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Performance Analysis of Port Companies

Study case: Annaba and Quebec Ports

Realized by

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Dedication

In the name of Allah, the Most Merciful and the Most Gracious,

First of all, I would like to extend my heartfelt appreciation to my beloved parents, my brother, family, and friends, whose unwavering support and encouragement have been a constant source of strength. Your love, prayers, and belief in me have propelled me forward and given me the confidence to pursue my dreams,

To all the mentors, teachers, and colleagues who have played a pivotal role in shaping my professional growth, I am truly grateful for your wisdom, guidance, and expertise. Your invaluable contributions have helped me develop new skills, expand my knowledge, and overcome challenges along the way.

Lastly, I acknowledge the countless blessings and opportunities that have come my way, and I humbly pray that my work and efforts serve as a means to make a positive impact on others and contribute to the betterment of society,

Thanks.

- *Selma*

Dedication

I dedicate this work to:

To my mother Assia and my father Hocine.You are a source of life, love and happiness for me, because without your sacrifices, your tenderness and your affection I could not reach the end, may God grant you happiness and long life,

To my grandmother Mimi, rest in peace with all my eternal love,

To my sisters Ikram, Sara, and Chahinez,

To all my beloved family,

To all my friends and relatives who have supported me,

Last but not least,to my partner Selma,

- Hadjer

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ملخص

يعتبر تطوير وتحديث الموانئ البحرية من أبرز اهتمامات سلطات الموانئ ولتحسين لوجستيات الموانئ، أُجريت مقارنة للكفاءة التقنية بين المحطات في مينائي عنابة في الجزائر وكيبيك في كندا، باستخدام منهجي تحليل الحدود العشوائية وتحليل مغلف البيانات على مجموعة من المؤشرات على مدى سنتين. وتظهر النتائج أن متوسط درجات الكفاءة الفنية يتراوح بين 53% و63% لنموذج التحليل الحدودي العشوائي، وبالنسبة لنموذج تحليل مغلف البيانات فإن معدل ثبات العائد إلى السعة للميناءين متقارب جدا حيث يبلغ حوالي 0.19 ومعدل تغير العائد إلى السعة لميناء عنابة 0.87 و 0.98 لميناء كيبيك. ويعتبر كل من الميناءين غير فعالين بسبب تعقيد أنشطة الموانئ وعدم انتظام سوق النقل.

الكلمات المفتاحية: الكفاءة الفنية، التحليل العشوائي، التحليل غير البارامتري، الموانئ البحرية، محطات الموانئ، تحليل الحدود العشوائية، تحليل مغلف البيانات.

Abstract

The development and modernisation of maritime ports are major concerns for port authorities. To improve port logistics, a comparison of technical efficiency between terminals in the ports of Annaba in Algeria and Quebec in Canada was carried out, using the SFA and DEA methods over a two-year period. The results show that the average technical efficiency scores vary between 53% and 63% for the SFA model, and for the DEA model, the CRS scores are close to 19.0 and the VRS scores are 87.0 for Annaba and 98.0 for Quebec. Both ports are considered inefficient due to the complexity of port activities and the irregularity of the transport market.

Keywords: Technical efficiency, stochastic analysis, non-parametric analysis, maritime ports, port terminals, SFA, DEA.

Résumé

Le développement et la modernisation des ports maritimes sont des préoccupations majeures des autorités portuaires. Pour améliorer la logistique portuaire, une comparaison de l'efficience technique entre les terminaux des ports d'Annaba en Algérie et de Québec au Canada a été réalisée, utilisant les méthodes SFA et DEA sur une période de deux ans. Les résultats montrent que les scores moyens d'efficience technique varient entre 53% et 63% pour le modèle SFA, et pour le modèle DEA, les scores CRS sont proches de 0,19 et les scores VRS sont de 0,87 pour Annaba et de 0,98 pour Québec. Les deux ports sont jugés inefficients en raison de la complexité des activités portuaires et de l'irrégularité du marché du transport.

Mots Clés : Efficience technique, analyse stochastique, analyse non parametrique, terminaux portuaires, SFA, DEA.

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List of Abbreviations

IMT : International Monetary Fund.

USD : United States Dollar.

MSC : Mediterranean Shipping Company.

COSCO : China Ocean Shipping Company.

GDP : Gross Domestic Product.

HDI : Human Development Index.

EPAN : ANNABA Port Company.

JSC : Joint-Stock Company (SPA).

DZD : Algerian Dinar.

SERPORT : Prt Services Group.

EPE : Public Economic Enterprise.

RO-RO : Roll-on/Roll-off.

DWT : Deadweight Tonnage.

M.O.T.S : Engines, Vehicles and Tractors.

STQ : Quebec Ferry Society.

DEA : Data Envelopment Analysis.

SFA : Stochastic Frontier Analysis.

PTE : Pure Technical Efficiency.

SE : Scale Efficiency.

CRS : Constant Return to Scale.

VRS : Variable Returns to Scale.

DMU : Decision Making Units.

BCC : Banker–Charnes–Cooper.

CCR : Charnes–Cooper–Rhodes.

IRS : Increasing Returns to Scale.

General Introduction

Today, ports play a key role in global supply chains. The development and modernization of seaports have become a key concern for port authorities.

This situation has led many companies to expand their geographical reach and activities. By 2023, according to TradeMap, Algerian exports reached 68.4 billion USD. Hydrocarbons account for 89.8% of total exports. The rest of the country's exports are made up of derivatives from the oil and gas industries (fertilizers, ammonia and oils from the distillation of tar) and agri-food products (dates, sugar), most of which are shipped by sea.

This development in international trade requires new strategies to create more favorable conditions than those offered by competitors in terms of port logistics. To achieve this, the Algerian port authorities, particularly the port of Annaba, have embarked on a quality approach (Quality Management System) based on continuous performance measurements of the best value for money. It is in this sense that this work is part of an approach that can better see the potential for improving port logistics by analyzing foreign and local port performance. The idea is to compare performance, and more particularly technical efficiency, between terminals located in two different regions: the first in Annaba, Algeria, and the second in Quebec, Canada.

Based on DEA (Data Envelopment Analysis) methods, which enable us to construct a frontier of efficiency for the best-performing port terminals, In contrast, the parametric stochastic frontier approach (SFA) addresses deviations from best practice involving statistical tests; we targeted seven terminals in Annaba and six terminals in Quebec to assess tonnage handled, loading time, number of ships handled, and terminal length over a two-year period for both ports.

The aim of this work is to respond to the problem raised by the management of the port of Annaba. Therefore, our attempt in this work is to answer the following question:

- How can port terminal performance be measured?

To clarify this issue, we proposed the following subquestions:

- How can the technical efficiency of ports be assessed?
- What types of inefficiency are seen at the port level?

In order to complete our end-of-study project, we divided the work into four chapters.

The first chapter will be devoted to a presentation of the world maritime transport market and the two ports, Port Annaba, Algeria, and Port Quebec, Canada. We close the chapter with a presentation of the activities and terminals of the two regions studied, the subject of our study.

The second chapter will be devoted to the presentation of the various notions of performance in general and technical efficiency in particular.

The third chapter will consist of developing the SFA (Stochastic Frontier Analysis) and DEA (Data Envelopment Analysis) methods to solve the problem of measuring the technical efficiency of the ports involved in the study.

The fourth chapter will be devoted to the results obtained by the two methods by means of descriptive statistics of the data collected at the level of the two ports, a categorization of the inputs and outputs with three explanatory criteria for an estimation of the stochastic production frontier represented, and on the basis of the frontier curve obtained, we will discuss our results.

Chapter 1

Study Area

Introduction

Maritime industry plays a crucial role in supporting the global trade ecosystem, serving as a primary mode of transportation for goods internationally. Shipping facilitates international trade by connecting global markets, fostering economic growth, and ensuring a smooth transportation of goods.

Maritime transport has long been at the heart of international trade, and is considered by governments to be a strategic sector of national power. In this respect, the sea is the safest, most widely used and most efficient mode of transport. It plays an important role in opening up and bringing regions and countries closer together. Indeed, maritime transport is the mode that dominates world trade in goods, and one of the main drivers of globalization.
In this chapter, we present a general overview of maritime transport and the different types of maritime markets, as well as a distinction between the port activities and players in the two regions - Annaba port (Algeria) and Quebec port (Canada).

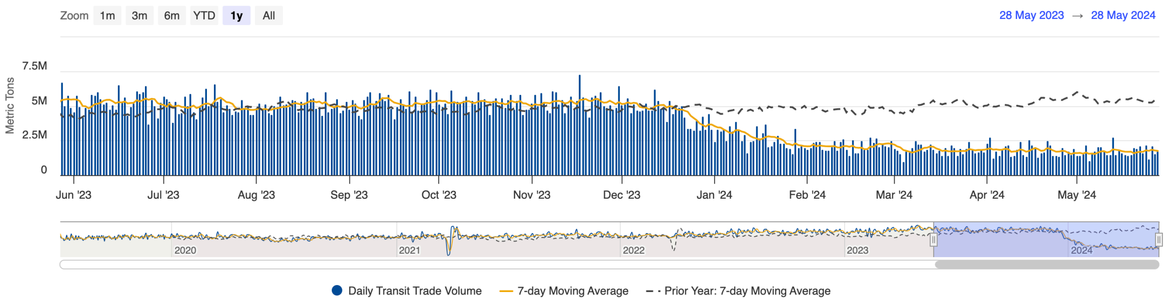
1.1 Generalities of Maritime Transport

Maritime transport is the oldest mode of transport; it grows faster than other modes. Since the 1960s, a new market for transport by sea has developed, that of maritime transport, whose development is closely linked to that of international trade. It remains by far the main mode of transport in the world, being both the least expensive and the best suited to heavy and bulky goods and products, such as cereals, hydrocarbons, fruit, etc. [2]

As the backbone of international trade, maritime transport is strongly impacted by international growth. For this reason, it is recording a continuous increase in its activity. This global market is therefore highly competitive and is also evolving rapidly in terms of fleet design, size, and performance. This mode of transport uses containers for the most part, as they are essential for linking the economies of different continents and facilitating the movement of goods from raw materials to finished products. This introduction provides an overview of the key statistical trends over the last ten years.

- Maritime transport accounts for around 80% of world trade by value and 90% by volume. [3]

- The attacks in the Red Sea have led to a sharp rise in freight rates, with most of the major international shipping companies deciding to reroute their ships to avoid passing through the Suez Canal, through which 12% of world trade usually passes. [4]



Source: UN Global Platform; PortWatch.

Figure 1.1: Suez canal: Transit trade volume 2023-2024

These attacks are forcing shipping companies to divert their ships from the Suez Canal to the Cape of Good Hope. According to data from the PortWatch website, managed by the International Monetary Fund (IMF), between 15 and 35 container ships passed through the Suez Canal every day at the beginning of May, compared with between 70 and 80 at the end of November 2023, a 50% drop.

Source: UN Global Platform; PortWatch.

Figure 1.2: New ship itinerary 2024

- COVID-19, the war in Ukraine, climate change, and geopolitics have wreaked havoc on shipping and logistics, blocking some ports and closing others, reconfiguring routes, lengthening delays, and increasing shipping costs.

- In ten years, the global container industry has grown significantly. The number of shipments worldwide is now around 65 million.
- International freight carried by container ships accounts for around 16%. However, container ships carry more than 60% of the total value of goods traded worldwide. [5]
- Containerization is essential to international shipping. It accounts for more than 60% of the total value of trade worldwide. Although bulk transport is more common in terms of weight, containerization is essential for the efficient transport of valuable goods.

1.1.1 Market Maritime Types

The size of the maritime freight transport market is estimated at 381.69 billion USD in 2024. All trade chains, including the major import and export trades, are facing a decline. Considering the circumstances of this period, various countries have banned the entry of containers and ships operating from other ports, particularly those transported from China. More than 50 000 merchant ships are involved in international trade, carrying all kinds of goods. The world fleet is registered in more than 150 countries and comprises more than a million seafarers of virtually every nationality, and it is expected to reach 471.81 billion USD by 2029. [6]

The African maritime transport market is the most challenging. The region is characterized by a lack of infrastructure, political instability, and a lack of investment. The market is also facing challenges related to piracy and security. [7]

The North American maritime transport market is growing rapidly. The region is home to some of the world's busiest ports, including Los Angeles and New York. The market is heavily regulated, with strict environmental and safety regulations in place. [7]

The two principal markets are:

1.1.1.1 Bulk Market

In the transport sector in general, bulk (dry or liquid) is characterized by the shipment of goods in the hold of the ship or in spaces provided for this purpose.

The transport of bulk goods has seen a marked upsurge since the mid-2000s, with the arrival of China on the international raw commodities market. [8]

Bulk maritime transport involves loading individual pieces of cargo into a vessel rather than using containers. It is generally used for oversized or irregularly shaped items that cannot be placed in standard containers. It involves three types of cargo: liquid bulk, dry bulk, and neo-bulk:

1. **Liquid Bulk**

   Liquid bulk denotes liquid that undergoes transportation in large volumes using pertinent bulk liquid transport. Typically, bulk liquids can't tolerate conventional transportation, unlike powders or granules. Such liquids include crude oil, vegetable oils, and certain chemicals. We acknowledge that such products require unique handling in designated carriers, and the capacity to implement successful bulk liquid transportation relies on the equipment used. Typically, vessels used for this purpose are tankers equipped with large tanks.

Figure 1.3: Crude oil tanker [1]

Figure 1.4: Chemical tanker [1]

Figure 1.5: Gas tanker [1]

Figure 1.6: Asphalt tanker [1]

2. **Neo -Bulk**

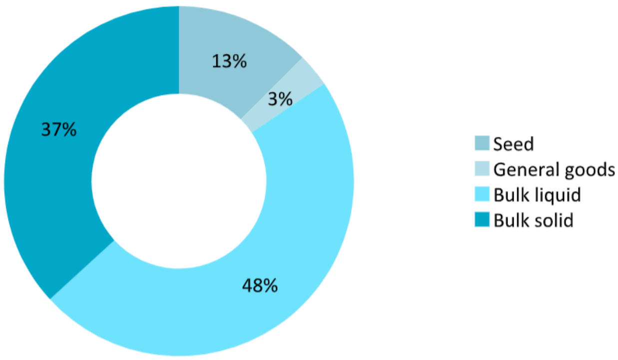
   It includes products that are unpackaged but not in fluid form, such as live animals and new vehicles.

3. **Dry Bulk**

   Dry bulk consists of mostly unprocessed materials that are destined to be used in the global manufacturing and production process. The commodities, which can include grain, metal, and energy materials, are transported long distances in bulk by sea in large cargo vessels.

Figure 1.7: Bulk carrier

We have taken the port of Quebec as an example, which is a major player in the transport of dry and liquid bulk. The statistics provided for the year 2021 show that liquid bulk is the main commodity handled, closely followed by dry bulk. As shown in the sector graph 1.8.



Source:www.portquebec.ca/en

Figure 1.8: Goods loaded/unloaded in 2021

1.1.1.2 Maritime Containerization Market

Maritime containerization is the practice of transporting goods in standardized shipping containers aboard ships. Its purpose is to streamline the process, protect cargo from damage, and increase efficiency in global trade. The advantages include easier handling, reduced labor costs, reduced theft, damage, and loss of goods, and faster transit times. This method has revolutionized the shipping industry over the years, leading to increased trade volumes and reduced transportation costs. As a result, the maritime containerization market continues to grow rapidly, with more companies adopting this method to stay competitive in the global market.

In terms of product type, the maritime containerization market is segmented into: [9]

- Ocean Vessel
- Cargo Type
- Port Management Model

Ocean vessel containerization refers to the process of transporting goods in standardized containers on ships. Cargo types include dry containers for general cargo, reefer containers for perishable goods, and tank containers for liquids. Port management models vary from landlord ports, where the government owns the port and leases out operations, to concessionaire ports, where private companies operate and manage the port facilities. Currently, dry containers are the dominant type that significantly holds market share in maritime containerization due to their versatility and widespread use for various types of cargo.

In terms of product application, the maritime containerization market is segmented into: [9]

- Oil and Gas
- Agriculture
- Consummer Goods

Maritime containerization is widely used in various industries, such as oil and gas, agriculture, consumer goods, and others. In the oil and gas industry, containers are used to transport equipment and tools to offshore rigs. In agriculture, containers are used to ship produce to different markets. For consumer goods, containers play a key role in global supply chain logistics. Containers can also be used in other industries for transportation and storage purposes. The fastest growing application segment in terms of revenue is the consumer goods industry. With the rise of e-commerce and global trade, there is an increasing demand for efficient and cost-effective containerized shipping solutions for consumer goods.

Container ships trace out trajectories across the globe, a vast network of maritime routes that embody the links between people all over the world, as shown in figure 1.9.

Source:www.shipmap.org

Figure 1.9: Container ship traffic

The leading largest shipping companies [10]:

1. **Moller-Maersk Group (Denmark)**

   As the world's largest container shipping company, Maersk has a long history of dominating the maritime containerization market. With innovative strategies such as digital transformation and sustainability initiatives, Maersk continues to lead the industry in terms of market growth and revenue figures.

2. **Mediterranean Shipping Company (Switzerland)**

   MSC is the second-largest container shipping line in the world, known for its global network and efficient operations. With a focus on customer-centric solutions and expansion into new markets, MSC has shown strong market growth prospects and revenue figures.

3. **China Ocean Shipping (Group) Company (COSCO)**

   COSCO is one of the largest state-owned shipping companies in China, with a strong presence in the global containerization market. With strategic acquisitions and partnerships, COSCO has been able to expand its market share and revenue figures significantly in recent years.

1.2 Algerian Economy and Canadian Economy - a comparison

The economic situation of an area is fundamental to the analysis of trends in port transactions. Therefore, it is essential to compare the economic environments of Algeria and Canada before moving on to a comparison of the port sectors, specifically a comparison of two active ports in each country. Starting by comparing data sheets with some indicators from both countries, as shown in the following table 1.1

	Algeria	Canada
Surface	2 381 741 5 (Land 100%; Water 0%) [11]	9 984 670 (Land 91,1%; Water 8,9%) [12]
Coastline (km)	2 148 [11]	202 080 [12]
Population	46 214 534 [13]	39 072 393 [14]
Capital city	Algiers	Ottawa
Largest city	Algiers	Toronto
Major ports	5 [15]	18 [16]
Government	Republic with a semi-presidential regime	Parliamentary democracy
Official languages	Arabic	English/ French
GDP in billions of dollars	244,7 [17]	2 139,84 [18]
GDP per capital (in$)	4 982 [19]	55 085,45 [18]
HDI	0,745 (rank: 91) [11]	0,936 (rank: 15) [12]

Tableau 1.1: Data sheets on Algeria and Canada

It has become invaluable to compare different environments in order to achieve better results and anticipate any operation. In fact, observing, understanding, and explaining processes that now take place on a transnational scale while having local impacts is no longer an exercise confined to a purely national context.

