Appendix 4.

$$\frac{2c_1t(4 - a_1 - a_2) - 2c_2t(4 - a_1 - a_2) + c_2^2}{18t} + \frac{c_1^2 - 2c_2c_1 + c_1\gamma(s_2 - s_1) - c_2\gamma(s_2 - s_1)}{18t}$$

If  $c_1 = c_2 = c$  and  $s_1 = s_2 = s$ ;

$$P_1^* = \frac{3c + t(2 + a_1 + a_2)}{3}$$

$$P_2^* = \frac{3c + t(4 - a_1 - a_2)}{3}$$

$$D_1^* = \frac{2 + a_1 + a_2}{6}$$

$$D_2^* = \frac{4 - a_1 - a_2}{6}$$

$$\pi_1^* = \frac{t(2 + a_1 + a_2)^2}{18}$$

$$\pi_2^* = \frac{t(4 - a_1 - a_2)^2}{18}$$

The first model optimal price, demand and profit expressions are obtainable under the same assumptions.

## **Conclusions**

I have gone through a series of market features that currently need to be reviewed by the AMT if the sector is to improve their performance and social welfare. Firstly, the monopoly rent seeking created by the artificial reduction of competitors by allowing the same economic group to occupy several terminals is not benefiting the consumers nor the cargo handlers. This occupation of several terminals lead to a slower evolution of quality of service as the neighbour seaports are controlled by the same firms leaving container cargo vessels with no other alternatives to load/unload. This scenario is aggravated by the Spanish seaports being at capacity limit and the constant growing demand for this sector allows for the Portuguese terminal handlers to be in a favourable situation. Furthermore, this scenario allows Port authorities, which are State owned to yearly have a net earning higher than most of the Portuguese private firms operating in other sectors. Quality of service is the method for competitors to capture more freight and distinguish themselves by the competitors, mathematical proof in appendix 4. Consistent investment is required in this sector if firms want to survive the constant technology evolution from the demand side, which can be mitigated if firms control all the terminals for containers in the neighbourhood, it gives a level of confidence that no one will invest in quality of service, creating a comfortable scenario for the firms to be in, with less uncertainty and firms may ultimately operate as a monopoly for residual demands, as seen to be the case of Setúbal. Having multiple terminals increase the multi-market contact between competitors allowing for coordinated effects and the sustainability of cartels to be more easily maintained. The public procurement process needs to be more transparent and to keep in mind estimated quantities moved, as well as planned investments, instead of only considering the estimated rent offer from the private firm.

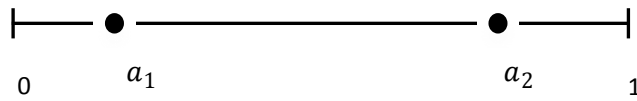
The concession period needs to be reviewed as longer periods of concession allows for the coordinated effects and the cartel agreements to hold easier. This is an important factor because Portugal have long concession periods but our neighbour country Spain is operating under even longer concession periods, which is an unfair position for the Portuguese firms to be in since they have less time to operate and plan long-term investments. I believe that the European commission needs to act in the Spanish market since they advise countries to look for concessions periods of no longer than 19 to 20 years and Spain has concession periods of 48 years. Portugal has one similar case but taking it as a new rule for the future concessions would be wrong even though Portugal faces an unfair competition with Spain on this matter.

Just like when PSA, SINES entered the market in 2004 the Portuguese market share for the container sector has been growing ever since, there might be incentives to allow other firms to enter the Portuguese market instead of having the same economic groups holding several terminals. The model that allowed to achieve a closer variable simulation to reality assumes collusion and monopolistic competition, which are models that are known to reduce the consumer surplus.

One major change for the sector that could may prove to be beneficial, would be the fusion of Lisbon and Setúbal seaports, operating under one Administrative Authority. Aside from the elimination of the double administrative costs, it has been shown that intra-port competition, or inter-port competition can create the same results in the consumer welfare if it is regulated. Therefore, having two seaports so close and with the current need to finance and invest in quality of service for the Lisbon seaport, this fusion could attract new firms to operate, creating a strong dynamism at the port. Since the available terminals count does not decrease, there is no competition reduction and it may be even easier to control whether the firms are indeed independent or if they have common interests, just like in the current structure the sector faces. Allowing Lisbon to be developed, as Leixões to the North and Sines to the South will reduce the asymmetries between seaports and terminals, making competition fair and the possibility to provide a better service to the consumer.

To finish, this thesis started with three questions; [1] understand the dynamics between competitors, [2] evaluate whether the current market structure can hurt the Portuguese government through a decrease of availability to pay rents over the concession period and lastly, [3] if terminal users are paying higher prices due to the market structure. After presenting the finding, in [1] it seems that competitors have common interests in several geographical points, hold terminals in different locations, creating multi-market contact, facilitating collusion in many ways. In [2] as was not expected, this structure does not hurt the Portuguese government, actually it benefits it by allowing Port Authorities to charge monopoly rents and allowing them to have net earnings ratios of 20% and in some cases close to 30%, remember that Port Authorities are state owned and should have as the main objective the maximization of welfare and not the profit maximization. Lastly in [3] the answer can't be 100% accurate and it can only be answered by changing the market structure, allowing more independent firms to compete and then compare present prices with the future prices. Nonetheless there are some evidences that under the given market structure, there are favourable conditions for the private owners to exhibit market power and an increase of prices.

**Appendix 1: Hotelling two-seaport model with symmetric costs**



Two seaports located at  $a_1$  and  $a_2$ ;

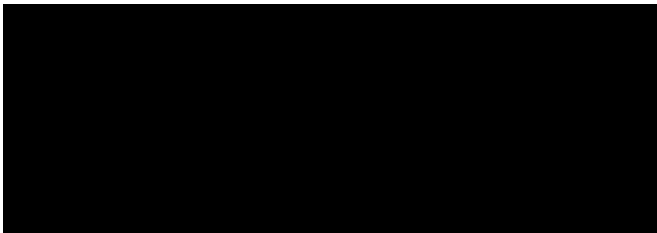
$R$  is the reservation price and is high enough to have every point of the  $[0; 1]$  line covered.