1.3 Port activity in Algeria

1.3.1 Annaba Port Company EPAN

EPAN emerged from the restructuring of the national port system in 1982. It became autonomous in 1989 in the form of a public economic company with the status of an JSC with a share capital of 3,000,000,000 DZD, whose portfolio is held today by the

Port Services Group, known as SERPORT. [20]

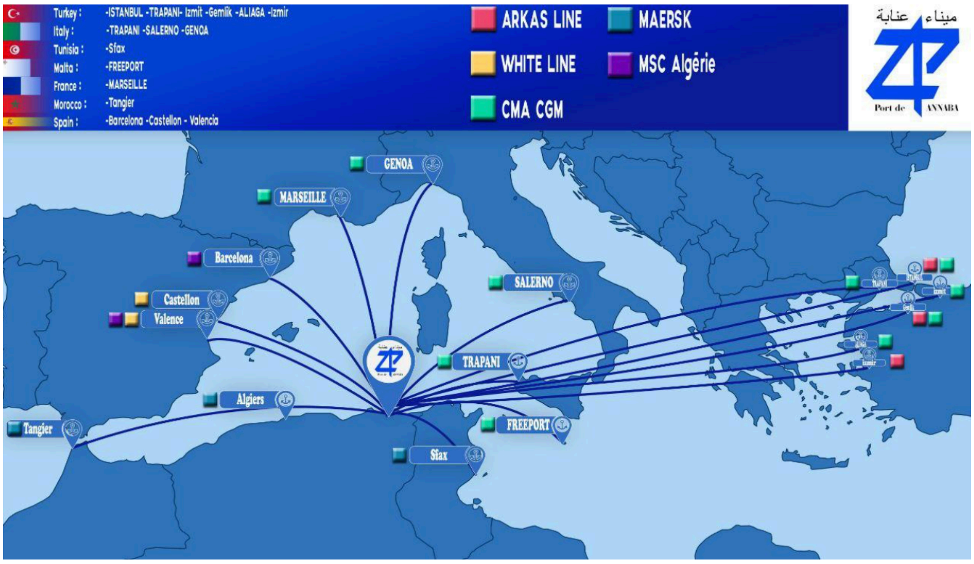
In accordance with its articles of association, EPAN carries out commercial activities in addition to its role as port authority. In other words, EPAN is responsible not only for the management and operation of port infrastructures but also for commercial operations relating to the handling of ships and goods transiting through the port, such as towing, handling, stevedoring, etc. [20]. It covers twelve of the country's wilayas, which are home to industrial zones with high development potential and natural resources such as iron ore mines, phosphate mines, and oil fields. It occupies a crucial position in international transactions, given its exceptional geographical location. It is currently considered the country's leading port in terms of non-hydrocarbon exports and fifth in terms of containers.

- Date of incorporation: 15.02.1988
- Legal form EPE/JSC
- Share capital: 3,000,000,000 DZD
- 06 Rue of Abdelmalek Ramdane, Annaba/ BP 1232 Annaba Algeria
- www.annaba-port.com

1.3.2 Geographic location

The Port of Annaba is considered the primary maritime hub in eastern Algeria and ranks as the second-largest port in the country based on tonnage. Situated at a strategic junction of major road and rail networks, it ensures efficient connectivity. The port is integrated into expressway networks serving the east and south-east regions, as well as the national rail network, facilitated by an electrified rail line connecting to the Ouenza iron mines and the El-Hadjar steel complex.

Moreover, Annaba International Airport is located just eleven kilometers away from the port facilities.



Source:www.annaba-port.com [20]

Figure 1.10: Strategic port location

1.3.3 The Main Sectors of Port activity

The size and specialization of the port determine the presence and extent of various terminals. The port terminal is organized into several distinct areas, each dedicated to handling and storing a particular type of cargo. The Port of Annaba's main sectors and terminals are:

1.3.3.1 Container Terminal

The container terminal at the port of Annaba is a multi-purpose facility, able to handle container ships as well as 8000 DWT RO-RO vessels. It handles 20' and 40' containers, including reefer containers, along with general cargo carried by RO-RO[1] vessels. This terminal is equipped with all the necessary facilities (operating building, storage area, rail track directly connected to the national rail network, and specific handling equipment).

1.3.3.2 Bulk and Steel Products Terminal

This terminal is mainly used to import coal and high-grade iron ore for the El Hajar steel complex. It is also used for importing and exporting steel and metallurgical products

[1] A combination of road and sea transport, where loaded road vehicles are driven on to a ferry or ship and off at the port of destination

marketed by SIDER ElHajar[2] steel complex.

1.3.3.3 Grain Terminal

This terminal is specifically designated for the transit of cereals and has the capacity to accommodate vessels with a minimum of 30 000 DWT.

1.3.3.4 General Cargo and Breakbulk Terminal

This terminal plays an essential role in the traffic of various types of goods, with six berths dedicated to the handling of goods in various forms of packaging. Additionally, there is a dedicated berth for the transportation of vegetable oil and sugar.
To streamline operations, the terminal is equipped with multiple mobile port cranes, telescopic cranes, forklift trucks, and an additional VIGAN[3] gantry crane specifically designed for grain handling, with a capacity of 250 tons per hour.

1.3.3.5 Phosphate Terminal

The phosphate terminal, managed by FERPHOS[4], is specially designed for phosphate mining activities. It is equipped with three telescopic gantry cranes, each with a capacity of 1000 tons per hour. These facilities are dedicated to the export of phosphate, an activity that has replaced the previous export of iron ore from Ouenza.

1.3.4 Annaba Port Actors

1.3.4.1 Shipowner

The shipowner, according to the general definition, is a natural or legal person who operates his own or a rented ship. A ship owner employs the captain and crew, and he is also civilly liable for obligations arising from the operation of the ship. So it is the owner of the ship or a person authorized to dispose of the ship on his behalf. In the maritime trader's law, a shipowner is specified by such phrases as “shipping company” or “ship trader.” [21]

The shipowner also has duties, such as applying to enter the ship into the register of ships, which he should do without delay after receiving the ship. The shipowner is also

[2] An Algerian company active in iron ore processing and steel production.
[3] Ship unloader
[4] Algerian mining companies

liable for damages caused by the ship's crew as well as for damage caused to third parties. He also takes part in any shipping accident investigation.

1.3.4.2 Charterer

The charterer is the intermediary between customers who have goods to be shipped and carriers. He looks for the best means of transport (cost, time, route) for his customer. A person who concludes a charter contract in order to reserve the use of a vessel or its capacity in whole or in part.Its role is to organize the link between the various carriers to ensure continuity of transport.

1.3.4.3 Freight Forwarder

A freight forwarder is a company or an individual who arranges the transportation of goods on behalf of a shipper or a consignee. Freight forwarders act as intermediaries between shippers and transportation providers, such as carriers, trucking companies, and shipping lines.

Freight forwarders provide a range of services, including negotiating freight rates, booking cargo space, preparing shipping documents, arranging customs clearance, and coordinating the movement of goods from origin to destination. They also provide advice and guidance to shippers on transportation options, shipping regulations, and documentation requirements.

1.3.4.4 Loader

The loader is defined as a person or company that carries out loading operations. In practice, the loader (often the exporter) does not carry out the loading; most of the work is done by the handling company at the port, but the port company is not considered to be a loader.

1.3.4.5 Stevedore

A stevedore is a person who works in ports, loading and unloading cargo from ships. The role of a stevedore is crucial in the maritime industry, ensuring the efficient and safe handling of goods as they are transferred between ships and land transport.

1.3.4.6 Customs Service

Customs is a state institution whose primary role is the control of foreign trade as well as procedures aimed at the harmonious development of the world economy. The customs administration plays an important role in international trade operations. The customs services are responsible for:

- Checking goods and related documents.
- Collecting duties and taxes.
- Monitoring the fulfilment of commitments and obligations.
- Promoting trade.
- Recording and penalising offences.

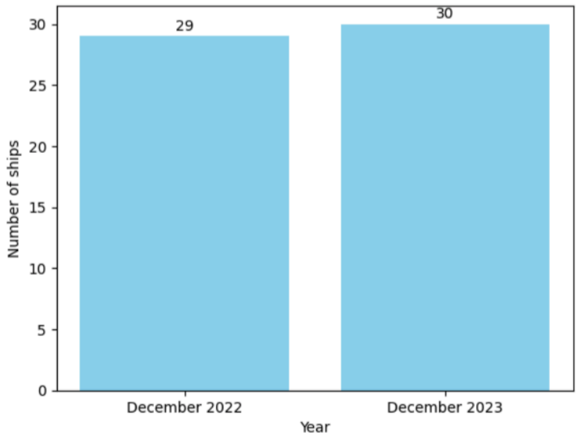
1.3.4.7 Gendarmerie Units

The mission of a port gendarmerie unit, more specifically the gendarmerie maritime, is to ensure the safety and security of maritime and port activities. It carries out administrative and judicial policing missions in places under naval command, as well as in places where safety and security are the navy's responsibility. The gendarmerie maritime is also responsible for protecting passenger ships, combating various forms of maritime crime (trafficking, piracy, organized crime, and cybercrime), and actively participating in the surveillance and protection of maritime approaches. [22]

1.3.5 Annaba's Port Activities

1.3.5.1 Number of Ships Handled

The figure 1.11 illustrates the number of ships handled at the EPAN terminal during the month of December for the years 2022 and 2023. This slight increase indicates a stable or slightly growing operation at the EPAN terminal.



Source: Calculations based on 2022-2023 data

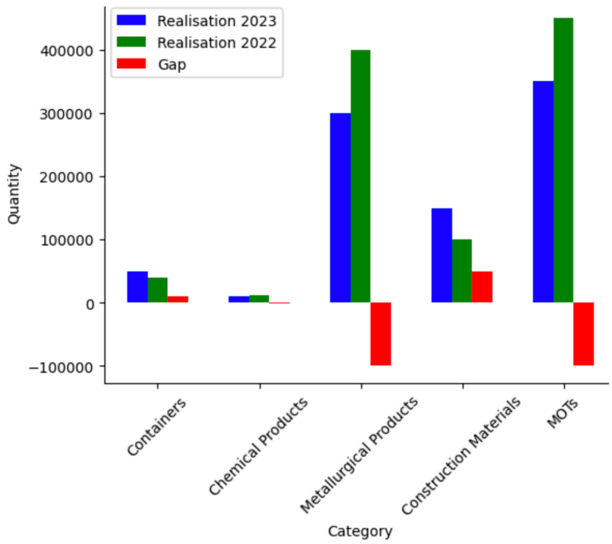
Figure 1.11: Number of ships realized 2022-2023

1.3.5.2 Comparison of Tonnage Realizations

The figure 1.12 illustrates the quantities of different categories of goods between the years 2022 and 2023. Additionally, it shows the difference (gap) between the quantities handled in these two years.

- The categories included are containers, chemical products, metallurgical products, construction materials, and MOTS[5].
- The quantity handled of containers in 2023 is higher than in 2022, with a positive gap.
- The quantity handled of chemical products for both years is relatively similar, with a negligible gap.
- The quantity handled of metallurgical products in 2023 is less than in 2022, showing a notable decrease and a negative gap.
- There is a significant increase in the quantity of construction materials handled in 2023 compared to 2022, resulting in a positive gap.
- There is also a significant decrease in the quantity handled by MOTS in 2023 compared to 2022, with a large negative gap.

[5] engines, vehicles, and tractors



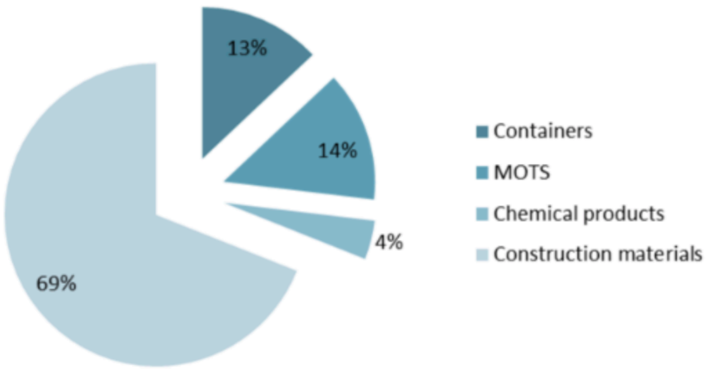
Source: Calculations based on 2022-2023 data

Figure 1.12: Achievement comparison 2022-2023

1.3.5.3 Tonnage Handled at EPAN Stations

The provided pie chart 1.13 illustrates the distribution of tonnage handled at the EPAN terminal during December 2023, by commodity category.

- The largest portion of the tonnage handled is attributed to construction materials, which make up 69% of the total tonnage.
- MOTS contribute 14% to the total tonnage handled.
- Containers account for 13% of the total tonnage handled. This substantial share highlights the relevance of containerized cargo in the terminal's activities, reflecting its critical role in the logistics and transportation industries.
- The least portion of the tonnage handled is attributed to chemical products, which make up 4% of the total tonnage.



Source: Calculations based on 2022-2023 data

Figure 1.13: Tonnage by category of freight

1.4 Port activity in Canada

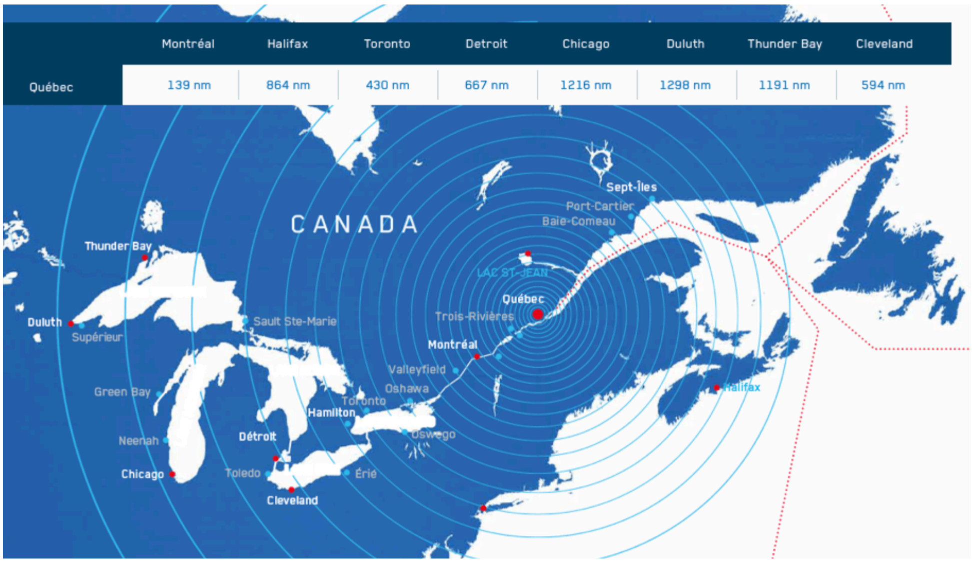
1.4.1 Quebec Port company

The port of Quebec is a Canadian seaport in the province of Quebec, founded in 1608 by Samuel de Champlain, with a history that makes it one of the oldest ports in North America. From its modest beginnings as a trading post, it has become a pillar of Canada's economic development. Today, the port boasts 14 modern terminals specializing in a variety of goods, from bulk and containers to forest products and metals. With some 28 million metric tons of cargo transshipped annually, it generates over $2 billion in economic issues and creates more than 8,000 direct and indirect jobs in the Quebec City region.

As the last deep-water port in the St. Lawrence/Great Lakes corridor, it plays a crucial role in transatlantic and North American trade, providing vital access to domestic and international markets. Furthermore, as a national port, it actively contributes to Canada's maritime strategy, promoting maritime trade, improving infrastructure, and implementing high environmental standards. The Port of Quebec embodies Canada's history, economic vitality, and strategic role in global maritime trade. [23]

1.4.2 Geographic Location

Quebec's port is the main gateway to the industrial and agricultural heartland of North America. It is positioned as the last deep-water port before the Great Lakes, with a depth of 15 meters at low tide. Located in Quebec City, province of Quebec, Canada, the port stretches along the banks of the St. Lawrence River, with distinct zones such as Beauport, Estuaire, Anse au Foulon, and Rive-Sud. These port areas are strategically positioned for maritime trade, being both close to downtown Quebec City and benefiting from direct access to the St. Lawrence River, one of North America's major waterways [23].



Source:www.portquebec.ca

Figure 1.14: Strategic port location

1.4.3 Main Sectors of Port activity

1.4.3.1 BEAUPORT sector

The Beauport sector is a major center of economic activity, home to a variety of industries such as chemicals, mining and metals, iron and steel, recycling, energy, and construction.

The area is also home to several port terminals: Beton Provincial, IMTT[6], VOPAK[7], and Glencore[8]. These terminals offer specialized infrastructure for the transshipment of bulk solids and liquids, with docks equipped for various capacities.

[6]The leader in sustainable bulk liquid storage solutions and proudly serves critical liquids players in North America

[7] An oil and gas company

[8]Glencore is one of the world's largest globally diversified natural resource companies and a major producer and marketer of more than 60 commodities. Their operations comprise around 150 mining, metallurgical, and oil production assets.

1.4.3.2 ESTUAIRE sector

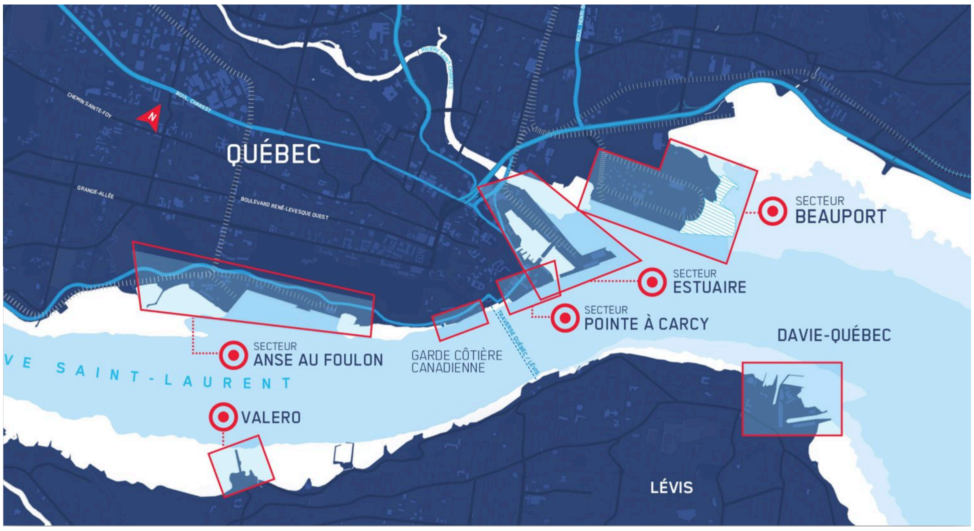
The estuary sector is a major hub of economic activity, with dominant sectors such as agri-food, construction, marine services, and ship repair, as well as general cargo and special cargo transportation, in addition to offering marina facilities. Key port terminals include Beton Provincial and Groupe Ocean, which provide specialized facilities for unloading a variety of goods. In addition, docking facilities are available to meet the needs of marinas and cruises, as well as the unloading of a variety of goods.