$t$  is the unitary transportation cost;

█ is the distance between indifferent consumer and seaport  $n$ ;

Costs are equal and denoted by  $c$ .

Indifferent consumer:



Demand for seaport 1:



Demand for seaport 2:

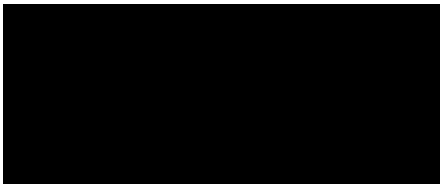


Profit maximization:



F.O.C:

$$\frac{\partial \pi_1}{\partial P_1} = 0$$

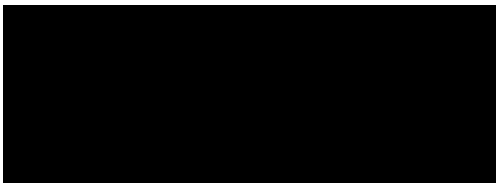


$$\text{MAX } \pi_2(P_1, P_2, a_1, a_2, c) = (P_2 - c_2) \cdot D_2$$



F.O.C:

$$\frac{\partial \pi_2}{\partial P_2} = 0$$



Finding optimal prices  $P_1^*$  and  $P_2^*$ ;



Profit for each seaport:



$$\begin{aligned} \pi_1^* &= \frac{3c + t(2 + a_1 + a_2)}{3} \left[ \frac{P_2^* - P_1^*}{2t} + \frac{a_1 + a_2}{2} \right] - c \left[ \frac{P_2^* - P_1^*}{2t} + \frac{a_1 + a_2}{2} \right] \leftrightarrow \\ &\leftrightarrow \frac{3c + t(2 + a_1 + a_2)}{3} \left[ \frac{\frac{3c + t(4 - a_1 - a_2)}{3} - \frac{3c + t(2 + a_1 + a_2)}{3}}{2t} + \frac{a_1 + a_2}{2} \right] - c \left[ \frac{\frac{3c + t(4 - a_1 - a_2)}{3} - \frac{3c + t(2 + a_1 + a_2)}{3}}{2t} + \frac{a_1 + a_2}{2} \right] \leftrightarrow \\ &\leftrightarrow \pi_1^* = \frac{t(2 + a_1 + a_2)^2}{18} \end{aligned}$$

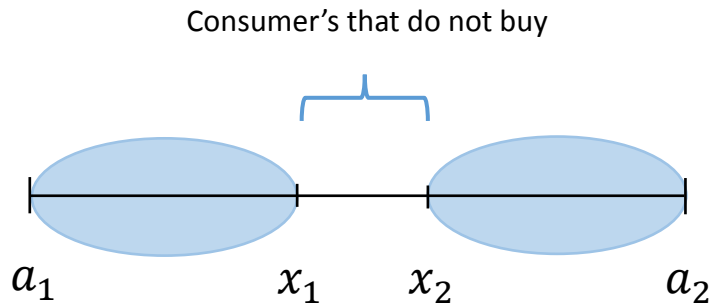
$$\pi_2^* = (P_2^* - c) \cdot D_2$$

$$\begin{aligned} \pi_2^* &= \frac{3c + t(4 - a_1 - a_2)}{3} \left[ \frac{P_1^* - P_2^*}{2t} + \frac{t(2 - a_1 - a_2)}{2} \right] - c \left[ \frac{P_1^* - P_2^*}{2t} + \frac{t(2 - a_1 - a_2)}{2} \right] \leftrightarrow \\ &\leftrightarrow \frac{3c + t(4 - a_1 - a_2)}{3} \left[ \frac{\frac{3c + t(2 + a_1 + a_2)}{3} - \frac{3c + t(4 - a_1 - a_2)}{3}}{2t} + \frac{t(2 - a_1 - a_2)}{2} \right] - c \left[ \frac{\frac{3c + t(2 + a_1 + a_2)}{3} - \frac{3c + t(4 - a_1 - a_2)}{3}}{2t} + \frac{t(2 - a_1 - a_2)}{2} \right] \end{aligned}$$

$$\pi_2^* = \frac{t(4 - a_1 - a_2)^2}{18}$$

## Appendix 2: Hotelling two-seaport model with local monopolies

Graphically we have:



Our Utility functions are given by:

$$U_{(1)} = R - t(x_1 - a_1) - P_1; \text{ Utility for buyers under seaport } a_1 \text{ niche market}$$

$$U_{(2)} = R - t(a_2 - x_2) - P_2; \text{ Utility for buyers under seaport } a_2 \text{ niche market}$$

Now that we have two monopolies operating,  $x_1$  and  $x_2$  locations will depend of travelling cost ( $t$ ) and prices  $P_1$  and  $P_2$ .  $x_1$  and  $x_2$  are the last consumer for each seaport respectively. Now we have that:

$U_{(1)}$  can be written as:

$$R - t(x_1 - a_1) - P_1 = 0 \leftrightarrow$$

$$\leftrightarrow R - tx_1 + ta_1 - P_1 = 0 \leftrightarrow$$

$$x_1 = \frac{R - P_1}{t} + a_1$$

$x_1$  is the demand for seaport located at  $a_1$ . Notice that when  $R$  increases,  $x_1$  moves to the right, meaning an increase on quantity bought, on the other side when  $P_1$  increases  $x_1$  moves to the left, we observe a decrease on quantity supplied. Lastly,  $x_1$  moves in the same direction of  $a_1$  and decreases when unitary transportation cost ( $t$ ) increases.

And;

$U_{(2)}$  can be written as:

$$R - t(a_2 - x_2) - P_2 = 0 \leftrightarrow$$

$$\leftrightarrow R - ta_2 + tx_2 - P_2 = 0 \leftrightarrow$$

$$x_2 = \frac{P_2 - R}{t} + a_2$$

Now,  $x_2$  analysis might seem confusing since we see  $x_2$  moving to the right when  $P_2$  increases, but notice that when  $x_2$  is moving to the right it is reducing quantity supplied by seaport located at  $a_2$ . Same goes for the  $R$  analysis,  $R$  is negatively impacting  $x_2$  which means, when  $R$  increases,  $x_2$  moves to the left, therefore increases quantity supplied.  $a_2$  and  $t$  analysis follow the same logic as the equivalent variables of demand for seaport located at  $a_1$ , when unitary transportation costs increase, quantity supplied decreases and when  $a_2$  moves to the right,  $x_2$  moves accordingly. Might be important to explain why does  $x_2$  moves to the right when  $t$  increases, notice that  $R$  is our reservation price, and we are considering that in order to have consumers such condition must be satisfied:  $R > P_2$ , so  $\frac{P_2 - R}{t} < 0$  and this is why  $x_2$  is moving to the right when  $t$  increases.

We now need to find optimal pricing for each seaport:

Seaport at  $a_1$ :

$$MAX \pi_1(P_1, c) = (P_1 - c)x_1$$

$$P_1 \left[ \frac{R - P_1}{t} + a_1 \right] - c \left[ \frac{R - P_1}{t} + a_1 \right]$$

F.O.C

$$\frac{\partial \pi_1}{\partial P_1} = 0 \leftrightarrow$$

$$\leftrightarrow \frac{R - 2P_1}{t} + a_1 + \frac{c}{t} = 0 \leftrightarrow$$

$$P_1 = P_1^* = \frac{R + c}{2} + \frac{ta_1}{2}$$

Now that we have  $P_1^*$  we can look for  $x_1^* = D_1^* = \frac{R - P_1^*}{t} + a_1$

$$D_1^* = \frac{R - \left[ \frac{R + c}{2} + \frac{ta_1}{2} \right]}{t} + a_1$$

$$D_1^* = \frac{R - c}{2t} + \frac{1}{2}a_1$$

Seaport at  $a_2$ :

$$\text{MAX } \pi_2(P_2, c) = (P_2 - c)(D_2)$$

$$P_2 \left[ \frac{P_2 - R}{t} + a_2 \right] - c \left[ \frac{P_2 - R}{t} + a_2 \right]$$

$$D_2 = 1 - x_2 = \frac{R - P_2}{t} + 1 - a_2$$

F.O.C

$$\frac{\partial \pi_2}{\partial P_2} = 0 \Leftrightarrow$$

$$\Leftrightarrow \frac{2P_2 - R}{t} + 1 - a_2 - \frac{c}{t} = 0 \Leftrightarrow$$

$$P_2 = \frac{R + c}{2} + \frac{t(1 - a_2)}{2}$$

$P_1$  and  $P_2$  are already our optimal monopoly prices, so we can replace them by  $P_1^*$  and  $P_2^*$  respectively.

$$P_1^* = \frac{R + c + ta_1}{2}$$

$$P_2^* = \frac{R + c + t(1 - a_2)}{2}$$

### Appendix 3: Cost limits comparison between the two previous models

Checking for costs (c) limits:

For the first model (Appendix 1) we had:

$$P_1^* = \frac{3c + t(2 + a_1 + a_2)}{3}$$

$$P_2^* = \frac{3c + t(4 - a_1 - a_2)}{3}$$

$$x_{(1,2)} = \frac{P_2^* - P_1^*}{2t} + \frac{a_1 + a_2}{2}$$

If  $a_1 = 0$  and  $a_2 = 1$  with  $t = 1$

$$P_1^* = c + 1$$

$$x_{(1,2)} = \frac{1}{2}$$

$$U_{(1)} = R - t(x_{(1,2)} - a_1) - P_1^* \leftrightarrow$$

$$\leftrightarrow R - \frac{1}{2} + 0 - c - 1 = 0 \leftrightarrow$$

$$\leftrightarrow c = R - \frac{3}{2}$$

Solving with the general expression:

$$U_{(1)} = R - t(x_{(1,2)} - a_1) - P_1^* \leftrightarrow$$

$$\leftrightarrow R - t\left(\frac{P_2^* - P_1^*}{2t} + \frac{a_1 + a_2}{2} - a_1\right) - P_1^* > 0 \leftrightarrow$$

$$\leftrightarrow R - t\left(\frac{\frac{3c + t(4 - a_1 - a_2)}{3} - \left[\frac{3c + t(2 + a_1 + a_2)}{3}\right]}{2t} + \frac{a_1 + a_2}{2} - a_1\right) - \frac{3c + t(2 + a_1 + a_2)}{3} > 0$$

$$\Leftrightarrow R > t \left( \frac{\frac{3c + t(4 - a_1 - a_2)}{3} - \left[ \frac{3c + t(2 + a_1 + a_2)}{3} \right]}{2t} + \frac{a_1 + a_2}{2} - a_1 \right) + \frac{3c + t(2 + a_1 + a_2)}{3}$$

$$\Leftrightarrow R > t \left( \frac{t(4 - a_1 - a_2) - t(2 + a_1 + a_2)}{6t} + \frac{a_1 + a_2}{2} - a_1 \right) + c + \frac{t(2 + a_1 + a_2)}{3} \Leftrightarrow$$

$$\Leftrightarrow R > t \left( \frac{2t(1 - a_1 - a_2)}{6t} + \frac{a_2 - a_1}{2} \right) + c + \frac{t(2 + a_1 + a_2)}{3} \Leftrightarrow$$

$$\Leftrightarrow R > t \left( \frac{2t(1 - a_1 - a_2) + 3t(a_2 - a_1)}{6t} \right) + c + \frac{t(2 + a_1 + a_2)}{3} \Leftrightarrow$$

$$\Leftrightarrow R > t \left( \frac{2t - 2ta_1 - 2ta_2 + 3ta_2 - 3ta_1}{6t} \right) + c + \frac{t(2 + a_1 + a_2)}{3} \Leftrightarrow$$

$$\Leftrightarrow R > t \left( \frac{2 - 5a_1 + a_2}{6} \right) + c + \frac{t(2 + a_1 + a_2)}{3} \Leftrightarrow$$

$$\Leftrightarrow R > \frac{t(2 - 5a_1 + a_2)}{6} + c + \frac{t(2 + a_1 + a_2)}{3} \Leftrightarrow$$

$$\Leftrightarrow R > \frac{t(2 - 5a_1 + a_2) + 2t(2 + a_1 + a_2)}{6} + c \Leftrightarrow$$

$$\Leftrightarrow R > \frac{6t - 3ta_1 + 3ta_2}{6} + c \Leftrightarrow$$

$$\Leftrightarrow R > t + \frac{t(a_2 - a_1)}{2} + c \Leftrightarrow$$

$$\Leftrightarrow c < R - t - \frac{t(a_2 - a_1)}{2}$$

Our general function when replaced by the above case where  $a_1 = 0$  and  $a_2 = 1$  with  $t = 1$ , we get the same result.