1.4.3.3 ANSE AU FOULOU sector

The Anse au Foulon sector hosts major industries such as energy, mining, agri-food, construction, and transportation. These port facilities are equipped with docks specifically designed for the supply of grains, fertilizers, deicing salt, dolomite, and limestone.

1.4.3.4 SOUTH SHORE AREA

The South Shore sector is characterized by several major activity sectors, including the Valero[9] energy refinery dock, the Davie shipyard[10] and the STQ[11].



Source:www.portquebec.ca

Figure 1.15: Port's main sectors

[9] publicly held company since 1997
[10] a shipbuilding company
[11] Société des traversiers du Quebec, since 1971

1.4.4 Quebec Port actors

1.4.4.1 Shipowner

Shipowners in Canada, particularly in the province of Quebec, are members of the St. Lawrence Shipowners Association (SLA)[12]. They operate mainly on the St. Lawrence and the Great Lakes, serving regions such as the Lower North Shore, the Nord of Quebec, the Canadian Arctic, Newfoundland, the Magdalen Islands, the Maritime Provinces, Anticosti Island, and a few foreign ports. However, some of them have a part of their fleet dedicated exclusively to international operations. [24]

1.4.4.2 Pilot

Pilots board commercial vessels using the shipping lane and are responsible for the navigation and maneuvering of the vessels. There are several piloting areas, and each pilot specializes in a specific area. The compulsory piloting areas on the St. Lawrence include:

- District 1: Montreal to Quebec City.
- District no 1.1: Montreal to Pointe-aux-Trembles.
- District no 2: from Quebec to Escoumins[13].

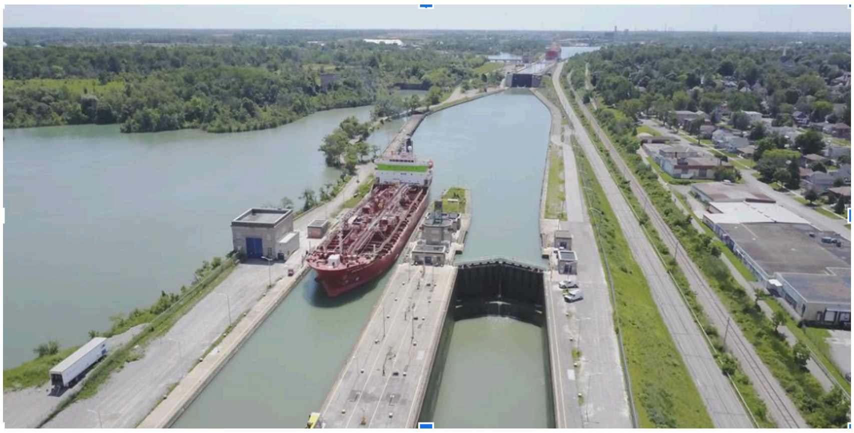
Piloting on the St. Lawrence follows specific rules for foreign and Canadian vessels. Foreign vessels over 35 meters in length must embark a pilot from Escoumins. For Canadian ships, those over 70 meters and 2400 tons in districts 1 or no. 1.1 , and over 80 meters and 3300 tons in district no. 2 must be piloted. Locally certified pilots guarantee safety when navigating in specific areas of the river. [25]

1.4.4.3 Bridge Lock Operators or Traffic Controllers

To sail from Montreal to Lake Erie, ships have to pass through 15 locks, requiring precise management of lockage operations and bridge openings.
The lock operator is responsible for managing and controlling all the maneuvers involved in operating a lock or bridge, such as those at Sainte-Catherine and Saint-Lamber. They work both on site and remotely from the operations control center, which has been located in Saint-Lambert since 2017.

[12] A service level agreement

[13] A municipality in La Haute-Côte-Nord Regional County Municipality in the Côte-Nord region of Quebec. It is located on the north shore of the maritime estuary of the St. Lawrence River



Source: grandslacs-voiemaritime.com

Figure 1.16: Vessel using a lock

1.4.4.4 Longshoremen/Stevedore

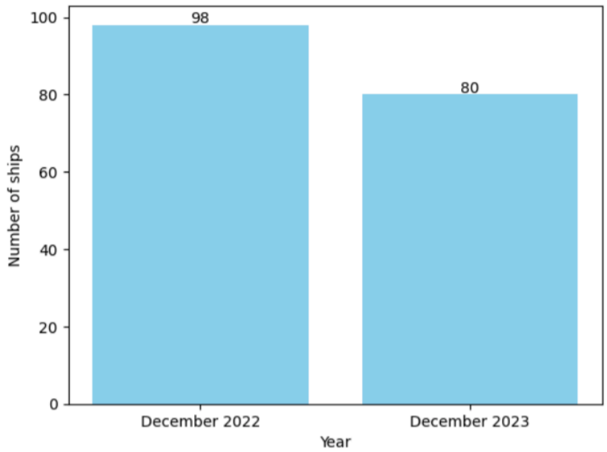
Stevedore is responsible for loading and unloading ships. He is responsible for storing the goods in port and ensuring that the cargo is properly and safely stowed on the ship. In Quebec, several companies offer stevedoring services in ports. These companies are generally represented by specialized employment agencies that coordinate requirements according to maritime traffic, types of goods, and lifting equipment needed.

Stevedoring requirements at each port are determined by various factors, such as the types and quantities of goods to be transhipped, as well as ship arrival times and the availability of handling equipment. All those involved in the St. Lawrence waterway work together to optimize operations and reduce vessel waiting times.

1.4.5 Quebec's port activities

1.4.5.1 Number of Ships Handled

The figure 1.17 illustrates the number of ships that passed through the Port of Quebec during December 2022 and 2023. There is a marked decrease in ship traffic from December 2022 to December 2023. Specifically, the number of ships dropped from 98 in December 2022 to 80 in December 2023. This represents a reduction of approximately 18.4% in the number of ships passing through the port.

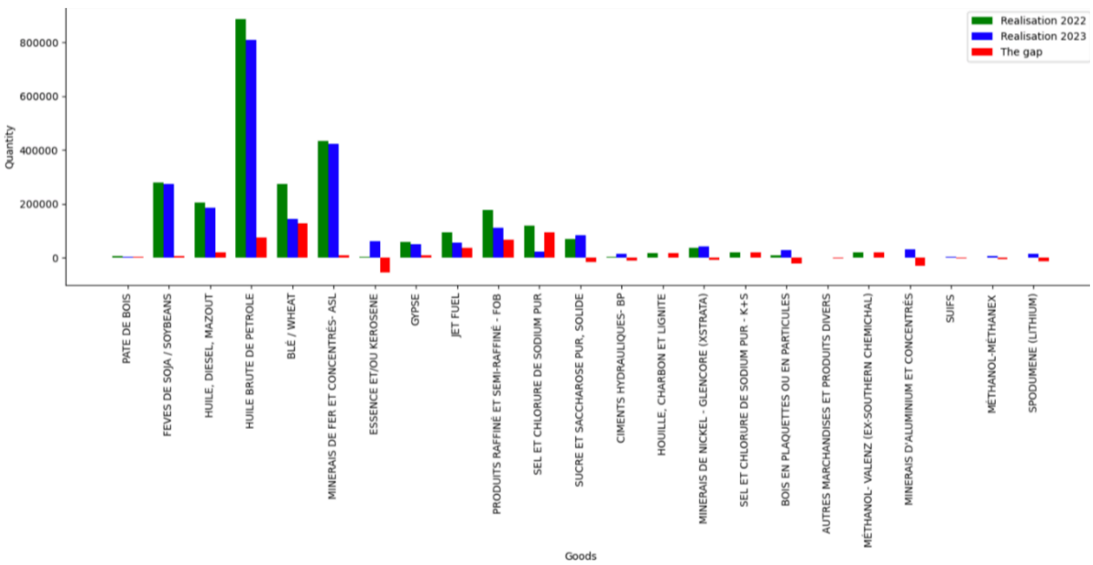


Source: Calculations based on 2022-2023 data

Figure 1.17: Number of ships realized 2022-2023

1.4.5.2 Comparison of Tonnage Realizations

The figure 1.18 illustrates the quantities of different categories of goods between 2022 and 2023, almost more than 20 types. The quantity handled of crude oil is the most important quantity compared to other products, with a positive gap. And it is followed directly by the iron ore in the second rank, with a negligible gap.

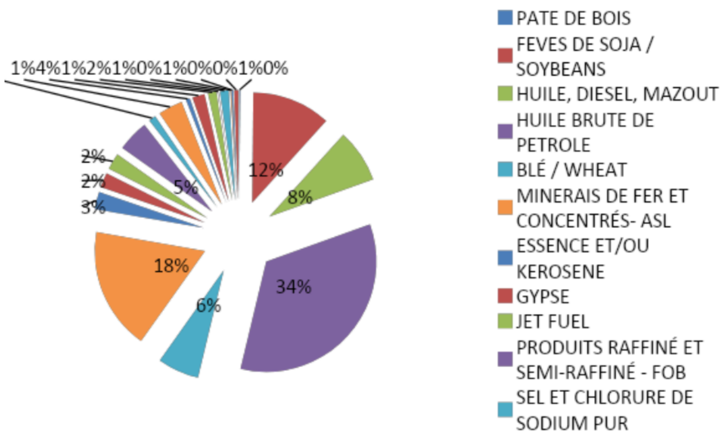


Source: Calculations based on 2022-2023 data

Figure 1.18: Achievement comparison 2022-2023 with gap

1.4.5.3 Tonnage Handled at Berths in Quebec's port

The provided pie chart 1.19 illustrates the distribution of tonnage by commodity category's with a predominance of petroleum products, particularly crude petroleum oil, which accounts for more than a third (34% of overall traffic). Iron ores follow with 18%, while soy beans represent 17.88%. These three dominant categories accounted for almost 64% of traffic. By contrast, other goods have smaller shares, such as wheat 6.09%, refined products 4.66% and sugar 3.60%. However, it should be noted that some products are relatively marginal in terms of contribution, such as methanol, which has shares of less than 1%.



Source: Calculations based on 2022-2023 data

Figure 1.19: Tonnage by category of freight

Conclusion

This chapter has highlighted the importance of maritime transport in the transport of freight around the world. Turning to the comparison of port activities, actors, and terminals of both ports, Annaba's port in Algeria and Quebec's port in Canada.

In the next chapters, we will use this data to compare both ports.

Chapter 2

Performance: Concept, Definition and Measurement Methods

Introduction

The logistics environment has changed considerably in recent years, due to the emergence of the global economy and the intensification of competition. As a result, ports are having to adopt new competitive strategies to satisfy their carriers and offer more favorable conditions than those offered by their competitors, in the hope of attracting other customers.

But as long as carriers see ports more as cost centers than as business partners, they evaluate and compare the services offered against those of competing ports, looking for better quality and cost. Also, port managers are now aware that they must imperatively improve their performance.

To do this, we need to start measuring port performance to find out how effective and efficient they are, to compare their current performance with that of the past, to compare their performance with that of competing ports, and, on the basis of current performance, to adapt future objectives.

In recent decades, there has been a growing theoretical and practical study of the measurement of port performance. But despite the diversity of tools and instruments available, no consensus on a single structure for port performance has been established. Moreover, there is much debate about the determinants to be taken into account in assessing port performance.

2.1 Concepts of Performance and Efficiency

2.1.1 Performance Concept

2.1.1.1 Etymology and Historical Background

Historically, the verb to perform, from which the word performance derives, did not appear in the English language until the fifteenth century. It meant "the accomplishment of a process or task, with the results that follow and the success that can be attributed to it." [26] The Anglo-Saxon verb "to perform" indicates the expression of an exploit or a yield. It also implies the accomplishment of an action.

The notion of performance was first used in the field of sport, then in the field of mechanics, before being applied by organizations. According to Pesqueux, "In the strict sense of the term, a performance is a quantified result with a view to ranking in relation to oneself, improving one's performance, and/or in relation to others. Performance assessment is therefore based on a benchmark, a measurement scale". [26] However, we would point out that the etymology of the word indicates both the richness of the concept and a certain ambiguity resulting from the polysemy of the word's meaning. Performance covers several concepts, such as effectiveness and efficiency. These two concepts are used interchangeably in the literature. A company can be effective without being efficient, and vice versa. Effectiveness measures the degree to which a company achieves its objectives, while efficiency refers to the way in which a company's resources are used.

2.1.1.2 Evolution of the Concept of Performance

In the early 19th century, the word "performance" was used to describe the results achieved by a horse in a race, and later by an athlete or sports team. From the twentieth century on, the term was also used to describe the calculated indications explaining the options of a machine.

Throughout the 20th century, the notion of performance evolved and expanded to take into account a wider range of practices in companies and other organizations. The rapprochement between the sporting world (the performance of the sports team) and the economic world (organizational performance in the company) leads to emphasizing the following points: [27]

- Organizational performance is a function of the objectives of the company and its internal or external guiding agents, just as sporting performance is assessed by reference to the athlete's objectives. Performance is the product of rapid convergence, an active concept, and an always temporary state.

- Organizational performance, like sporting performance, is about the individual's ability to improve through persistent, consistent, and logical effort. performance of a sports team depends on its ability to work together; the performance of a company depends on its ability to break down the barriers in its organization and to develop ways of coordinating and learning collectively between its various functions.

- In the field of mechanics, machines are designed with specific goals in mind. In the same way, the organization has objectives and uses logical means to achieve them.

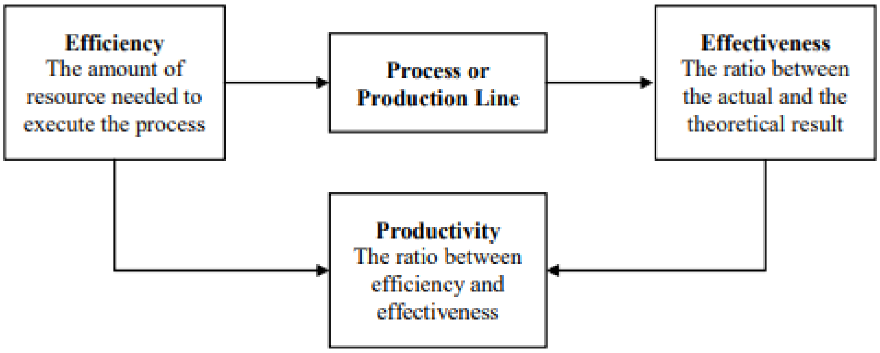
The notion of performance evolved considerably throughout the 19th and 20th centuries. This evolution has enabled it to cover several concepts and several fields, including the concept of organizational performance.

2.1.1.3 Definitions

Mentzer and Konrad (1991) define performance as "an investigation of the effectiveness and efficiency of carrying out a given activity." . [28] Neely et al. (1995) define performance as "the process of quantifying the efficiency and effectiveness of an action.". [29]

The last two definitions show that performance is made up of two essential dimensions: effectiveness and efficiency. Effectiveness refers to the extent to which customer requirements are met, while efficiency measures how the company's resources are used to respond economically to customer demands. [30] Although the notion of performance extends to several dimensions, the word is recognized above all from an economic and financial evaluation perspective.

The concepts of effectiveness, efficiency, and productivity are complementary to the concept of performance. A high-performance company is one that is effective, efficient, and relevant. In other words, it achieves its objectives using a minimum of resources. [31] The figure 2.1 shows the relationship between efficiency, effectiveness, and productivity.



Source: Buyukkilic, 2004: 22.

Figure 2.1: Efficiency, Effectiveness and Productivity Relationship

On the other hand, you can be effective without being efficient, and vice versa. An organization that achieves its objectives but uses more resources than planned (the budget, for example) is effective but not efficient. On the contrary, if it respects the limits of the budget but does not achieve its objectives or takes longer than expected to achieve them, it will be efficient but not effective. [32]

To put it another way, effectiveness is the extent of achieving an objective, while efficiency is the degree to which resources have been used economically. [33] Simply put, efficiency is "doing things right," and effectiveness is "doing the right things." [34]

2.1.1.4 Difficulty of measuring performance

A number of researchers have investigated the measurement of port performance but have been unable to reach any consensus on the most optimal way of measuring a port's performance.

There are several reasons for the divergence in this area of research. First is the difference in the definition of performance; second is the complexity of the operational and spatial dimensions; and third is the difference in perception between the various port stakeholders. The combination of these factors creates confusion about what to measure, how to measure it, and how to compare it to what. These differences explain the diversity of port performance measurements. And as long as there is no unanimously adopted approach to the roles and functions of ports, the subject of what to measure and how to measure it will remain debatable. [35]

2.1.1.5 Performance Measurement

In recent years, researchers have shown a growing interest in improving performance measurement systems. Performance measurement systems are a set of measures used to assess the effectiveness and efficiency of actions. And few manage to understand them as a balanced framework for measuring their performance.

In the port sector, measurement systems used are sometimes incompatible with the integration of various members of the supply chain, which is often ignored. Port authorities need a measurement system to determine performance that reflects the reality of seaports and takes into account the interests of different players in the chain. [35]

Although performance is a relative concept, it is defined as the degree of success in achieving specified goals. [36] Performance can also be explained by the production function. Production processes transform specific inputs into specific outputs. Production function also explains the relationship between changes in the amount of input and output in this process [37]. By making a basic definition of production function for a product, we tried to determine the maximum amount of product that can be produced with alternative input combinations (frontier models) such as labor, capital, and warehouse space. [38]

As with other businesses, evaluating port performance or measuring terminal efficiency is very important from an economic, functional, and strategic perspective. Methods used for performance measurement vary according to assumptions about data, production technology, and the and the economic behavior of decision-making units and the types of measures applied.

And despite the development of port performance models and measures, they have always been criticized for not encompassing all port structures. Some measures only concern container terminals, while others only look at port inputs and outputs, such as the DEA (Data Envelopment Analysis) method applied by Tongzon in 2001 [39]. However, the performance results obtained do not reflect the performance of the port as a whole. Literature presents intra-port and inter-port measurement methods: [35]

- **Intra-port:**

  Intra-port performance was measured by comparing actual port throughputs with their optimum throughputs. Then, in 1994, Talley presented a methodology for selecting port performance indicators that correspond to optimum economic throughput for assessing a port's performance.

- **Inter-port:**

  In order to solve the problem of increased competition, Heaver (1995) suggests that ports develop a performance testing program. But despite all studies on factors influencing port performance, the literature does not present a consistent analytical approach to measuring performance. [40] Chow et al. (1994) have pointed out that conventional performance indicators remain incomplete measures. [41] In this context, progress has been made, leading to two approaches, Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA), which are increasingly used to analyze port production and performance. [42]

The way in which the performance of an organization is evaluated depends on the objectives assigned to management. The objective of this study is to evaluate the performance level of two port companies: the port of Annaba and the port of Quebec. This evaluation will be carried out by measuring efficiency. For this reason, the following section will be devoted solely to defining efficiency.