The following expressions for  $c$  means that  $c$  can increase up to that value:

$$c < R - t - \frac{t(a_2 - a_1)}{2}$$

If

$c > R - t - \frac{t(a_2 - a_1)}{2}$  Demand is 0.

Now for the second model (Appendix 2) we had:

$$P_1^* = \frac{R + c + ta_1}{2}$$

$$D_1^* = \frac{R - c}{2t} + \frac{1}{2}a_1$$

If  $a_1 = 0$  and with  $t = 1$

$$P_1^* = \frac{R + c}{2}$$

$$D_1^* = \frac{R - c}{2}$$

Replacing in our utility function:

$$U_{(1)} = R - t(x_1^* - a_1) - P_1^* \leftrightarrow$$

$$\leftrightarrow R = \left[ \frac{R + c}{2} \right] + x_1^* \leftrightarrow$$

$$\leftrightarrow \frac{R}{2} = x_1^* + \frac{c}{2} \leftrightarrow$$

$$\leftrightarrow R = 2x_1^* + c \leftrightarrow$$

$$\leftrightarrow R = 2 \left[ \frac{R - c}{2} \right] + c$$

$$U_{(1)} = 0$$

In a monopoly consumer surplus is always 0, there is a full extraction of the consumer surplus. Although consumer surplus is zero, consumer's only buy up to the point where  $R = P_1^* + t(x_1^* - a_1)$  if  $R < P_1^* + t(x_1^* - a_1)$  demand is zero and if  $R = P_1^* + t(x_1^* - a_1)$  utility is zero.

General expression:

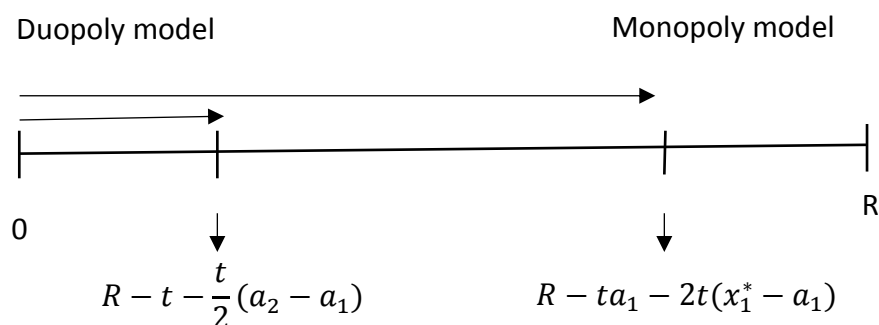
$$\begin{aligned}
 R &= \frac{R + c + ta_1}{2} + t(x_1^* - a_1) \leftrightarrow \\
 \leftrightarrow R - \frac{1}{2}R &= \frac{c + ta_1}{2} + t[x_1^* - a_1] \leftrightarrow \\
 \leftrightarrow \frac{1}{2}R &= \frac{c + ta_1}{2} - t[x_1^* - a_1] \leftrightarrow \\
 \leftrightarrow R &= c + ta_1 + 2t[x_1^* + a_1] \leftrightarrow \\
 \leftrightarrow R &= c + ta_1 + 2t\left[\frac{R - c}{2t} + \frac{1}{2}a_1\right] - 2ta_1 \leftrightarrow \\
 \leftrightarrow R &= c + ta_1 - R - c + ta_1 - 2ta_1 \leftrightarrow \\
 \leftrightarrow 0
 \end{aligned}$$

So what is the c value? The cost value can increase up to this point:

$$\begin{aligned}
 R &> P_1^* + t(x_1^* - a_1) \leftrightarrow \\
 \leftrightarrow R &> \frac{R + c + ta_1}{2} + t(x_1^* - a_1) \leftrightarrow \\
 \leftrightarrow c &< R - ta_1 - \frac{t}{2}(x_1^* - a_1)
 \end{aligned}$$

The cost value  $c \in (0, R)$  if transportation costs are zero ( $t = 0$ ), when  $c = R$  our only consumer is the one that don't have to move, in other words the one at the same location as  $a_1$  ( $a_1 = x_1$ ).

Graphically we have that:



In a Monopoly model the range for cost inefficiency increases.

#### **Appendix 4: Two-seaport model with non-symmetric variable costs and quality of service**

2 seaports Model with non-symmetric quality of service and positive and different variable costs.

The same model as in appendix 1 adding the following:

$s$  is representing the quality of service of seaports and it goes into the utility function as a variable that is increasing the utility,  $\gamma$  is a coefficient of the quality of service, it is linked with consumer's perspective and value for the quality of the given seaport.