2.1.2 Efficiency Concept

In economic literature, the concept of efficiency is abundantly used to measure the performance of production units. It is therefore important to understand why this question of efficiency has gradually become relevant at the organizational level. According to economic theory, the concept of efficiency refers to the Pareto[1] optimum. [43] Efficiency in a public organization such as the one we are studying can be defined as the level at which producers manage to achieve a result with the minimum of resources. [32]

Since then, the concept of efficiency has been the subject of a multitude of scientific studies and research. For more than half a century, several authors have successively

[1] A theory, which maintains that 80 percent of the output from a given situation or system is determined by 20 percent of the input.

attempted to clarify this concept. Debreu (1951), Koopmans (1951), Shephard (1953), and Farrell (1957) were the first to take an interest in the concept of efficiency. Their work is considered to be the starting point for the construction of the concept.

Koopmans (1951) was the first to propose a measure of the concept of efficiency relating to the analysis of production. He proposed a formalization of technical efficiency that allows technical efficiency to be broken down into scale efficiency and pure technical efficiency. Debreu (1951) was the first to measure it empirically, using resource utilization coefficients (measures of the output-input ratio) to describe the maximum of an equi-proportional reduction in all inputs that allows the production process to subsist. Shephard (1953) introduced the input distance function to measure inefficiency by taking into account the possibility of integrating multi-output production processes. [44]

In his article, Farrell (1957) provided a theoretical reasoning tool based on the micro-economic concept of the marginal rate of substitution. He was the first to clearly define the concept of economic efficiency and to divide it into two terms: technical efficiency and allocative efficiency. This is the approach adopted today by the economic literature, which identifies three forms of efficiency in productive activities: technical, allocative, and economic efficiency. [45] Before explaining the conceptual framework that guides our research, we would like to briefly outline the theoretical foundations. [31] [32]

Although productivity and efficiency, which are concepts related to performance, are often used interchangeably in the literature, they are defined differently by many researchers. Productivity is defined as producing the output with the least cost or obtaining the optimum output with the resources available, while efficiency is defined as reaching the maximum output by utilizing the resources in the best possible way. [46] Productivity and efficiency are also different in terms of process. While the efficiency period is short, the productivity process is usually longer. For For example, while the process of becoming more effective as a result of a manufacturer company using all inputs at the optimal level is short, the process of increasing productivity by minimizing the residues of resources is generally longer. [47] [38]

2.1.2.1 Distinction between Different Types of Efficiency

Many authors have revealed the existence of several types of efficiency: technical efficiency, scale efficiency, and allocative efficiency. It should be noted that economic efficiency corresponds to the product of two types of efficiency combined (technical and allocative efficiency). [48] An organization is considered economically efficient "if it is both technically efficient and allocates its productive resources efficiently." [49]

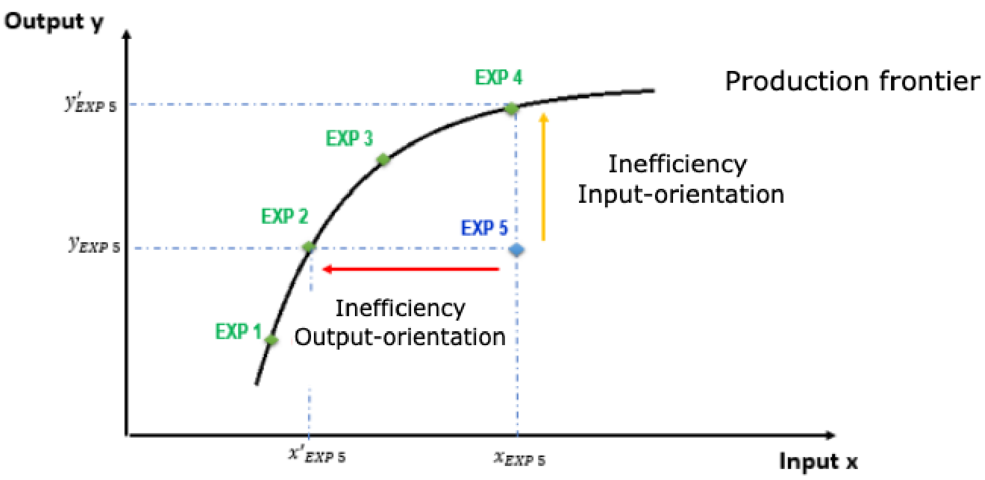
1. **Notion of Technical Efficiency**

   The notion of technical efficiency has already been the subject of numerous theoretical investigations. We therefore review successive definitions of this concept.

   Technical efficiency is defined as the firm's ability to make optimal use of resources. According to Ghali et al. (2014), technical efficiency concerns the farm's ability to avoid waste through good management of available resources. In the same vein, Djimasra (2009) describes it as a company's ability to produce efficiently with necessarily limited resources at its disposal. For Farrell (1957), this concept is measured on the basis of best practices in the sector. In other words, it measures how well a business makes the most of the inputs that go into the production process. [44]

   A production unit is technically efficient when it is located on the frontier, i.e., it consists of producing the highest possible level of output for a given level of input (output-orientation, maximization of output) or it consists of using the lowest possible level of input for a given level of production (input-orientation).

   Technical efficiency is measured by the difference between the observed level of production and the optimal level of output determined by the production frontier. The figure 2.2 presents a graphical illustration of technical efficiency (mono output/mono input function). [44]



Source:inspired by Farrell, 1957,Ben Farah 2018

Figure 2.2: Graphic illustration of efficiency concept based on production function (input-oriented or output-oriented)

The production function is defined as a function relating to the combination of all efficient points. The deviation from best practice determines a firm's degree of (in)efficiency. Figure 2.2 shows that farms numbered 1, 2, 3, and 4 are technically efficient, as they lie directly on the frontier curve of production function. However, farm 5 is inefficient because it lies below the production frontier. Therefore, the producer would have the option of employing fewer inputs without reducing the level of output produced by moving from $\mathrm{x_{EXP5}}$ to $\mathrm{x'_{EXP5}}$ (input-orientation) or increasing the level of output obtained by keeping the same levels of inputs constant by therefore moving from $\mathrm{y_{EXP5}}$ to $\mathrm{y'_{EXP5}}$ (output-orientation).

Technical efficiency is decomposed into pure technical efficiency (PTE) and scale efficiency (SE) (Latruffe and Piet, 2013). [50] This decomposition depends on hypotheses made about the nature of returns to scale. Scale efficiency provides information on the optimal level of farm size. It can be used to assess whether a farm's yields are increasing, constant, or decreasing. It therefore reflects the suitability of a production unit at its optimum scale. The optimal scale is understood here as being the best situation that a production unit can achieve by proportionally increasing the quantity of all its factors. Pure technical efficiency, on the other hand, provides information on how production units's resources are managed (Latruffe, 2013; Blancard et al., 2013). In the case of constant returns to scale, it is assumed that an increase in the quantity of inputs consumed would lead to a proportional increase in the quantity of outputs produced. In the case of variable returns to scale (increasing or decreasing), on the other hand, the quantity of outputs produced is assumed to increase more or less proportionally than the increase in inputs. [44]

2. **Notion of Allocative Efficiency**

"The concept of allocative efficiency refers to the relative prices of production factors (labor, capital). It involves measuring, for a given level of production, the proportions in which production factors are used and choosing the combination of inputs so as to minimize their cost" [44]. According to Piotlepetit and Rainelli (1996), [51] allocative efficiency is defined by the way in which the entrepreneur sets the proportions between the different inputs participating in the productive combination based on their respective prices.

3. **Illustration of Efficiency Types**

According to Farrell (1957), a measure of efficiency must therefore be based on the frontier of set production possibilities rather than on standard econometric analysis, which seeks an equation of a straight line that best describes the observations, treats extreme data as outliers, and produces an average assessment of performance. Instead, it would be the data as a whole that could contribute to estimating efficiency, and the extreme level of certain performances could identify efficient or inefficient practices.

The figure 2.3, proposed by Farrell (1957), illustrates the distinction between efficiency types, where there are two factors of production (labor L and capital K). The isoquant SS' represents the production frontier, which is defined as the set of input combinations that are technically efficient for a given output level. Points above the isoquant characterize inefficient firms. The straight line (AA') graphically represents the ratio of input prices determined by the market. As such, point Q represents a technically efficient firm, using two factors of production in the same ratio as the firm located at point P. All points on the production frontier are technically efficient and have a technical efficiency score equal to 1, whereas any point inside the isoquant is technically inefficient for that level of production. The technical efficiency of the farm at point P is given by the $\frac{OQ}{OP}$ ratio, which varies between zero and unity. Efficient firms have a ratio equal to 1, and those whose ratio is less than 1 must reduce the input used by $(1-\frac{OQ}{OP})$. For example, if the ratio is 0.85, you need to reduce your input by 15% to become efficient and be positioned on the curve.

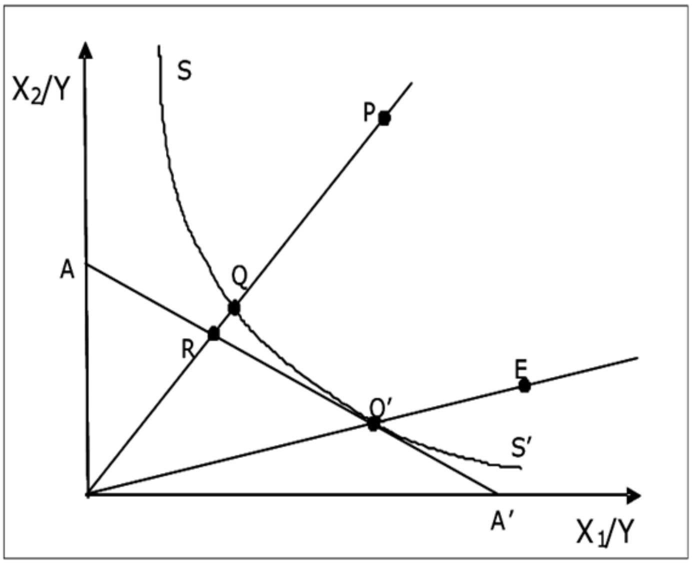
Although technically efficient, not all points on the isoquant are allocatively efficient. Allocative efficiency is measured by the difference between production costs and technical efficiency. Even if technical efficiency is 100% at these two points, production costs at Q' represent only $\frac{OR}{OQ}$ fraction of those at point Q. This ratio is then defined as a measure of price efficiency, or allocative efficiency. All points on isocost (AA') are allocatively efficient, but not all are feasible.

According to Farrell (1957), economic efficiency corresponds to technical efficiency and allocative efficiency combined. It is obtained at point Q'. Economic efficiency at point P can also be written as :

$$ETT_i = \frac{OR}{OP} = \frac{OQ}{OP} \times \frac{OR}{OQ} = ET_i \times EA_i$$

According to Farrell (1957), economic efficiency corresponds to technical efficiency and allocative efficiency combined. It is obtained at point Q'. Economic efficiency at point P can also be written as:

As a result, point P is neither technically nor allocatively efficient. Point Q, while technically efficient, is allocatively inefficient. Point E is allocatively efficient, but technically inefficient. Finally, the points on the OE line are all allocatively efficient, but only point Q' is technically efficient and therefore also economically efficient (the optimal production point).



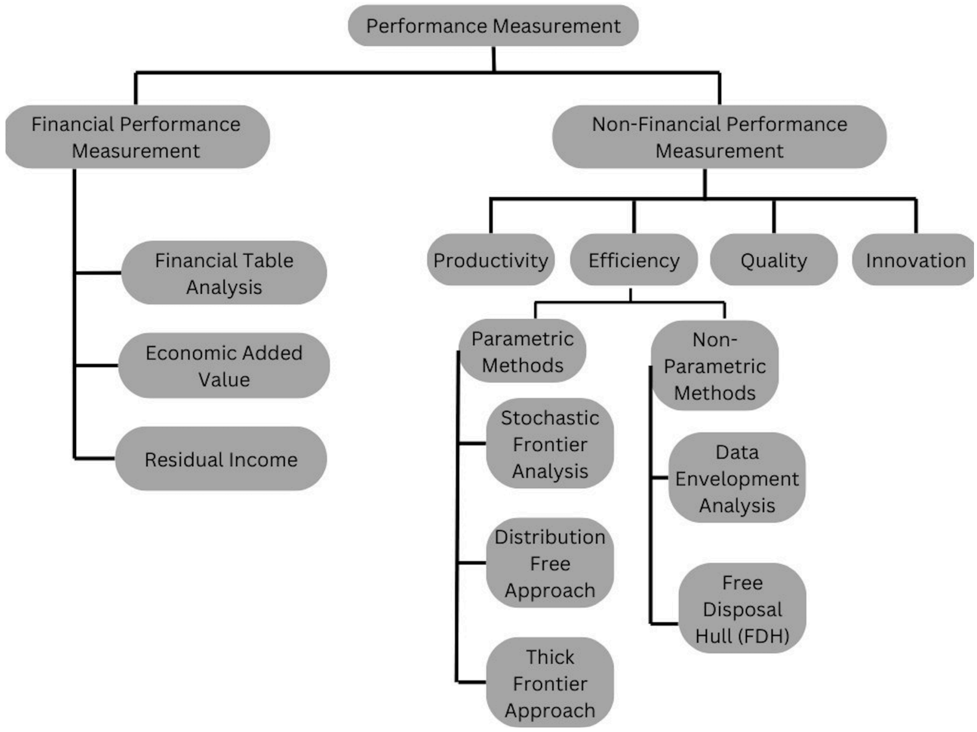
Source: Farrell, 1957.

Figure 2.3: Technical and Allocative Efficiencies

In our study, we looked at the measurement of technical efficiency to study the performance of both ports. Indeed, the measurement of technical efficiency is considered a prerequisite to the evaluation of global performance. There are several methods of assessing technical efficiency in the economic literature. By highlighting the advantages and disadvantages of each approach, we justify, in what follows, the choice of approach that we adopt in our work and the difference between them.

2.2 Different Approaches to Estimating Efficiency

After introducing the concept of efficiency in the previous section, we set out the main methods for measuring it. In the economic literature, these methods of analyzing efficiency can be classified “according to the intended form of the frontier, the estimation technique used to obtain it, and the nature of the deviation between observed output and optimal output.” [52] Also, the literature reveals a variety of practical methods for estimating the production frontier and, consequently, technical efficiency. The figure 2.4 summarizes the diversity of methods for evaluating production efficiency.



Source: Caglar and Oral, 2011: 667

Figure 2.4: Performance Measurement Systems

With regard to the efficiency estimation methods available, two main approaches have been adopted in economic literature and are the most widely used for establishing a production frontier and estimating technical efficiency: one parametric, an econometric approach known as stochastic frontier analysis (SFA), and the other non-parametric, an approach based on mathematical programming known as data envelope analysis (DEA). The main distinguishing feature of these approaches lies in their assumptions concerning the inclusion of residuals (random factors) and functional or non-functional specifications of production function. Thus, each of both methods is based on a different conception of the construction of this efficient frontier. Nevertheless, all these techniques have advantages as well as weaknesses, which limit the scope of their applications as efficiency evaluation tools. These have been extensively described in the literature by several authors, such as Coelli et al. (1998) and Amara et al. (2000. [44] A detailed study of parametric and non-parametric methods will be discussed in the following section.

2.2.1 Non-parametric Approach DEA

Origin of DEA method can be traced back to Rhodes'doctoral thesis (1978), which later contributed to development of Charnes, Cooper and Rhodes (CCR) model. CCR model is an extension of the work of Farrell (1957) who initiated the measurement of technical efficiency using only input and output. Since CCR model, DEA method has been applied to multiple inputs and outputs. [53] [54]

DEA method is used to assess the performance of organisations (Decision Making Units or DMUs) that transform resources (inputs) into services (outputs). It is suitable for both private and public sector organisations. It can also be applied to entities such as companies, cities, regions, countries, etc. DEA method was developed by Charnes et al (1978, 1981) to evaluate the efficiency of a US federal programme to allocate resources to schools ("Follow Through Programme"). It was then widely used in other public organisations (hospitals, social services, unemployment offices, power plants, police units, army corps, waste treatment plants, public transport companies, forestry companies, libraries, museums, theatres, etc.) and in the private sector (banks, insurance companies, retail outlets, etc.).

Each organisation's efficiency score is calculated relative to an efficiency frontier. Organisations located on the frontier have a score of 1 (or 100%). Organisations that are below the frontier have a score of less than 1 (or 100%) and therefore have room to improve their performance. It should be noted that no organisation can be located above the efficiency frontier, as it is not possible to obtain a score higher than 100%. Organisations on the frontier serve as peers (or benchmarks) for inefficient organisations. These peers are associated with observable best practice. The DEA method is therefore a benchmarking technique. [55] [32]

The DEA method is a tool for analysis and decision support in the following areas:

- By calculating an efficiency score, it indicates whether an organization has room for improvement.
- By setting target values, it indicates how much input needs to be reduced and outputs increased for an organization to become efficient.
- By identifying the type of returns to scale, it indicates whether an organization needs to increase or reduce its size in order to minimize its average production cost.
- By identifying the benchmark peers, it determines which organizations have the best practices to analyze.

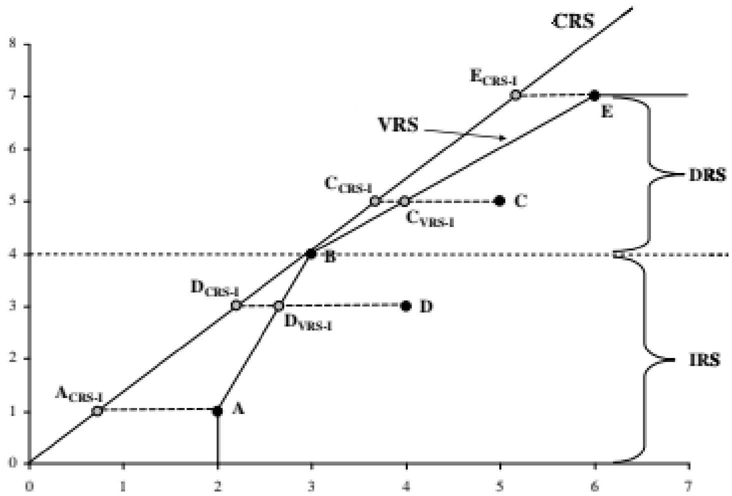
2.2.1.1 Basic Models of DEA

Two basic models are used in DEA, each leading to the identification of a different efficiency frontier.

The first model assumes that organizations evolve in a situation of constant returns to scale (CRS). It is appropriate when all organizations have reached their optimal size. It should be noted that the hypothesis of this model is very ambitious. To operate at their optimal size, organizations must evolve in an environment of perfect competition, which is rarely the case. The CRS model calculates an efficiency score called total technical efficiency.

The second model assumes that organizations evolve in a situation of variable returns to scale (VRS). It is appropriate when organizations are not operating at their optimum size. This hypothesis is preferred in cases of imperfect competition or regulated markets. The VRS model calculates an efficiency score called pure technical efficiency.

“Comparing the two models allows us to identify the sources of inefficiency. Constant returns to scale technical efficiency is the overall measure of an organization’s performance. It is made up of a measure of pure technical efficiency (technical efficiency assuming variable returns to scale) and a measure of scale efficiency (SE)”. [55]



Source: Jean-Marc Huguenin, 2013

Figure 2.5: Basic DEA models

According to [55], the situations of the five organizations in terms of returns to scale are specifically described below (Figure 2.5):

- Civil Registry Office A is located on the VRS border (but not on the CRS border). Its inefficiency is due to its sub-optimal size. A operates in a situation of increasing returns to scale. A variation in output of 1% results in a variation in input of less than 1%.

- Civil Registry Office D is located neither on the VRS border nor on the CRS border. Its inefficiency is due, on the one hand, to its perfect management and, on the other, to its suboptimal size. D evolves in a situation of increasing returns to scale. A variation in output of 1% translates into a variation in input of less than 1%.

- Civil Registry Office B is located on both the VRS and CRS borders. It is not inefficient. B operates in a situation of constant returns to scale. A 1% change in output results in a 1% change in input.

- Civil Registry Office C is located neither on the VRS border nor on the CRS border. Its inefficiency is due, firstly, to its perfect management and, secondly, to its sub-optimal size. C evolves in a situation of diminishing returns to scale. A variation in output of 1% translates into a variation in input of more than 1%.

- Civil Registry Office E is located on the VRS border (but not on the CRS border). Its inefficiency is due to its sub-optimal size. E operates in a situation of diminishing returns to scale. A variation in output of 1% results in a variation in input of more than 1%.

2.2.1.2 DEA Orientations

The DEA model can be either input-oriented or output-oriented:

- In an input-oriented DEA model, inputs are minimized for a given level of outputs. It indicates how much an organization can reduce its inputs while producing the same level of output.

- In an output-oriented DEA model, outputs are maximized for a given level of inputs. It indicates how much an organization can increase its outputs with the same level of inputs.

Frontier efficiency differs between CRS and VRS models (as shown in figure 2.5). However, within each of these models, the frontier will not be affected by input or output orientation. The efficiency frontier of the VRS model will be exactly the same, with either input or output orientation. Organizations located on the frontier of an input-oriented system will also be located on the frontier of an output-oriented system. In the CRS model, technical efficiency scores are the same for both input and output orientations. In the VRS model, however, these scores differ according to the orientation chosen. Coelli and Perelman (1996, 1999) note, however, that in many situations. [32]

2.2.1.3 Selection Between the Two Orientations

The orientation of the model should be chosen according to the variables (inputs or outputs) over which decision-makers have the greatest management power. For example, a public school principal probably has more management power over teaching staff (input) than over the number of pupils enrolled or pupil results (outputs). In this case, an input orientation is more appropriate.

In the public sector, but sometimes also in the private sector, a certain level of resources is allocated and guaranteed to organizations. In such cases, decision-makers seek to maximize the services provided and therefore choose an output-oriented approach. On the other hand, if the objective of decision-makers is to produce a certain level of output, they seek to minimize resource consumption. They therefore opt for an input orientation.

If no constraints are imposed on decision-makers and if they exercise management power over both resources (inputs) and services (outputs), the orientation of the model depends on the objectives set for the organizations. Is the aim to reduce costs (input orientation) or maximize production (output orientation)?

2.2.2 Parametric Approach SFA

Farrell (1957) was at the origin of the deterministic and parametric approaches. [45] The deterministic parametric frontier production function estimated by Aigner and Chu (1968) is based on the hypothesis of a production function giving the maximum possible output from factors of production. A production, cost, or profit frontier is said to be deterministic if we assume that deviations between the estimated function and actual observations correspond exclusively to production inefficiencies. It therefore has a fixed frontier in the sense that it has a single error term, which is positive and enables inefficiency to be detected.

This estimation technique is easier to estimate but is highly sensitive to measurement error. In addition, it neglects the possibility that a firm's performance may be affected by random effects beyond the producer's control (such as climatic hazards, input shortages, price fluctuations, etc.). [56]

2.2.2.1 Stochastic Production Functions

The major limitation of the first so-called deterministic frontiers developed is that they do not take into account the random variations (noise) inherent in measurements. All deviations from the frontier are considered to be technical inefficiencies. Aigner, Lovell, and Schmidt (1977), Battese and Corra (1977), and Meeusen and van den Broeck (1977) simultaneously developed stochastic frontier models (SFA) to deal with this limitation. These models include a positive efficiency term (like deterministic approaches).

In our study, we will estimate the production function for measurement of technical efficiency. In the SFA model, the error term is composed of technical inefficiency ("u") and white noise ("v"). Concerning the asymmetric term "u," an assumption must be made about its distribution in order to be able to separate the two contributions to the deviation from the frontier. The problem is that there is no theoretical model that allows a particular distribution to be chosen as hypothetical. Efficiency results are potentially sensitive to assumptions about the distribution of the asymmetric variable. Distributions frequently used are semi-normal distributions, exponential distributions, truncated normal distributions, and gamma distributions. And the symmetrical "v" element allows for purely random variations, reflecting measurement errors, model misspecification (variations linked to variables not taken into account in the model), and uncontrollable factors.

A stochastic production frontier function is specified as:

$$y_i = f(x_i, \beta) \exp(\epsilon_i)$$

with i= 1,2,.......,n and $\epsilon_i = v_i - u_i$
where
y_i: production observed;
x_i: input vector;
β: unknown parameters to estimate;
v_i: random measurement error term, normally distributed $(0.\sigma_v^2)$;
u_i: A non-negative random component, represents technical inefficiency;

However, during recent decades, the basic model has been extended in many directions and has been applied in many areas of economics. Literature on SFA has also been rapidly extended in recent years. Further extensions were made based on the type of data. It is now possible to use panel[2] data to measure the time-varying technical efficiencies. Besides, the selection of production function in measuring efficiency scores has also become rapidly diverse during recent decades.

The main reason for the extensive use of frontier analysis in economics is that, contrary to the neoclassical approach, it assumes every firm is fully efficient, when in

[2]a collection of quantities obtained across multiple individuals that are assembled over even intervals in time and ordered chronologically

reality firms are hardly fully efficient (Kumbhakar and Tsionas, 2006). Why do two identical paddy farmers produce different levels of output with the same level of input combination or the same level of output with different cost structures? The reason is economic inefficiency, which is the combination of technical, allocative, and distribution inefficiency and some unexpected exogenous shocks (Kumbhakar and Lovell, 2000).

The literature has mostly discussed two types of technical efficiency under the parametric approach. These are: (a) input-oriented (IO) technical efficiency; (b) output-oriented (OO) technical efficiency (Fare and Lovell, 1978; Farell, 1957). Literature has grown rapidly with output-oriented technical efficiency rather than input-oriented technical efficiency. Kumbhakar and Trionas (2006) stated, "Almost the entire literature on SFA models is filled with papers in which the output-oriented measure of technical efficiency is routinely used." [57]

2.3 DEA versus SFA

The DEA approach has a number of advantages (Kalaitzandonakes et al., 1992). [58] over the parametric method. These have been sufficiently highlighted in the literature (Coelli et al., 1998; Amara and Romain, 2000). [59] [45] Chachoua (2018) [54] summarizes some of the advantages of the DEA method:

- The DEA method takes into account several inputs producing several outputs in a synthetic, reliable, and original analysis of performance.
- Data envelopment analysis also has the merit of measuring the relative performance of a production unit compared with a group belonging to a given sector, such as banking, health, transport, agriculture, etc.
- The DEA method does not specify the functional relationship between inputs and outputs (the production function) or the distribution of the error term.
- The method also makes it possible to analyze the results by identifying the sources of inefficiency, evaluating the management, and evaluating the policies and strategies adopted. [60] In other words, the set of efficient units can be considered a benchmark for inefficient units.
- The availability of software tools in the form of solvers (DEAP, MaxDEA Pro, WinDeap, and EMS) makes it possible to introduce a very large number of obser-

vations into research into the relative performance of production units.

However, the DEA method also has a number of limitations, which may have consequences for the nature of the results obtained. One of the major criticisms of this method is that it ignores measurement errors and the influence of exogenous factors on the efficiency frontier. This means that statistical errors, random shocks, or white noise cannot be taken into account. [44] In such cases, the reliability of the results may be seriously called into question.

Then, the DEA method is not suitable for statistical testing and hypothesis testing (Amarav and Romain, 2000), as it is a non-parametric method where the boundary is determined by the data. Also, the frontier function estimated using this approach is very sensitive to extreme observations, which trace this frontier. However, there may be units outside the sample that are more efficient than the best in the sample.

The table 2.1 summarizes the main points of comparison between both approaches:

SFA approach (Stochastic Frontier Analysis)	DEA approach (Data Envelopment Analysis)
Parametric method: Statistical tests and analyses can be carried out using the statistical properties of the production function.	Non-parametric method: Hypotheses cannot be tested. Does not take sufficient account of statistical errors.
Uses maximum likelihood econometrics to estimate model parameters and test their significance.	Based on linear mathematical programming.
The parametric approach encompasses both deterministic and stochastic frontiers. It takes random factors into account (the stochastic frontier).	No random variation is possible. It is always deterministic, so it considers that any deviation from the production frontier is a source of inefficiency.
It's not always possible to break down the various components of inefficiency, particularly for multi-product technologies (the estimate generally only concerns a single product).	It can be used to estimate frontier production functions in situations with different multi-products and multi-inputs.
The functional form must be specified. It requires the technology to be represented by a particular parametric form.	No particular functional relationship specification for the technology.

Source: Author, 2024; inspired by Chaffai, 1997

Tableau 2.1: Comparison of parametric and non-parametric approaches

Conclusion

A comparison of the parametric and non-parametric approaches reveals the advantages and limitations of each approach. In the literature, numerous studies have utilized both approaches for comparison. These studies generally demonstrate that the results from both methods are complementary and consistent in analyzing efficiency scores.

In our study, we will employ both parametric and non-parametric approaches, stochastic frontier analysis (SFA), and data envelopment analysis (DEA), to estimate the technical efficiency of each port. In the DEA model, we will calculate efficiency scores, while in the SFA model, we will additionally examine the impact of certain explanatory variables on inefficiency.

Chapter 3

Benchmarking the Technical Efficiency of Port Terminals by using SFA and DEA

Introduction

The aim of this section is to present models used to measure and compare the performance of port terminals and to produce a benchmark that will enable the performance of each terminal to be defined on the basis of a set of parameters considered to be of interest for port activities in the ports under study. This performance will be assessed through technical efficiency, which identifies best practices and detects sources of inefficiency.

This chapter deals with efficiency models for port terminals, followed by an analysis of the validation conditions for these selected methods. We have opted for the measurement approaches of production function estimation (SfA) and data envelopment analysis (DEA) because, in addition to being widely used, their current application aims to provide a better assessment of technical efficiency.

3.1 Selection of Input and Output Clusters

In many studies, with many methodologies and research scopes, different ports in many countries have been investigated. Studies focusing on port performance measurement have generally aimed for the measurement of efficiency and effectiveness. Although port efficiency and port productivity seem to be similar to each other, they have different meanings. While efficiency expresses how the resources are being used, productivity deals with the relationship between inputs, processing, and the outputs obtained at the end of this process. [61]

Tableau 3.1: Port Efficiency Studies and Methodologies

first part				
Author(s)	**Year**	**Method**	**Inputs**	**Outputs**
Lopez Bermudez et.al.	2019	SFA	Frequency of ship calls.	Throughput (TEU).
Kutin et al.	2017	DEA	Draft, Terminal area, Quay length, Number of quay cranes and RTGs, Number of trucks	Container throughput.

continuation of table 3.1

Author(s)	**Year**	**Method**	**Inputs**	**Outputs**
Serebrisky et al.	2016	SFA	Area, Length, Mobile/quay cranes, Ship's cranes(dummy)	Throughput
Almawsheki and shah	2015	DEA	Terminal area, Quay length, Quay cranes, Yard equipment, Maximum draft	Container throughput
Rajasekar and Deo	2014	DEA	Number of berth, Berth length, Number of equipment, Number of employee	Throughput, Total cargo traffic
Schoyen and Odeck	2013	DEA	Berth length, Terminal area, Yard gantry cranes, Straddle carriers	Container throughput, Container handling trucks
Yuen et al.	2013	DEA	Berth length, Total shore length, Port area, Number of SSG, Number of storage yard cranes	throughput
Bichou	2013	DEA	Terminal area, Maximum draft, Total shore length, Quay crane index, Storage yard stowing index, Trucks and Vehicules, Gates	Throughput
Bichou	2012	DEA	Terminal area, Maximum draft, Quay length, Quay crane index, Gates	Container throughput

SFA and DEA methods have been widely used by researchers in order to determine the efficiency and productivity of container terminals around the globe.

The selection of variables in the study to assess the efficiency of the ports in review is therefore not fortuitous. It depends on the empirical review and the availability of data. The selection of variables for two models to assess port efficiency in review is therefore not fortuitous. It was guided first by the nature of the port logistics value chain and secondly by similar studies carried out and grouped in table 3.1. The final selection was determined by the availability of data over the period chosen.

3.1.1 DEA Model

In the DEA model, we have chosen one output (loading/unloading quantity) and three inputs (loading time, number of vessels, terminal length).

3.1.2 SFA Model

In this study, output is defined as the tonnage unloaded. Inputs are explanatory variables; Variables used in this study are those available for both ports, i.e., the Algerian port “Port Annaba” and the Canadian port “Port Quebec.”. They are loading or unloading time, terminal length, and the number of vessels handled during the study period. For the factors likely to influence technical efficiency, a set of factors was collected from the managers of two ports, and we retained three criteria that are common and considered interesting. These factors are “easy access” to port on a scale of 0 (difficult access), 1 (moderately difficult access), 2 (easy access), “security” on a scale of 0 (absence of security), 1 (presence of security), “draught” on a scale of 0 (low draft), 1 (medium draft), and 2 (adequate draft).

3.2 Specification of Models

After selecting the study sample (terminals), the input variables (production explanatory variables), the output variable (tonnage unloaded), and the inefficiency explanatory variables, we will specify the models to be used for estimating technical efficiency.

First, we use a parametric approach to determine technical efficiency scores. We estimate a stochastic production frontier from sample data using Frontier 4.1 software, which takes into consideration explanatory variables of inefficiency.

Secondly, a non-parametric approach is used to determine the technical efficiency scores of each port terminal. A linear program will be solved on the basis of sample data using WinDeap2.1 software.

3.2.1 Stochastic Function Method

The first method for studying the technical efficiency of terminals is a parametric approach, which proposes an approximation of a function by a functional form known a priori (Cobb douglas, translog, etc.), i.e., a mathematical equation gives a form to an efficient frontier. These approaches can be deterministic when they attribute any deviation from the frontier to efficiency and stochastic when the deviation from the frontier is the result of inefficiency on the one hand and randomness and measurement error on the other. In our study, we have chosen the stochastic approach. Two stochastic functions are used in the literature: the production function and the stochastic cost function. We chose the production function to measure technical efficiency. Before estimating production function (SFA) using Frontier 4.1 software, the following tests, which are preliminary to any measurement, were carried out using SPSS software.

1. A first test to check the independence of the error term. Independence means that the residuals are distributed independently of each other; this test is performed using the Durbin-Watson test. A Durbin-Watson test with a score close to 2 indicates the absence of autocorrelation of the residuals. The result of this test obtained by SPSS software is: Durbin-Watson d-statistic (2.06); this value is approaching 2, indicating weak autocorrelation, i.e., almost zero.

Model overview[b]

Modèle	R	R-deux	R-deux ajusté	Erreur standard de l'estimation	Durbin-Watson
1	,531[a]	,282	,184	11432510,740	2,069

a. Prédicteurs : (Constante), terminal, nombre, delai

b. Variable dépendante : tonnage

Source: Data calculated using SPSS software.

Figure 3.1: Result of error term independence

second test to check the correlation between the input variables (production explanatory variables). This test uses the tolerance measure and the Variance Inflation Factor (VIF), which must be less than 10, indicating the absence of multicollinearity. This test was performed by SPSS using the VIF command and indicates that all results are below 10.

Coefficients[a]

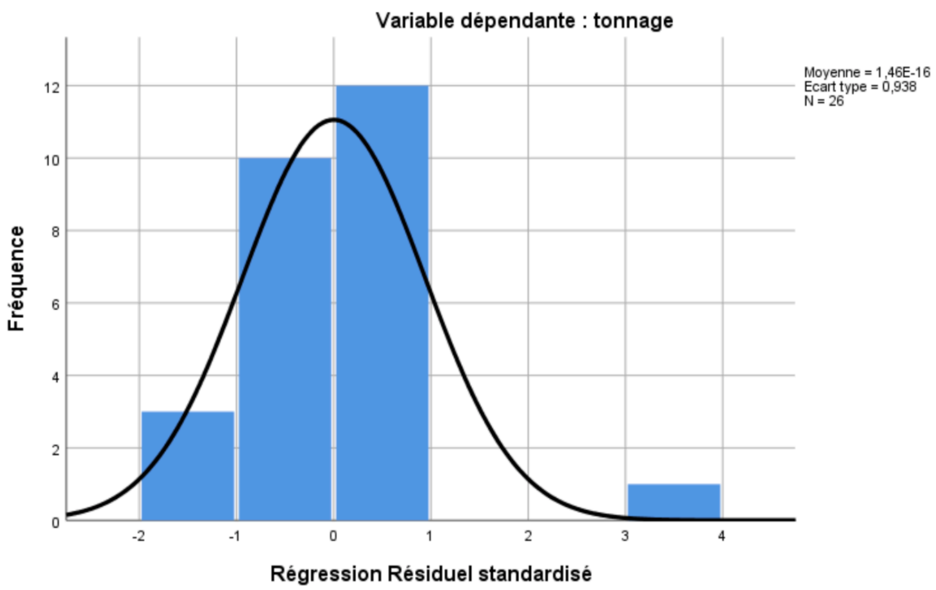
Modèle		Coefficients non standardisés B	Erreur standard	Coefficients standardisés Bêta	t	Sig.
1	(Constante)	-9185487,667	16405178,074		-,560	,581
	délai	1427,016	4543,512	,097	,314	,756
	nombre	337769,930	138407,413	,722	2,440	,023
	terminal	-4914,519	8507,789	-,193	-,578	,569

a. Variable dépendante : tonnage

Source: Data calculated using SPSS software.

Figure 3.2: VIF test results

2. As a third test to test the normality of the residuals, several methods already mentioned look at the distribution of the errors (goodness of fit test χ^2), Kolmogorov-Smirnov test, graphical tests, etc.). We performed the graphical test using SPSS software, and the figure below shows that the distribution of the residuals is normal.