I am assuming that  $\gamma > 0$  and  $\gamma s > 0$

General expression of the indifferent consumer for this model:

$$U_{X_{(n-1,n)}} \leftrightarrow R - t(X_{(n-1,n)} - a_{n-1}) - P_{n-1} + \gamma s_{n-1} = R - t(a_n - X_{(n-1,n)}) - P_n + \gamma s_n$$

Indifferent consumer between seaport 1 and 2 expression:

$$U_{X_{(1,2)}}(1) = U_{X_{(1,2)}}(2)$$

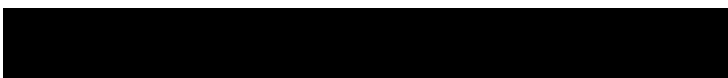
$$R - t(X_{(1,2)} - a_1) - P_1 + \gamma s_1 = R - t(a_2 - X_{(1,2)}) - P_2 + \gamma s_2$$

$$X_{(1,2)} = \frac{P_2 - P_1 - \gamma(s_2 - s_1)}{2t} + \frac{a_1 + a_2}{2}$$

Demand for seaport 1:



Demand for seaport 2:

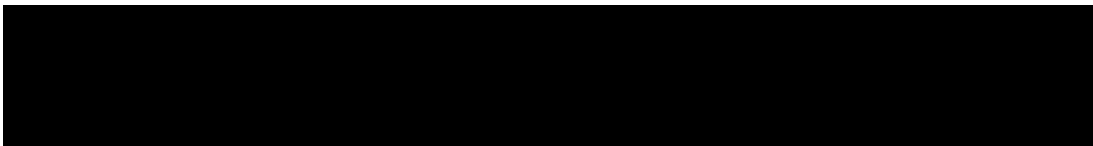
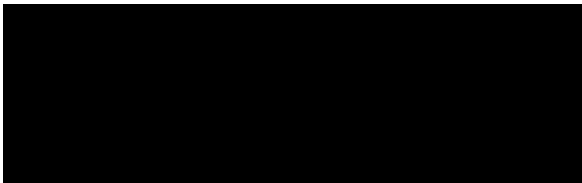


Profit maximization:



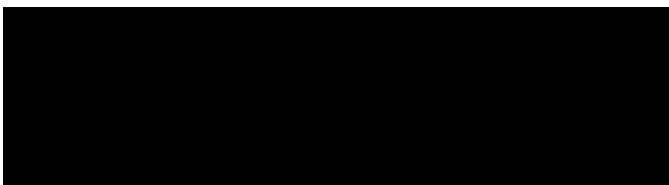
F.O.C:


$$\frac{\partial \pi_1}{\partial P_1} = 0$$

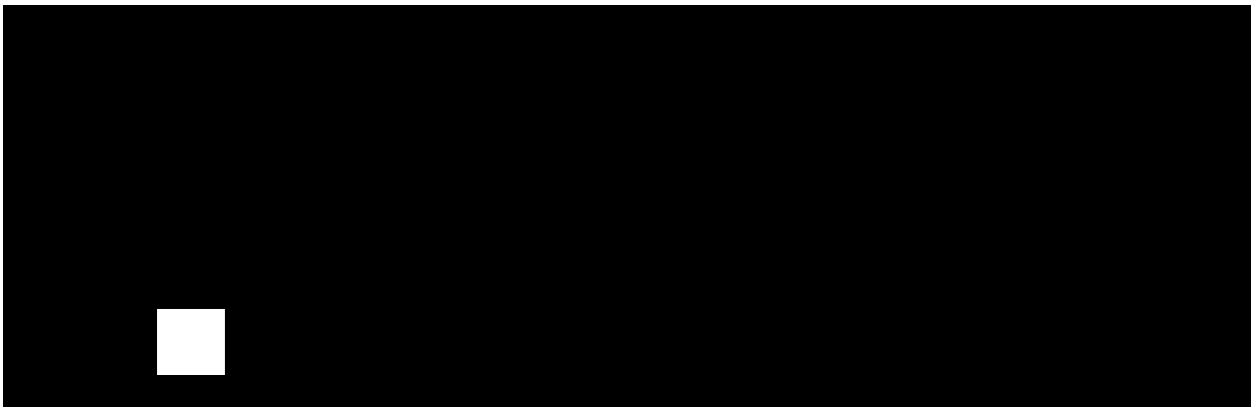


F.O.C:

$$\frac{\partial \pi_2}{\partial P_2} = 0$$

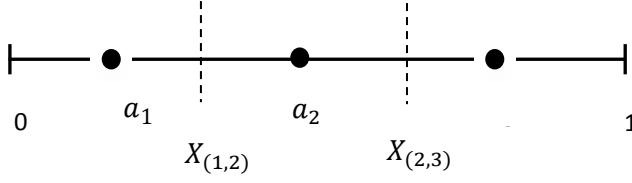


Finding optimal prices ;





## Appendix 5: Three-seaport model with non-symmetric costs



Utility expressions for consumers that travel for each seaport:

$$U_{(1)} = R - t(X_{(1,2)} - a_1) - P_1; \text{ Utility from buying at seaport } a_1$$

$$U_{(3)} = R - t(a_3 - X_{(1,2)}) - P_3; \text{ Utility from buying at seaport } a_2$$

$$U_{(2)} \begin{cases} R - t(a_2 - X_{(1,2)}) - P_2 & \text{if } a_2 > X_i; \text{ if consumer is to the left of seaport } a_2 \\ R - t(X_{(2,3)} - a_2) - P_2 & \text{if } a_2 < X_i; \text{ if consumer is to the right of seaport } a_2 \end{cases}$$

$X_i$  is the  $i^{th}$  consumer located along the  $[0,1]$  line;

Now to derive  $X_{(1,2)}$  and  $X_{(2,3)}$  which are the indifferent consumers of this model:

$$X_{(1,2)} \leftrightarrow U_{(1)} = U_{(2)} \leftrightarrow$$

$$\leftrightarrow R - t(X_{(1,2)} - a_1) - P_1 = R - t(a_2 - X_{(1,2)}) - P_2 \leftrightarrow$$

$$\leftrightarrow X_{(1,2)} = \frac{P_2 - P_1}{2t} + \frac{a_1 + a_2}{2}$$

$$X_{(2,3)} \leftrightarrow U_{(2)} = U_{(3)} \leftrightarrow$$

$$\leftrightarrow R - t(X_{(2,3)} - a_2) - P_2 = R - t(a_3 - X_{(1,2)}) - P_3 \leftrightarrow$$

$$\leftrightarrow X_{(2,3)} = \frac{P_3 - P_2}{2t} + \frac{a_2 + a_3}{2}$$

From these utility functions and indifferent consumers, we can derive all demands:

$$D_1 = X_{(1,2)} \leftrightarrow$$

$$\leftrightarrow D_1 = \frac{P_2 - P_1}{2t} + \frac{a_1 + a_2}{2}$$

$$D_2 = \frac{P_3 - P_2}{2t} - \frac{P_2 - P_1}{2t} + \frac{a_3 - a_1}{2}$$

$$D_3 = 1 - X_{(2,3)} \leftrightarrow$$

$$\leftrightarrow D_3 = \frac{P_2 - P_3}{2t} + \frac{2 - a_2 - a_3}{2}$$

If we assume that prices are equal,  $P_1 = P_2 = P_3 = P$  our demand functions become:

$$D_1 = \frac{a_1 + a_2}{2}$$

$$D_2 = \frac{a_3 - a_1}{2}$$

$$D_3 = \frac{2 - a_2 - a_3}{2}$$

With,  $a_1 = 0$ ,  $a_2 = \frac{1}{2}$  and  $a_3 = 1$

$$D_1 = \frac{1}{4}$$

$$D_2 = \frac{1}{2}$$

$$D_3 = \frac{1}{4}$$

When prices are equal and we consider the location to be a strategic variable, the first impression would be that demands would also be equal, but this is not the case. Demands are not equal along seaports; this is because the centre seaport is better positioned than the seaports on the extremes of the  $[0; 1]$  line. As the seaports located on the extremes start moving to the centre,  $D_2$  starts to go down as the other demands  $D_1$  and  $D_3$  start going up, this is due to the fact that seaports that once were on the extremes dislocated to a closer location of the centre and the influential zone of the centre seaports becomes smaller and smaller. The following variable demonstrates this reasoning:

Proof:

$$\text{If, } a_1 = \frac{1}{4}, a_2 = \frac{1}{2} \text{ and } a_3 = \frac{3}{4}$$

$$D_1 = 0.375$$

$$D_2 = \frac{1}{4}$$

$$D_3 = 0.375$$

As the extreme seaports dislocated to the quartiles,  $D_2$  was reduced by half and  $D_1$  and  $D_3$  increased by the same relative proportion. Lastly let us confirm that demands are concave and that terminals have an incentive to reduce prices in order to capture higher demands:

$$\frac{\partial D_1}{\partial P_1} = -\frac{1}{2t}$$

$$\frac{\partial D_2}{\partial P_2} = -\frac{2}{2t}$$

$$\frac{\partial D_3}{\partial P_3} = -\frac{1}{2t}$$

From the above result, it can be seen that the derivative of the demand with respect to prices of the respective seaport is negative, so we conclude that seaport demands are concave with respect to prices and thus, seaports have incentives to decrease prices to capture higher demands.

Profit expression functions:

$$\pi_1 = (P_1 - c_1) \cdot D_1 \leftrightarrow$$

$$\leftrightarrow \pi_1 = P_1 \left[ \frac{P_2 - P_1}{2t} + \frac{a_1 + a_2}{2} \right] - c_1 \left[ \frac{P_2 - P_1}{2t} + \frac{a_1 + a_2}{2} \right]$$

$$\pi_2 = (P_2 - c_2) \cdot D_2 \leftrightarrow$$

$$\leftrightarrow \pi_2 = P_2 \left[ \frac{P_3 - P_2}{2t} - \frac{P_2 - P_1}{2t} + \frac{a_3 - a_1}{2} \right] - c_2 \left[ \frac{P_3 - P_2}{2t} - \frac{P_2 - P_1}{2t} + \frac{a_3 - a_1}{2} \right]$$

$$\pi_3 = (P_3 - c_3) \cdot D_3 \leftrightarrow$$

$$\leftrightarrow \pi_3 = P_3 \left[ \frac{P_2 - P_3}{2t} + \frac{2 - a_2 - a_3}{2} \right] - c_3 \left[ \frac{P_2 - P_3}{2t} + \frac{2 - a_2 - a_3}{2} \right]$$

Let us take the first order conditions:

$$MAX \pi_1(P_1, P_2, a_1, a_2, t, c_1) = P_1 \left[ \frac{P_2 - P_1}{2t} + \frac{a_1 + a_2}{2} \right] - c_1 \left[ \frac{P_2 - P_1}{2t} + \frac{a_1 + a_2}{2} \right] \leftrightarrow$$

$$\leftrightarrow \frac{\partial \pi_1}{\partial P_1} \leftrightarrow \frac{P_2 - 2P_1}{2t} + \frac{a_1 + a_2}{2} + \frac{c_1}{2t} = 0 \leftrightarrow$$

$$P_1 = \frac{P_2 + c_1}{2} + \frac{t(a_1 + a_2)}{2}$$

$$MAX \pi_2(P_2, P_1, a_2, a_1, t, c_2) = P_2 \left[ \frac{P_3 - P_2}{2t} - \frac{P_2 - P_1}{2t} + \frac{a_3 - a_1}{2} \right] - c_2 \left[ \frac{P_3 - P_2}{2t} - \frac{P_2 - P_1}{2t} + \frac{a_3 - a_1}{2} \right] \leftrightarrow$$

$$\leftrightarrow \frac{\partial \pi_2}{\partial P_2} \leftrightarrow \frac{P_3 - 4P_2 + P_1}{2t} + \frac{a_3 - a_1}{2} + \frac{2c_2}{2t} \leftrightarrow$$

$$\leftrightarrow P_2 = \frac{P_1 + P_3 + 2c_2}{4} + \frac{t(a_3 - a_1)}{4}$$

$$\begin{aligned}
MAX \pi_3(P_3, P_2, a_3, a_2, t, c_3) &= P_3 \left[ \frac{P_2 - P_3}{2t} + \frac{2 - a_2 - a_3}{2} \right] - c_3 \left[ \frac{P_2 - P_3}{2t} + \frac{2 - a_2 - a_3}{2} \right] \leftrightarrow \\
\leftrightarrow \frac{\partial \pi_3}{\partial P_3} = 0 &\leftrightarrow \frac{P_2 - 2P_3}{2t} + \frac{2 - a_2 - a_3}{2} + \frac{c_3}{2t} = 0 \leftrightarrow \\
\leftrightarrow P_3 &= \frac{P_2 + c_3}{2} + \frac{t(2 - a_2 - a_3)}{2}
\end{aligned}$$