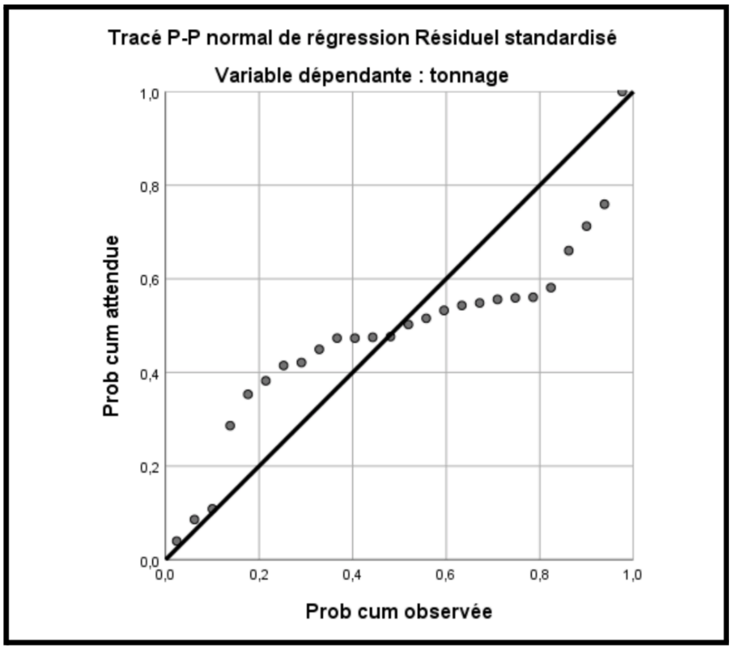


Source: Data calculated using SPSS software.

Figure 3.3: normal distribution of residuals

3. A fourth test is needed to verify the condition of linearity between dependent and

independent variables. To do this, the appearance of the scatterplot graph obtained from SPSS allows us to conclude that there is a linear relationship between dependent variables and independent variables. The figure below shows an almost linear relationship between input and output variables.



Source:Author, data calculated using SPSS software.

Figure 3.4: Linear relationship between inputs and outputs

4. A fifth test for homoscedasticity, homoscedasticity indicates that variance of one variable is compatible with variance of another variable. This postulate is verified using SPSS software, which gives a non-significant result using the H_0 hypothesis, which means that homoscedasticity is present ().

H_0 = absence of homoscedasticity.
H_1 = homoscedasticity exists.

After checking five tests on our data to obtain the most reliable estimators, we specified the SFA model and tested its validity (SFA) through hypothesis testing to choose the most appropriate model. Empirical estimation of production function was then carried out using FRONTIER4.1 software.

3.2.1.1 The Used Model Presentation

Variables of the final model retained are: output represented by tonnage, and inputs (explanatory variables of terminal operation), which are: loading time, number of vessels, terminal length, and explanatory variables of technical inefficiency, which are security, easy access, and draft, knowing that our model was estimated by data from 26 terminals.

The translog stochastic production model used to measure the technical efficiency of each terminal in both ports is:

$$\begin{aligned}\mathrm{Prod}_{it} = {} & \beta_0 + \beta_1\mathrm{time} + \beta_2\mathrm{ships} + \beta_3\mathrm{terminal} + \frac{1}{2}\beta_{11}\mathrm{time} * \mathrm{time} \\ & + \frac{1}{2}\beta_{22}\mathrm{ships} * \mathrm{ships} + \frac{1}{2}\beta_{33}\mathrm{terminal} * \mathrm{terminal} + \beta_{12}\mathrm{time} * \mathrm{ships} \\ & + \beta_{13}\mathrm{time} * \mathrm{terminal} + \beta_{23}\mathrm{ships} * \mathrm{terminal} + v_{it} - u_{it}\end{aligned} \tag{3.1}$$

The model for the inefficiency term is written as follows:

$$u_{it} = \delta_0 + \delta_1\mathrm{access} + \delta_2\mathrm{security} + \delta_3\mathrm{draught} + w_{it} \tag{3.2}$$

With :
time: loading time;
ships: number of ships handled;
terminal: length of terminal;
access: access to the port;
security: security;
draught: length of draught;
v_{it}: random error term;
u_{it}: inefficiency term of the i -th terminal in period t;
w_{it}: error term of the inefficiency term;
β: coefficients of the stochastic production frontier model;
δ: coefficients of the inefficiency model.

3.2.2 Data Envelopment Analysis (DEA) Model

The second methodology adopted to study the technical efficiency of port terminals is a non-parametric approach. This method uses two models to estimate efficiency. The first model, CRS, assumes that all operators operate with constant returns to scale, while the second model, VRS, assumes that all operators operate with varying returns to scale.

In our study, we will choose two models, CRS and VRS, to measure total and pure technical efficiency, respectively. Scale efficiency is obtained by dividing the technical inefficiency score of the VRS and CRS models, thereby determining how much scale efficiency can be improved so that operators operate at an optimal size.

Moreover, since in the port sector, the tonnage of goods handled is modulated instantaneously by demand, which is not controllable, a choice of input orientation that minimizes port operating factors is essential. The model below is a linear program of CRS input orientation for terminal k selected, given that the variables chosen are: output, tonnage handled, and three inputs.

1. **CRS model, input orientation of port terminal k among 26 terminals**
   Dual equation

$$\text{Minimize } \theta_k - \epsilon S^{+}_{\text{time}} - \epsilon S^{-}_{\text{ships}} - \epsilon S^{-}_{\text{terminal}} - \epsilon S^{-}_{\text{security}} - \epsilon S^{-}_{\text{draught}} \tag{3.3}$$

$$y_{\text{time},k} - \sum_{j=1}^{26} \lambda_j y_{\text{time},j} + S^{+}_{\text{time}} = 0 \tag{3.4}$$

$$\theta_1 x_{\text{ships},k} - \sum_{j=1}^{26} \lambda_j x_{\text{ships},j} - S_{\text{ships}} = 0 \tag{3.5}$$

$$\theta_1 x_{\text{time},k} - \sum_{j=1}^{26} \lambda_j x_{\text{time},j} - S_{\text{time}} = 0 \tag{3.6}$$

$$\theta_1 x_{\text{ships},k} - \sum_{j=1}^{26} \lambda_j x_{\text{ships},j} - S_{\text{ships}} = 0 \tag{3.7}$$

$$\theta_1 x_{\text{terminal},k} - \sum_{j=1}^{26} \lambda_j x_{\text{terminal},j} - S_{\text{terminal}} = 0 \tag{3.8}$$

$$\lambda_j, s_r, s_i \geq 0 \quad \forall j = 1, \ldots, 26, \quad r = 1, \quad i = 1, \ldots, 3 \tag{3.9}$$

2. **VRS model, input orientation of port terminal number k among 26 terminals**
   Dual equation

$$\text{Minimize } \theta_k - \epsilon S^{+}_{\text{time}} - \epsilon S^{-}_{\text{ships}} - \epsilon S^{-}_{\text{terminal}} - \epsilon S^{-}_{\text{security}} - \epsilon S^{-}_{\text{draught}} \tag{3.10}$$

$$y_{\text{time},k} - \sum_{j=1}^{26} \lambda_j y_{\text{time},j} + S^{+}_{\text{time}} = 0 \tag{3.11}$$

$$\theta_1 x_{\text{ships},k} - \sum_{j=1}^{26} \lambda_j x_{\text{ships},j} - S_{\text{ships}} = 0 \tag{3.12}$$

$$\theta_1 x_{\text{time},k} - \sum_{j=1}^{26} \lambda_j x_{\text{time},j} - S_{\text{time}} = 0 \tag{3.13}$$

$$\theta_1 x_{\text{ships},k} - \sum_{j=1}^{26} \lambda_j x_{\text{ships},j} - S_{\text{ships}} = 0 \tag{3.14}$$

$$\theta_1 x_{\text{terminal},k} - \sum_{j=1}^{26} \lambda_j x_{\text{terminal},j} - S_{\text{terminal}} = 0 \tag{3.15}$$

$$\sum_{j=1}^{26} \lambda_j = 0 \tag{3.16}$$

$$\lambda_j, s_r, s_i \geq 0 \quad \forall j = 1, \ldots, 26, \quad r = 1, \quad i = 1, \ldots, 3 \tag{3.17}$$

With :

y_{rk}: the quantity of output r produced by organisation k;

x_{ik} : the quantity of input i consumed by organisation k;

λ_j: represents the weight associated with the outputs and inputs of organisation j;

θ_k: represent the technical efficiency of organisation k ;

s_r: representing slacks on outputs and if slacks on inputs;

3.3 The Sample Study

We chose to evaluate 7 existing port terminals (containers, chemicals, metallurgical products, M.O.T.S., agricultural products, petroleum products, and construction materials) at Annaba port and 6 terminals at Quebec port (petroleum derivatives, agriculture, agricultural and industrial supplies and fertilizers, ore concrete (cement), chemicals, and miscellaneous products). The sample includes 13 terminals taken over two years (2022-2023), which gives 26 measures to test their efficiency in terms of input and output and in terms of inefficiency.

3.4 Data Processing Software

In order to process data relating to terminal characteristics in each country, we have used three software packages, which are the most appropriate for our study:

1. **SPSS**

   SPSS software was initially used to check the validation constraints of production function estimation applicability, and in this respect, several tests were examined in order to move on to the analysis of stochastic estimation.

2. **Win DEAP 2.1**

   The computer program DEAP 2.1 In Windows (WinDeap 2.1), it was used to construct the terminal production curve through data envelope analysis (DEA) by calculating the CRS, VRS, and EE.

3. **Frontier 4.1**

   A computer program for stochastic srontier production and sost function estimation was used to obtain maximum likelihood estimates of stochastic production and production frontier parameter numbers. The two main model specifications considered in the program are the time-varying inefficiency model and the model specification in which inefficiency effects are directly influenced by a number of variables.

Conclusion

This chapter presents the study area and sample, as well as the methods and software used to analyze the technical efficiency of terminals in the two countries. A comparison of the terminals of two ports located in Annaba and Quebec. A non-parametric statistical method to measure CCR (constant scale return) model scores and VRS (variable scale return) model scores. These measures allow us to compare the two zones used to assess technical efficiency. The two main models are the time-varying inefficiency model and the model specification, in which the inefficiency effects are directly influenced by a number of variables. These models are run by software packages that are most commonly used to assess technical efficiency.

Chapter 4

Results and Discussion

Introduction

This chapter compares the performance of both port terminals in the Annaba and Quebec regions. It will analyze and interpret empirical results of technical efficiency estimates using the non-parametric method (DEA) and econometric estimates of technical efficiency associated with the stochastic SFA function of port terminals. The chapter begins with a static data description, followed by an estimation of technical efficiency using two software programs, Frontier4.1 and WinDEAP2.1, and finally an interpretation and comparison of terminals in the two regions.

4.1 Technical efficiency Results and Interpretation

This first part focuses on the presentation of results obtained by the DEA method, which analyzes the technical efficiency of port terminals located in Algeria and Canada, specifically the ports of Annaba and Quebec, and the results of the technical inefficiency also obtained by the estimation of the SFA model.

The main objective of this study is to determine the presence of technical inefficiencies in various terminals, measure their scores, and determine all explanatory factors of inefficiency.

4.1.1 Results of DEA Model

In this section, we will evaluate the performance of port terminals using a parametric method based on linear programming to solve models and assess the technical efficiency of each terminal (DMU). As a reminder, for each unit (terminal), the approach consists of comparing inputs (loading and unloading times, number of vessels, and terminal length) with their output (tonnage). We will use both the constant returns to scale (CRS) model by Charnes, Cooper, and Rhodes (CCR-1978) and the variable returns to scale (VRS) model by Banker, Charnes, and Cooper (BCC-1984). The selection of these two models will allow us to calculate pure technical efficiency and scale efficiency in order to obtain the total efficiency of each terminal.

As a reminder, DEA models can be input-oriented (objective: minimize inputs while maintaining the same level of outputs) or output-oriented (objective: increase outputs with the same level of inputs) (Malana and Malano, 2006). [62]

Our main objective was to measure efficiency under the assumption that a DMU can produce different quantities of output using the same quantity of inputs, because each DMU uses a fixed quantity of inputs to produce different levels of output. Thus, the method compares each DMU with the most efficient DMU. Finally, efficiency estimations are done using WinDeap software.

4.1.2 Models and Descriptive Statistics for the Sample

The analysis of port terminal efficiency is based on the concomitant use of two categories of return-to-scale models: the constant return-to-scale (CRS) model of Charnes, Cooper, and Rhodes and the variable return-to-scale (VRS) model of Banker, Cooper, and Rhodes. At this stage, deducing scale efficiency (SE) is the ultimate aim.

Field Internship

A field survey took place over a period of two months. It covered two countries, including port terminals in Annaba, Algeria (containers, chemical products, metallurgical products, MOTS, agricultural products, petroleum products, and construction materials) and port terminals in Quebec (petroleum derivatives, agriculture, agricultural and industrial supplies and fertilizers, ore, concrete (cement), chemical products, and miscellaneous products).

4.1.3 Sample Descriptive Statistics

The construction of a technical efficiency model is based on determining the most appropriate inputs and outputs for analyzing the technical efficiency of port terminals. Port efficiency at the terminal level is based on three key indicators: handled tonnage, number of vessels, and loading and unloading time.

Port	Characteristics	Tonnage	Unloading time	Number of vessels	Terminal length
Annaba Algeria	Mean	436010	2759	23	508
	Standard deviation	556187	551	3	198
	Minimum	3554	1840	18	180
	Maximum	2468234	3700	28	950
	Observation	14	14	14	14
Quebec Canada	Mean	9911627	1408	72	1368
	Standard deviation	11655198	250	14	198
	Minimum	67132.08	858.67	51	1120
	Maximum	60980681	2066	98	1700
	Observation	12	12	12	12

Source: Calculations based on 2022-2023 data

Tableau 4.1: Sample descriptive statistics

Once the inputs and outputs are chosen, we can define a curve corresponding to the best output/input ratios, known as the "efficiency frontier.". This frontier can be used to identify and rank units with a high likelihood of inefficiency.

4.1.4 Parameters of DEA

Tableau 4.2: Parameters of DEA model

first part						
Port	**Terminal**	**Type**	**Tonnage**	**Unloading time**	**Number of vessels**	**Terminal length**
Annaba	1	Containers	403312	2140	28	950
		Containers	419320	2980	26	950
	2	Chemical products	20739	2090	21	505
		Chemical products	90658	2510	24	505
	3	M.O.T.S	3554	3210	21	350
		M.O.T.S	13314	2980	22	350
	4	Construction materials	2468234	3520	25	460
		Construction materials	2297092	3700	20	460
	5	Metallurgical products	39037	3007	24	350
		Metallurgical products	64923	3700	27	350
	6	Agricultural products	186059	2140	27	760
		Agricultural products	16935	1980	23	760
	7	Food products	52606	2830	20	180
		Food products	28352	1840	18	180

continuation of table 4.2						
Port	**Terminal**	**Type**	**Tonnage**	**Unloading time**	**Number of vessels**	**Terminal length**
Quebec	1	Chemical products	727327	1753	80	1120
		Chemical products	5893879	1669	56	1120
	2	Other goods and miscellaneous products	112407	959	52	1498
		Other goods and miscellaneous products	364083	1503	51	4198
	3	Agricultural products	1448516	959	62	1500
		Agricultural products	8680036	2066	52	1500
	4	Mineral	1555620	859	72	1700
		Mineral	16994823	1484	77	1700
	5	Petroleum and derivatives	21690568	1428	79	1200
		Petroleum and derivatives	60980681	1353	94	1200
	6	Wood in chips or particles	67132	1434	98	1190
		Wood in chips or particles	424448	1426	86	1190

4.2 Terminals Efficiency Analysis (DEA)

An analysis of port terminal efficiency scores is carried out for two ports. The unit of analysis adopted in our case is the port terminal. The Annaba region has seven port terminals, and the Quebec region has six port terminals. The scale model is derived from the terminal efficiency analysis, which is based on the simultaneous use of two categories of model scales, the CRS and VRS models.

4.2.1 Annaba Port Area

The average efficiency score using technology (CRS) in Annaba Port 4.1 is around 0.20. This apparently low value means that loading times, the number of vessels handled, and terminal length did not produce the expected results in terms of tonnage.

```
Instruction file = $$TEMP$$.INS
Data file        = $$ANNABA$$.DTA

 Input orientated DEA

 Scale assumption: VRS

 Slacks calculated using multi-stage method


 EFFICIENCY SUMMARY:

  firm  crste  vrste  scale

    1  0.269  0.980  0.274 irs
    2  0.201  0.718  0.280 irs
    3  0.014  0.880  0.016 irs
    4  0.052  0.753  0.068 irs
    5  0.002  0.857  0.002 irs
    6  0.007  0.818  0.009 irs
    7  1.000  1.000  1.000  -
    8  1.000  1.000  1.000  -
    9  0.021  0.750  0.028 irs
   10  0.035  0.668  0.052 irs
   11  0.124  0.911  0.136 irs
   12  0.012  0.929  0.013 irs
   13  0.054  1.000  0.054 irs
   14  0.029  1.000  0.029 irs

 mean  0.201  0.876  0.212

Note: crste = technical efficiency from CRS DEA
      vrste = technical efficiency from VRS DEA
      scale = scale efficiency = crste/vrste
```

Source: winDEAP results

Figure 4.1: CRS, VRS and EE scores at Annaba port

About technology (VRS), the score obtained by Annaba port is 0.87, with two terminals having an optimum VRS of 1. With two terminals showing an optimum VRS of 1, this efficiency can be explained, according to data observed, by a rather efficient management of available resources. Scale efficiency showed a low score of 0.21. This inefficiency can be explained, according to data observed, by a rather inefficient management of available resources in general.

The decomposition of efficiency of scale has enabled us to make other readings on the returns (constant, decreasing, and increasing) of terminals. For Annaba port, results show that terminals operate largely under increasing returns to scale and one terminal (over two periods, 2022–2023) under constant returns to scale (score equal to 1). Scale efficiency presents two situations: a first situation of constant returns to scale, i.e., the situation has reached its optimal size (or its efficient scale). A second situation is increasing returns to scale (IRS). An organization in this situation has not yet reached its optimum size. To improve its scale efficiency, it must increase its tonnage processing production at the terminals, i.e., a variation in output production of 1% implies a variation in input consumption of less than 1%.