Now for the optimal pricing  $P_i^*$  seaports will act as they knew what their price functions were and will replace them by its true values:

$$\begin{aligned}
&\left\{ \begin{aligned} P_1^* &= \frac{P_2^* + c_1}{2} + \frac{t(a_1 + a_2)}{2} \\ P_2^* &= \frac{P_1^* + P_3^* + 2c_2}{4} + \frac{t(a_3 - a_1)}{4} \\ P_3^* &= \frac{P_2^* + c_3}{2} + \frac{t(2 - a_2 - a_3)}{2} \end{aligned} \right\} \leftrightarrow \left\{ \begin{aligned} P_2^* &= \frac{P_2^* + c_1}{8} + \frac{t}{8}(a_1 + a_2) + \frac{P_3^* + 2c_2}{4} + \frac{t}{4}(a_3 - a_1) \end{aligned} \right\} \leftrightarrow \\
&\leftrightarrow \left\{ \begin{aligned} \frac{7P_2^*}{8} &= \frac{2P_3^* + 4c_2 + c_1}{8} + \frac{t}{8}(a_2 + 2a_3 - a_1) \end{aligned} \right\} \leftrightarrow \\
&\leftrightarrow \left\{ \begin{aligned} P_2^* &= \frac{2P_3^* + 4c_2 + c_1}{7} + \frac{t}{7}(a_2 + 2a_3 - a_1) \end{aligned} \right\} \leftrightarrow \\
&\leftrightarrow \left\{ \begin{aligned} P_3^* &= \frac{2P_3^* + 4c_2 + c_1}{14} + \frac{t}{14}(a_2 + 2a_3 - a_1) + \frac{c_3}{2} + \frac{t}{2}(2 - a_2 - a_3) \end{aligned} \right\} \leftrightarrow \\
&\leftrightarrow \left\{ \begin{aligned} \frac{12P_3^*}{14} &= \frac{4c_2 + c_1 + 7c_3}{14} + \frac{t}{14}(14 - 6a_2 - 5a_3 - a_1) \end{aligned} \right\} \leftrightarrow \\
&\leftrightarrow \left\{ \begin{aligned} P_3^* &= \frac{4c_2 + c_1 + 7c_3}{12} + \frac{t}{12}(14 - 6a_2 - 5a_3 - a_1) \end{aligned} \right\} \leftrightarrow \\
&\leftrightarrow \left\{ \begin{aligned} P_2^* &= \frac{56c_2 + 14c_1 + 14c_3}{84} + \frac{t}{84}(28 - 12a_2 - 10a_3 - 2a_1) + \frac{4c_2 + c_1}{7} + \frac{t}{7}(a_2 + 2a_3 - a_1) \end{aligned} \right\} \leftrightarrow \\
&\leftrightarrow \left\{ \begin{aligned} P_2^* &= \frac{56c_2 + 14c_1 + 14c_3}{84} + \frac{t}{84}(28 + 14a_1 - 14a_3) \end{aligned} \right\} \leftrightarrow \\
&\leftrightarrow \left\{ \begin{aligned} P_1^* &= \frac{56c_2 + 14c_1 + 14c_3}{168} + \frac{t}{168}(28 + 14a_3 - 14a_1) + \frac{c_1}{2} + \frac{t}{2}(a_1 + a_2) \end{aligned} \right\} \leftrightarrow
\end{aligned}$$

$$\leftrightarrow \left\{ \begin{array}{l} P_1^* = \frac{98c_1 + 56c_2 + 14c_3}{168} + \frac{t}{168}(28 + 70a_1 + 84a_2 + 14a_3) \leftrightarrow \\ \text{-----} \\ \text{-----} \end{array} \right.$$

$$\leftrightarrow \left\{ \begin{array}{l} P_1^* = \frac{7c_1 + 4c_2 + c_3}{12} + \frac{t}{12}(2 + 5a_1 + 6a_2 + a_3) \\ P_2^* = \frac{8c_2 + 2c_1 + 2c_3}{12} + \frac{t}{12}(4 + 2a_3 - 2a_1) \\ P_3^* = \frac{7c_3 + 4c_2 + c_1}{12} + \frac{t}{12}(14 - 6a_2 - 5a_3 - a_1) \end{array} \right.$$

**Replacing optimal prices in seaports demand function:**

$$D_1^* = \frac{P_2^* - P_1^*}{2t} + \frac{a_1 + a_2}{2} \leftrightarrow$$

$$\leftrightarrow D_1^* = \frac{\frac{8c_2 + 2c_1 + 2c_3}{12} + \frac{t}{12}(4 + 2a_3 - 2a_1)}{2t} - \left[ \frac{\frac{7c_1 + 4c_2 + c_3}{12} + \frac{t}{12}(2 + 5a_1 + 6a_2 + a_3)}{2t} \right] + \frac{a_1 + a_2}{2} \leftrightarrow$$

$$\leftrightarrow D_1^* = \frac{c_3 + 4c_2 - 5c_1}{24t} + \frac{1}{24}(2 + 5a_1 + 6a_2 + a_3)$$

$$D_2^* = \frac{P_3^* - P_2^*}{2t} - \frac{P_2^* - P_1^*}{2t} + \frac{a_3 - a_1}{2} \leftrightarrow$$

$$\leftrightarrow D_2^* = \frac{\frac{7c_3 + 4c_2 + c_1}{12} + \frac{t}{12}(14 - 6a_2 - 5a_3 - a_1)}{2t} - \left[ \frac{\frac{8c_2 + 2c_1 + 2c_3}{12} + \frac{t}{12}(4 + 2a_3 - 2a_1)}{2t} \right] - \frac{P_2^* - P_1^*}{2t} + \frac{a_3 - a_1}{2} \leftrightarrow$$

$$\leftrightarrow D_2^* = \frac{5c_3 - 4c_2 - c_1}{24t} + \frac{1}{24}(10 - 7a_3 - 6a_2 + a_1) - \frac{P_2^* - P_1^*}{2t} + \frac{a_3 - a_1}{2} \leftrightarrow$$