4.2.2 Quebec Port Area

The average efficiency score using technology (CRS) in Quebec terminals is around 0.19. This apparently low value means that the operation and organization of port flows have not produced the expected results in terms of tonnage handled.

```
Instruction file = $$TEMP$$.INS
Data file        = $$quebec$$.DTA

 Input orientated DEA

 Scale assumption: VRS

 Slacks calculated using multi-stage method


 EFFICIENCY SUMMARY:

  firm  crste  vrste  scale

    1  0.014  1.000  0.014 irs
    2  0.162  1.000  0.162 irs
    3  0.003  1.000  0.003 irs
    4  0.011  1.000  0.011 irs
    5  0.036  1.000  0.036 irs
    6  0.257  1.000  0.257 irs
    7  0.040  1.000  0.040 irs
    8  0.340  0.820  0.415 irs
    9  0.423  0.997  0.424 irs
   10  1.000  1.000  1.000  -
   11  0.001  0.993  0.001 irs
   12  0.008  0.995  0.008 irs

 mean  0.191  0.984  0.198

Note: crste = technical efficiency from CRS DEA
      vrste = technical efficiency from VRS DEA
      scale = scale efficiency = crste/vrste
```

Source: winDEAP results

Figure 4.2: CRS, VRS and EE scores at Quebec port

About technology (VRS), the score obtained by Quebec Port is 0.98. According to the data observed, this efficiency can be explained by the presence of resources and adequate organization at port level. Scale efficiency showed a low score of 0.19. This inefficiency can be explained, according to data observed, by a rather inefficient management of available resources in general. Results show that terminals operate largely under increasing returns to scale and one terminal under constant returns to scale (score equal to 1). An organization in this situation has not yet reached its optimal size. To improve its scale efficiency, it must increase its tonnage processing production at the terminal level, i.e., a variation in output production of 1% implies a variation in input consumption of less than 1%.

4.2.3 Simultaneous Score

The average efficiency score using CRS, as shown in figure 4.3, is around 0.08. This apparently low value means that existing infrastructure in both ports has not produced the expected results in terms of tonnage.

```
Instruction file = $$TEMP$$.INS
Data file        = $$deux ports$$.DTA

 Input orientated DEA

 Scale assumption: VRS

 Slacks calculated using multi-stage method

 EFFICIENCY SUMMARY:

  firm  crste  vrste  scale

    1   0.022  0.808  0.027 irs
    2   0.025  0.706  0.035 irs
    3   0.002  0.876  0.002 irs
    4   0.006  0.752  0.008 irs
    5   0.000  0.857  0.000 irs
    6   0.001  0.818  0.001 irs
    7   0.152  0.823  0.185 irs
    8   0.177  1.000  0.177 irs
    9   0.003  0.750  0.003 irs
   10   0.004  0.668  0.006 irs
   11   0.011  0.813  0.013 irs
   12   0.001  0.895  0.001 irs
   13   0.006  1.000  0.006 irs
   14   0.003  1.000  0.003 irs
   15   0.014  0.784  0.018 irs
   16   0.016  0.811  0.020 irs
   17   0.003  1.000  0.003 irs
   18   0.011  0.819  0.013 irs
   19   0.036  1.000  0.036 irs
   20   0.257  0.737  0.349 irs
   21   0.040  1.000  0.040 irs
   22   0.034  0.749  0.045 irs
   23   0.423  0.909  0.465 irs
   24   1.000  1.000  1.000  -
   25   0.001  0.912  0.001 irs
   26   0.008  0.879  0.009 irs

 mean   0.087  0.860  0.095

Note: crste = technical efficiency from CRS DEA
      vrste = technical efficiency from VRS DEA
      scale = scale efficiency = crste/vrste
```

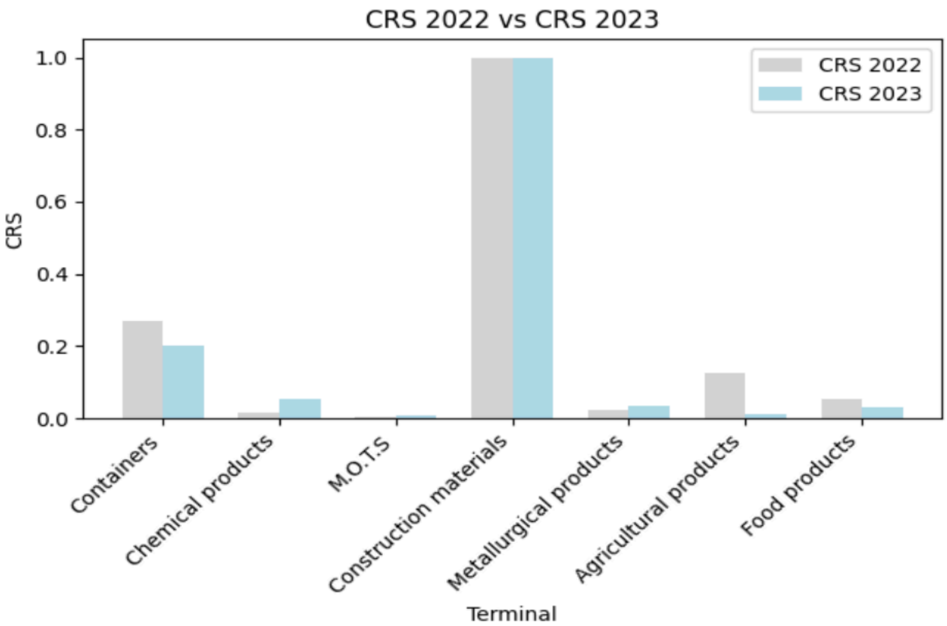
Source: winDEAP results

Figure 4.3: CRS, VRS and EE scores for both ports

Regarding VRS technology, the score obtained is 0.86. This efficiency can be explained, according to data observed, by the presence of resources and adequate organization at port level. Scale efficiency showed a low score of 0.09. This inefficiency can be explained by the rather inefficient management of available resources in general. For both ports, the results show that terminals operate largely under increasing efficiency of scale and a terminal under constant efficiency (score equal to 1). To improve its efficiency of scale, it needs to increase its tonnage processing output at the terminal level.

4.2.4 Results in Graphs

1. **Annaba Port**

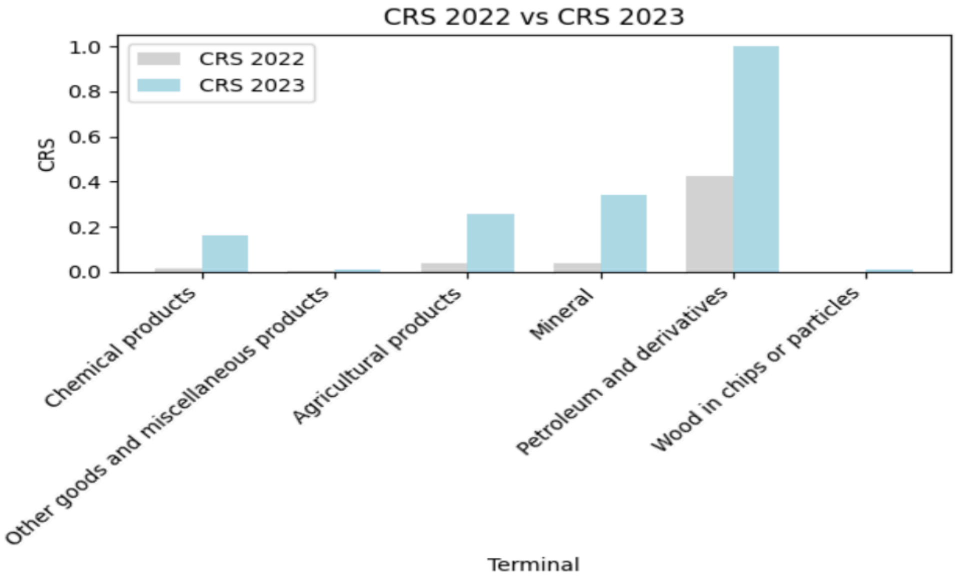


Source: Calculations based on 2022-2023 data

Figure 4.4: CRS values-Annaba's port 2022-2023

The graph 4.4 shows the CRS values of Annaba Port for 2022 and 2023. Construction materials terminals achieved maximum efficiency according to the CCR/CRS model, with a value of 1 (100%) in each year, indicating optimal use of available resources. In contrast, other terminals show an efficiency of less than 0.2, implying significant technical inefficiency in relation to the efficiency frontier.

2. **Quebec Port**

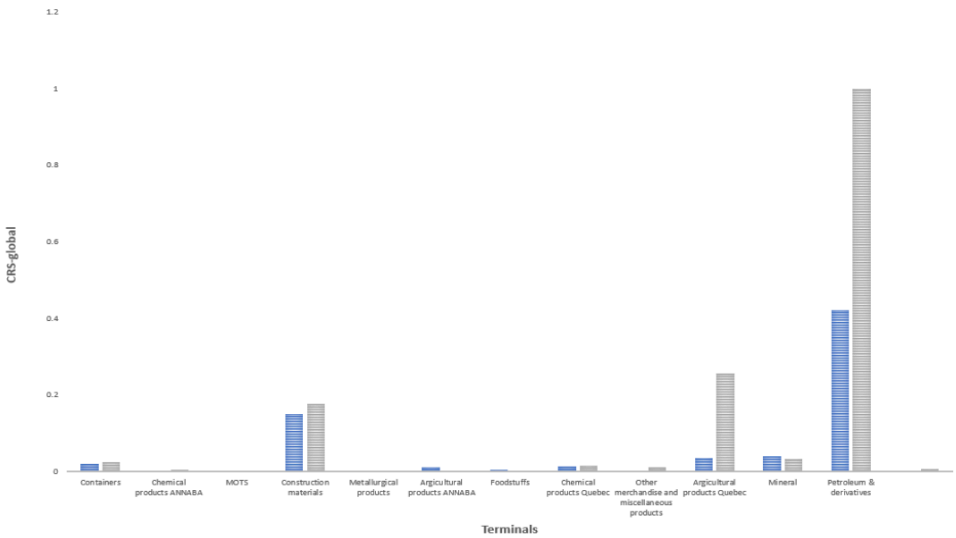


Source: Calculations based on 2022-2023 data

Figure 4.5: CRS values-Quebec's port 2022-2023

This graph 4.5 shows CRS values for 2022 and 2023 Quebec port. "Petroleum and Derivatives" terminal in 2023 reaches a maximum value of 1, indicating optimal efficiency under constant returns to scale; the value in 2022 is less than 1. On the other hand, the "Goods and Miscellaneous Products" terminal in both years has a CRS value close to 0, indicating significant technical inefficiency. These values show that some terminals use their resources much more efficiently than others.

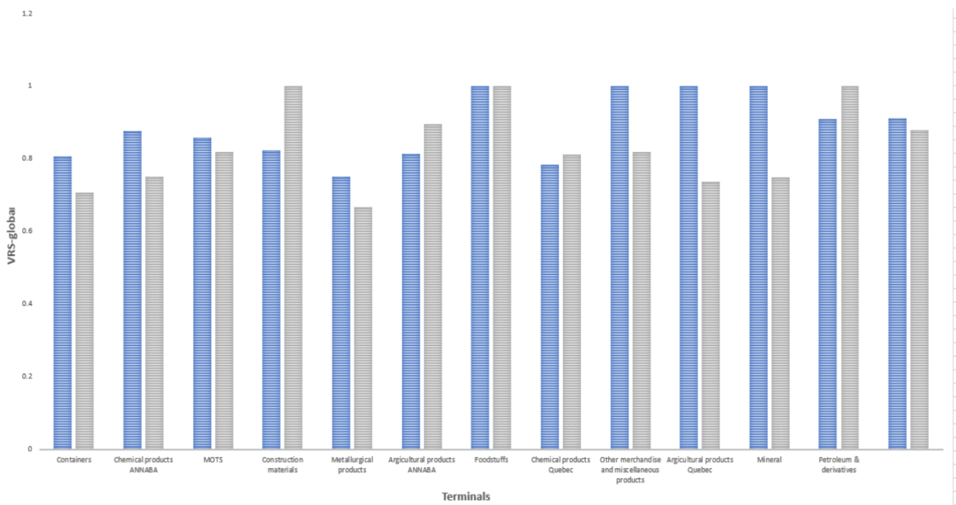
3. **Both Ports**



Source: Calculations based on 2022-2023 data

Figure 4.6: CRS values: Annaba and Quebec ports 2022-2023

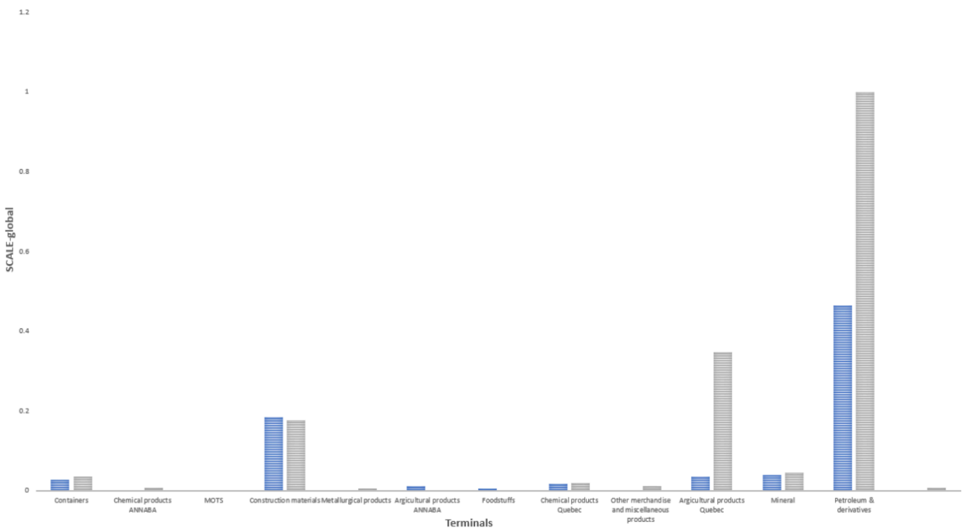
The graph 4.6 shows CRS values for both ports for 2022 and 2023. In 2023, only the "petroleum" terminal will achieve optimum efficiency according to the CRS model, with a value of 1. In contrast, other terminals all show an efficiency of less than 1, indicating inefficiency in their use of resources in relation to the efficiency frontier.



Source: Calculations based on 2022-2023 data

Figure 4.7: VRS values: Annaba and Quebec ports 2022-2023

The graph 4.7 shows VRS values for both ports for 2022 and 2023. In 2023. In 2022, the food, construction materials, and oil terminals reached an optimum value of 1, indicating maximum efficiency. Goods, agricultural products, and mineral terminals also reached this optimum value in 2022. In 2023, in addition to the terminals mentioned for 2022, construction materials and petroleum terminals also achieved an optimum value, indicating an improvement in their efficiency compared with the previous year.



Source: Calculations based on 2022-2023 data

Figure 4.8: SCALE values: Annaba and Quebec ports 2022-2023

For scale efficiency graph 4.8 for both ports, only the oil terminal reaches an optimum value of 1 in 2023. Other terminals show values below 1, indicating that they are not exploiting their resources on an optimal scale during these periods.

4.2.5 Technical Efficiency of both ports

The efficiency score for ports in Algeria and Canada over a two-year period is calculated using the production-oriented CCR-DEA model, assuming constant returns to scale (CRS). Technical efficiency results were obtained using WinDeap software. This production-oriented DEA model makes it possible for port comparisons whose input and output values can be double those of an average port. Therefore, the use of TRC assumes that a small port can operate as efficiently as a much larger port.

Year	Mean (%)	Minimum	Number of efficient terminal
2022	89	75	13
2023	83	67	13
Average	86	71	

Source: Calculations based on 2022-2023 data

Tableau 4.3: Technical efficiency score

The technical efficiency scores for 2022 and 2023 in Table 4.3 show the average efficiency scores, minimum values, and number of efficient terminals. With an average technical efficiency score of 89% in 2022 and 83% in 2023,

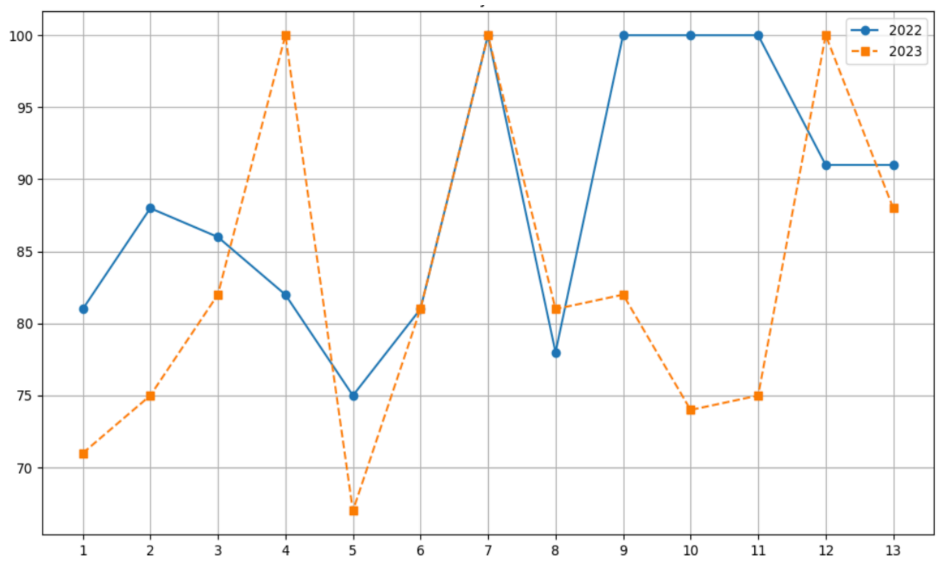
There is a slight decrease of 6%. It should be noted that in both years, there were 13 terminals operating efficiently. Table 4.4 details specific technical efficiency scores for each terminal in Algeria and Canada. In 2022, Algeria will have achieved optimal efficiency values for food products (100%) and construction materials (100%), while Canada will have achieved efficiency values of 100% for other goods and miscellaneous products. In 2023, Algeria maintained high efficiency in food products (100%) and showed improvements in M.O.T.S. (82%). Canada has improved its efficiency in petroleum and its derivatives (100%) and wood products (88%).

Port	N°	Terminal	2022	2023
Annaba	1	Containers	81%	71 %
	2	Chemical products	88%	75%
	3	M.O.T.S	86%	82%
	4	Construction materials	82%	100%
	5	Metallurgical products	75 %	67%
	6	Agricultural products	81%	81%
	7	Food products	100%	100%
Quebec	8	Chemical products	78%	81%
	9	Other goods and miscellaneous products	100 %	82%
	10	Agricultural products	100 %	74%
	11	Mineral	100 %	75 %
	12	Petroleum and derivatives	91%	100 %
	13	Wood in chips or particles	91 %	88%

Source: Calculations based on 2022-2023 data

Tableau 4.4: Percentage efficiency of terminals

The DEA model produces an efficiency score generally between 0 and 1, which is expressed as an efficiency percentage between 0% and 100%. The upper limit is set at 1 or 100% to reflect the idea that a unit cannot be more than 100% efficient.



Source: Calculations based on 2022-2023 data

Figure 4.9: Technical Efficiency for 2022 and 2023

The graph 4.9 presents terminal efficiency for two countries, Canada and Algeria, for 2022 and 2023. Terminals that achieve 100% efficiency create a frontier, indicating optimal performance compared to those with lower efficiency scores.

4.3 Terminals Efficiency Analysis (SFA)

Estimation results of the SFA model, type "translog," are directly provided by the Frontier 4.1 program. In this section, we have introduced our variables: tonnage (output), loading time, number of vessels at quay, and terminal length (three inputs), along with three explanatory criteria for this estimation, namely security, draft, and easy access, to estimate the stochastic production frontier represented by the partial production elasticities.