$$\leftrightarrow D_2^* = \frac{4c_3 + 4c_1 - 8c_2}{24t} + \frac{1}{24}(8 + 4a_3 - 4a_1)$$

$$D_3^* = \frac{P_2^* - P_3^*}{2t} + \frac{2 - a_1 - a_2}{2} \leftrightarrow$$

$$\leftrightarrow D_3^* = \frac{\frac{8c_2 + 2c_1 + 2c_3}{12} + \frac{t}{12}(4 + 2a_3 - 2a_1)}{2t} - \left[ \frac{\frac{7c_3 + 4c_2 + c_1}{12} + \frac{t}{12}(14 - 6a_2 - 5a_3 - a_1)}{2t} \right] + \frac{2 - a_1 - a_2}{2} \leftrightarrow$$

$$D_3^* = \frac{4c_2 + c_1 - 5c_3}{24t} + \frac{1}{24}(14 - 5a_3 - 6a_2 - a_1)$$

Now if we assume costs to be equal  $c_1 = c_2 = c_3 = c$  and standard locations  $a_1 = 0$ ;  $a_2 = \frac{1}{2}$  and  $a_3 = 1$ , replacing in the demand functions, we get:  $D_1^* = 0.25$ ;  $D_2^* = 0.5$  and  $D_3^* = 0.25$ .

### **Optimal profit expression for seaport 1**

If  $c_1 = c_2 = c_3 = c$

$$\pi_1^* = \frac{t}{288} (2 + 5a_1 + 6a_2 + a_3)^2$$

With this condition, I can compare the optimal profit expression with the one from Appendix 1.

### **Comparing optimal profit expression for two and three competitors**

From appendix 1,

$$\pi_1^* = \frac{t(2 + a_1 + a_2)^2}{18}$$

Replacing in both expressions by the same value for each variable; let's assume  $t = 1$ ,  $a_1 = 0.2$ ,  $a_2 = 0.75$  and  $a_3 = 0.5$

### **For the two-seaport model profit expression**

$$\pi_1^* = \frac{t(2 + a_1 + a_2)^2}{18} \leftrightarrow$$

$$\leftrightarrow \pi_1^* = \frac{1}{18} (2 + 0.2 + 0.75)^2 \leftrightarrow$$

$$\leftrightarrow \pi_1^* = \frac{3481}{7200}$$

### **For the Three-seaport model profit expression**

$$\pi_1^* = \frac{t}{288} (2 + 5a_1 + 6a_2 + a_3)^2 \leftrightarrow$$

$$\leftrightarrow \pi_1^* = \frac{t}{288} (2 + 1 + 3 + 0.75)^2 \leftrightarrow$$

$$\leftrightarrow \pi_1^* = \frac{2025}{12800}$$

Notice that for the second expression I replaced  $a_2$  for the value assumed by  $a_3$ , this was because I introduced  $a_3$  with a value that is between  $a_1$  and  $a_2$ , so in the order meet the right dynamics of the optimal profit expression, the adjustment had to be made, although it does not affect the veracity of the argument. If for instance  $a_3$  was to take a value higher than 0.75, the argument would still be true. So, the conclusion is that as the number of competitors increase, the profits decrease.

## **References**

Autoridade da Mobilidade e Transportes, “Acompanhamento dos mercados portuários”, relatório de novembro (2015): 1-13.

Autoridade da Mobilidade e Transportes, “Regulação da Mobilidade e Transportes”, Pronúncia Nº6 (2016).

D’Aspremont, Claude., et al., “On Hotelling’s “stability in competition””, *Econometrica*, 47-5 (1979): 1145-1150.

Hotelling, Harold., “Stability in competition”, *Economic Journal*, 39 (1929): 41-57.

IEVA, grupo de trabalho para as infraestruturas de elevado valor acrescentado “Relatório final” (2014): 65-104, 196-223.

Marques, Rui Cunha., Fonseca, Álvaro., “Market structure, privatisation and regulation of Portuguese seaports”, *Maritime Policy & Management: The flagship journal of international shipping and port research*, 37-2 (2010): 145-161.

Notteboom, Theo E., “Concentration and the formation of multi-port gateway regions in the European container port system: an update”, *Journal of Transport geography*, 18 (2010): 567-583.

Notteboom, Theo., Kaselimi, Vicky., “The value of opening terminals to private operators” *Port Technology International*, 55 (2012): 12-13

Sánchez, Ricardo J., Wilsmeier, Gordon., “Maritime sector and ports in the Caribbean: the case of CARICOM countries”, *Natural resource and infrastructure division, UNCTAD* (2009): 23-34.

Silva, José Amado., Cardadeiro, Eduardo., d’Alte, Tiago Souza., “Revisão do modelo contratual e mecanismos de regulação do setor portuário”, relatório final, *Universidade Autónoma de Lisboa* (2013): 12-80.

Tirole, Jean., Ivaldi, Marc., Jullien, Bruno., Rey, Patrick., Seabright, Paul., “The economics of tacit collusion”, *Final report for DG competition, European commission* (2003).

Zhou, Xin. “Competition or cooperation: a simulation of the price strategy of ports”, *International journal of simulation model*, 14-4 (2015): 463-474.

Danger, Ken., Capobianco, Antonio., “Guidelines for fighting bid rigging in public procurement”, *OECD, Competition – The key to productivity and growth* (2012).

Zhan. James., “How to utilize FDI to improve transport infrastructure – ports: Lessons from Nigeria”, *UNCTAD, Investment Advisory Series B-9* (2011): 20-46.

Langen, Peter., Pallis, Athanasios., “Analysis of the benefits of intra-port competition” (2005).

Meersman, Hilde., Van de Voorde, Eddy., Vanelslender, Thierry., “Port competition revisited”, *Review of Business and Economic Literature*, 55-2 (2010): 210-233.

Reeven, Peran., "The effect of competition on Economic rents in seaports", *Journal of transport economics and policy*, 44-1 (2010): 79-92.