The results of production frontier estimations are grouped in the table 4.5. We recall that the estimation of stochastic production function type is calculated on the basis of a panel dataset of 26 port terminals over a period of two years (2022–2023). Its variables consist of one output (handled tonnage) and three inputs (terminal length, loading time, and number of vessels) and three explanatory variables of inefficiency, which are security, draft, and easy access, which were collected by the ship operations manager.

Tableau 4.5: Table of variables for estimating production frontier (SFA)

first part								
Sequence	Period	Tonnage	Unloading time	Number of Vessels	Terminal length	Easy access	Security	Draught
1	1	403312	2140	28	950	1	0	1
2	1	419320	2980	26	950	1	0	1
3	1	20739	2090	21	505	1	1	1
4	1	90658	2510	24	505	1	1	1
5	1	3554	3210	21	350	0	1	1
6	1	13314	2980	22	350	0	1	1
7	1	2468234	3520	25	460	1	0	1
8	1	2297092	3700	20	460	1	0	1
9	1	39037	3007	24	350	1	1	1
10	1	64923	3700	27	350	1	1	1
11	1	186059	2140	27	760	1	0	1
12	1	16935	1980	23	760	1	0	1
13	1	52606	2830	20	180	1	1	0
14	1	28352	1840	18	180	1	1	0
15	1	727327	1753	80	1120	2	1	2
16	1	5893879	1669	56	1120	2	1	2
17	1	112407	959	52	1498	2	1	2
18	1	364083	1503	51	1498	2	1	2
19	1	1448516	959	62	1500	2	1	2
20	1	8680036	2066	52	1500	2	1	2

continuation of table 4.5								
Sequence	Period	Tonnage	Unloading time	Number of Vessels	Terminal length	Easy access	Security	Draught
21	1	1555620	859	72	1700	2	1	2
22	1	16994823	1484	77	1700	2	1	2
23	1	21690568	1428	79	1200	2	1	2
24	1	60980681	1353	94	1200	2	1	2
25	1	67132	1434	98	1190	2	0	2
26	1	424448	1426	86	1190	2	0	2

4.3.1 Annaba Port Area

Once the Frontier 4.1 program has run the input data, i.e., the four variables tonnage, loading time, terminal length, number of vessels handled, and three explanatory variables (security, easy access, draft),. Results from figure 4.10 show a gamma estimator value of 0.91, which is significant at the 1% threshold, indicating that the model is good. The gamma value illustrates "that the variation at the level of the units studied (terminals) in relation to the estimated frontier" is explained by the technical inefficiency at 91% of this variability. Therefore, 91% of data variation between terminals can be attributed to technical inefficiency, while the remaining 8% is pure "noise.". Additionally, the LR (Likelihood Ratio) statistic also shows a significant value at the 1% level, indicating the effects of the model's technical inefficiency.

```
Output from the program FRONTIER (Version 4.1c)

instruction file = terminal
data file =        Annaba.txt

 Tech. Eff. Effects Frontier (see B&C 1993)
 The model is a production function
 The dependent variable is logged

the ols estimates are :

                  coefficient      standard-error    t-ratio

  beta 0         -0.23962717E+02  0.11713193E+02 -0.20457887E+01
  beta 1         -0.29335782E-08  0.10859784E-08 -0.27013228E+01
  beta 2          0.20225215E+01  0.14291472E+01  0.14151947E+01
  beta 3          0.16325495E-08  0.19404353E-08  0.84133160E+00
  beta 4          0.16427044E+01  0.28701137E+01  0.57234819E+00
  beta 5          0.29006167E-08  0.30907351E-08  0.93848762E+00
  beta 6          0.25719000E+01  0.71717487E+00  0.35861547E+01
  beta 7         -0.38509246E-09  0.13003409E-08 -0.29614731E+00
  sigma-squared   0.94673112E+00
log likelihood function =  -0.13550873E+02
the estimates after the grid search were :

  beta 0         -0.23215216E+02
  beta 1         -0.29335782E-08
  beta 2          0.20225215E+01
  beta 3          0.16325495E-08
  beta 4          0.16427044E+01
  beta 5          0.29006167E-08
  beta 6          0.25719000E+01
  beta 7         -0.38509246E-09
  delta 0         0.00000000E+00
  delta 1         0.00000000E+00
  delta 2         0.00000000E+00
  delta 3         0.00000000E+00
  sigma-squared   0.96449982E+00
  gamma           0.91000000E+00
```

Source: FRONTIER results

Figure 4.10: SFA results of Annaba port

The negative sign (-) in the inefficiency model indicates that dominant variables represented by the characteristics “security, easy access, and draft” increase the technical efficiency of tonnage handling in the study region. Ultimately, a gamma value of 91% demonstrates that inefficiency is caused by factors that can be controlled by port operators, while 9% is due to uncontrollable random factors. Also, the (σ^2) is estimated at 0.91, which is a significant value at the 1% level, showing that technical inefficiency was the cause of variation in tonnage handled at port.

4.3.2 Quebec Port Area

The results from the following figure 4.11 show a gamma estimator value of 0.78, i.e., 78% of variation in data between terminals can be attributed to technical inefficiency, while the remaining 22% is due to pure “noise.”. The LR (Likelihood Ratio) statistic also shows a significant value at the 1% level, indicating the effects of the model’s technical inefficiency.

```
Output from the program FRONTIER (Version 4.1c)

instruction file = terminal
data file =        Quebec.txt

 Tech. Eff. Effects Frontier (see B&C 1993)
 The model is a production function
 The dependent variable is logged

the ols estimates are :

                  coefficient      standard-error    t-ratio

  beta 0         -0.51808536E+01  0.25813005E+02 -0.20070711E+00
  beta 1          0.33318282E-07  0.23229620E-07  0.14343016E+01
  beta 2         -0.28227497E+01  0.27363946E+01 -0.10315580E+01
  beta 3         -0.60241937E-08  0.40158967E-08 -0.15000868E+01
  beta 4          0.29943478E+01  0.26760109E+01  0.11189595E+01
  beta 5         -0.23478487E-08  0.37528520E-08 -0.62561718E+00
  beta 6          0.40895227E+01  0.10781031E+01  0.37932575E+01
  beta 7          0.16817127E-08  0.58489128E-08  0.28752569E+00
  sigma-squared   0.14690450E+01

log likelihood function =  -0.12743264E+02

the estimates after the grid search were :

  beta 0         -0.44858742E+01
  beta 1          0.33318282E-07
  beta 2         -0.28227497E+01
  beta 3         -0.60241937E-08
  beta 4          0.29943478E+01
  beta 5         -0.23478487E-08
  beta 6          0.40895227E+01
  beta 7          0.16817127E-08
  delta 0         0.00000000E+00
  delta 1         0.00000000E+00
  delta 2         0.00000000E+00
  delta 3         0.00000000E+00
  sigma-squared   0.97267803E+00
  gamma           0.78000000E+00
```

Source: FRONTIER results

Figure 4.11: SFA results of Quebec port

Positive (+) in the inefficiency model indicates that dominant variables represented by the characteristics “security, easy access, and draft” decrease the technical efficiency of tonnage handling in the study region. Ultimately, a gamma value of 78% demonstrates that inefficiency is caused by factors that can be controlled by port operators, while 22% are due to uncontrollable random factors. Also, the (σ^2) is estimated at 0.97, which is a significant value at the 1% level, showing that technical inefficiency was the cause of variation in tonnage handled at port.

4.3.3 SFA Model Results for both ports

The results for the port of Annaba show a value for the gamma y estimator equal to 0.91 and significant at the 1% threshold, indicating that the model is good. The value of gamma illustrates ”that the variation at the level of the units studied (terminals) in relation to the estimated frontier” is explained by the technical inefficiency at 91% of this variability.

The results from the port of Quebec show a value for the gamma y estimator equal to 0.78. Thus, 78 % of the variation in data between terminals can be attributed to technical inefficiency and the remaining 22 % to pure "noise.".

```
Output from the program FRONTIER (Version 4.1c)

instruction file = terminal
data file =        globall.txt

 Tech. Eff. Effects Frontier (see B&C 1993)
 The model is a production function
 The dependent variable is logged

the ols estimates are :

                  coefficient      standard-error    t-ratio

  beta 0         -0.12957205E+02  0.16069011E+02 -0.80634738E+00
  beta 1         -0.34952441E-08  0.16837296E-08 -0.20758940E+01
  beta 2          0.16459366E+01  0.14475179E+01  0.11370751E+01
  beta 3          0.10506192E-08  0.21445665E-08  0.48989818E+00
  beta 4         -0.21097911E-01  0.12741515E+01 -0.16558400E-01
  beta 5         -0.52378782E-09  0.18878499E-08 -0.27745205E+00
  beta 6          0.22890526E+01  0.99439841E+00  0.23019472E+01
  beta 7         -0.13888447E-08  0.14993579E-08 -0.92629296E+00
  sigma-squared   0.28184361E+01

log likelihood function =  -0.45582347E+02

the estimates after the grid search were :

  beta 0         -0.11587465E+02
  beta 1         -0.34952441E-08
  beta 2          0.16459366E+01
  beta 3          0.10506192E-08
  beta 4         -0.21097911E-01
  beta 5         -0.52378782E-09
  beta 6          0.22890526E+01
  beta 7         -0.13888447E-08
  delta 0         0.00000000E+00
  delta 1         0.00000000E+00
  delta 2         0.00000000E+00
  delta 3         0.00000000E+00
  sigma-squared   0.38274116E+01
  gamma           0.77000000E+00
```

Source: FRONTIER results

Figure 4.12: Production frontier of the two ports

4.4 Comparison of Technical Efficiency Results using the DEA and SFA Methods

To recap, the DEA method attributes any deviations from the frontier solely to inefficiencies. On the other hand, the parametric stochastic frontier approach considers these deviations as a combination of random error ("white noise") and inefficiency. Therefore, SFA not only statistically tests hypotheses but also constructs confidence intervals.

Using these methodologies, this summary in Figure 4.13 indicates the tonnages managed by Annaba and Quebec ports through both DEA and SFA models. Terminals at these ports achieved average efficiency scores ranging from 53% to 63% with the SFA model. In comparison, the DEA model shows very similar CRS values for both ports, approximately 0.19, and VRS values of 0.87 for Annaba and 0.98 for Quebec.

technical efficiency estimates : Annaba

firm	year	eff.-est.
1	1	0.90227201E+00
3	1	0.52325337E+00
5	1	0.10955335E+00
7	1	0.99947201E+00
9	1	0.67414740E+00
11	1	0.33583953E+00
13	1	0.31540096E+00
2	2	0.27204688E+00
4	2	0.16283692E+00
6	2	0.92469491E+00
8	2	0.67637911E+00
10	2	0.52393046E+00
12	2	0.29164631E+00
14	2	0.79055598E+00

mean efficiency = 0.53585923E+00

technical efficiency estimates :Quebec

firm	year	eff.-est.
1	1	0.25628677E+00
2	1	0.68794730E+00
3	1	0.89388956E+00
4	1	0.55666005E-01
5	1	0.87169851E+00
6	1	0.98015901E+00
7	2	0.52436533E+00
8	2	0.99962258E+00
9	2	0.42656531E+00
10	2	0.89625797E+00
11	2	0.69176303E+00
12	2	0.37185677E+00

mean efficiency = 0.63800651E+00

DEA Annaba

EFFICIENCY SUMMARY:

firm	crste	vrste	scale	
1	0.269	0.980	0.274	irs
2	0.201	0.718	0.280	irs
3	0.014	0.880	0.016	irs
4	0.052	0.753	0.068	irs
5	0.002	0.857	0.002	irs
6	0.007	0.818	0.009	irs
7	1.000	1.000	1.000	-
8	1.000	1.000	1.000	-
9	0.021	0.750	0.028	irs
10	0.035	0.668	0.052	irs
11	0.124	0.911	0.136	irs
12	0.012	0.929	0.013	irs
13	0.054	1.000	0.054	irs
14	0.029	1.000	0.029	irs
mean	0.201	0.876	0.212	

DEA Quebec

EFFICIENCY SUMMARY:

firm	crste	vrste	scale	
1	0.014	1.000	0.014	irs
2	0.162	1.000	0.162	irs
3	0.003	1.000	0.003	irs
4	0.011	1.000	0.011	irs
5	0.036	1.000	0.036	irs
6	0.257	1.000	0.257	irs
7	0.040	1.000	0.040	irs
8	0.340	0.820	0.415	irs
9	0.423	0.997	0.424	irs
10	1.000	1.000	1.000	-
11	0.001	0.993	0.001	irs
12	0.008	0.995	0.008	irs
mean	0.191	0.984	0.198	

Source: FRONTIER results

Figure 4.13: Comparison of results between SFA & DEA

Several lessons can be drawn from comparing the results of the two methods, which are summarized below:

- It can be seen that in the SFA model, all 26 terminals are inefficient over the years 2022–2023, while in the DEA model, some terminals (two terminals) have a technical efficiency of 100% using either the CRS or VRS model. This difference can be explained by the fact that the SFA method breaks down the observed value in relation to the production frontier into two terms: inefficiency and random errors, whereas the DEA method, which is deterministic, considers any deviation from the frontier as inefficiency.
- Each method has advantages over the other; we can say that SFA and DEA are

complementary, for the DEA method is a non-parametric method, i.e., deterministic, that does not take measurement errors into account, but it has advantages. The first is the establishment of decision units presenting the reference for each terminal inefficiency to which it must compare to review its management of resources, and the second is to determine the shares of the size of the management problem in the calculation of inefficiency. As for the SFA, it is derived from the parametric stochastic frontier and the deterministic non-parametric frontier; it takes into account the error term and determines the explanatory variables of the inefficiency on the basis of statistical tests.

- The most common comparison is between the technical efficiency results obtained by SFA and those obtained by DEA CRS, as the latter takes into account the effect of terminal size.

Conclusion

In this chapter, we compared port terminals in Algeria and Canada by measuring technical efficiency using two different approaches. The first approach is non-parametric, represented by CRS and VRS models, as well as scale efficiency. The second approach is parametric stochastic, represented by efficiency scores and the estimation of factors influencing them. Finally, we compared the two approaches results, DEA and SFA.

General Conclusion

Measuring performance is a major concern for port terminals, with the aim of studying and improving the extent to which international trade is increasing. Our work is based on the comparison of technical efficiency measures obtained from two methods of stochastic frontier analysis (SFA) and data envelope analysis (DEA) for both ports, Annaba in Algeria and port of Quebec in Canada. Our two models indicate that port terminals in Annaba and Quebec have varying scores. The average technical efficiency estimated in the SFA model is higher than that obtained from DEA analysis.

The key conclusions we can draw from this study are:

- Port terminals in Annaba and Quebec obtained average efficiency scores using the SFA model between 53% and 63%, respectively, and for the DEA model, we find a very similar CRS for ports of around 0.19 and a VRS of 0.87 for Annaba and 0.98 for Quebec.
- In the SFA model, all 26 terminals are inefficient for 2022 and 2023, but in the in the DEA model, some terminals (two) have a technical efficiency of 100% using either the CRS or VRS model.
- This difference can be explained by the fact that the SFA method decomposes observed value in relation to the production frontier into two terms: inefficiency and random errors, whereas the DEA method, which is deterministic, considers any deviation from the frontier as inefficiency.
- The most common comparison is between the technical efficiency results obtained by SFA and those obtained by DEA CRS, as the latter takes into account the effect of terminal size.

To conclude, both ports are inefficient due to the complexity of port activities and the irregularity of the transport market.

Bibliography

[1] Wikipedia. Navire-citerne, 2024. Accessed: 2024-03-20.

[2] Antoine Frémont. Le transport maritime depuis 1945 : facteur clé de la mondialisation.

[3] CNUCED. Les grandes tendances du transport maritime en 2022: Analyses et recommandations de la cnuced, 2022.

[4] Ronan Kerbiriou, Brigitte Daudet, and Yann Alix. Comment le conflit israël-hamas redessine les routes du transport maritime, 2024. ffhal-04501181f.

[5] Stallion Express. Global container shipping statistics, 2024. Accessed: 2024-04-28.

[6] Mordor Intelligence. Marché mondial du transport maritime de fret, 2024. Accessed: 2024-05-28.

[7] Precedence Research. Maritime transport market size, share, trends, report 2023-2032, 2023. Accessed: 2024-04-07.

[8] Y. Alix and R. Lacoste, editors. *Logistique et Transport des Vracs*. Editions ems Management Société, 17 rue des Métiers, 14123 Cormelles-le-Roya, 2013.

[9] Rowing Research. Rowing research linkedin page, 2024. Consulté le 6 mai 2024.

[10] LinkedIn. Global maritime containerization market size & share, 2024. Accessed: 2024-05-28.

[11] Wikipedia contributors. Geography of algeria, 2024. Accessed: 2024-04-14.

[12] Statistics Canada. Geography. https://www150.statcan.gc.ca/n1/pub/11-402-x/2011000/chap/geo/geo-eng.htm, 2024. Accessed: April 14, 2024.

[13] Population Today. Algérie population 2024, 2024. Accessed: 2024-05-28.

[14] World Population Review. Canada population 2024, 2024. Accessed: 2024-05-28.

[15] Marine Insight. 5 major ports of algeria. https://www.marineinsight.com/ports/5-major-ports-of-algeria/, Date of publication not provided. Accessed: Insert date of access.

[16] GeeksforGeeks. List of major ports in canada, 2024. Accessed: 2024-05-28.

[17] France Direction générale du Trésor. Indicateurs et conjonctures : Algérie, 2024. Accessed: 2024-05-28.

[18] Banque mondiale. Gdp (current lcu), 2024. Accessed: 2024-05-28.

[19] Direction générale du Trésor. Indicateurs et conjonctures, 2024. Consulté le 6 juillet 2024.

[20] Port of Annaba. Port of annaba, 2024. Accessed: 2024-03-16.

[21] ShipHub. What does the shipowner do?, 2024. Accessed: 2024-05-02.

[22] Ministère de la Défense Nationale de l'Algérie. Organisation et missions, 2024. Consulté le 8 mars 2024.

[23] Port de Québec. Port de québec, 2024. Accessed: 2024-04-31.

[24] Armateurs du Saint-Laurent. Bottin du transport maritime courte distance, 2016.

[25] Association des pilotes maritimes du Canada. Région des laurentides, 2024. Extrait de https://pilotagecanada.ca/fr/regionlaurentides.html.

[26] Yvon Pesqueux. La notion de performance globale. In *Cinquième Forum international ETHICS*, page 6, Tunisie, December 2004.

[27] M. Maadani and K. Said. *Management et pilotage de la performance*. Édition Hachette, Paris, France, 2009.

[28] J. T. Mentzer and B. P. Konrad. An efficiency/effectiveness approach to logistics performance analysis. *Journal of Business Logistics*, 12(1):33–62, 1991.

[29] A. Neely, M. Gregory, and K. Platts. Performance measurement system design. *International Journal of Operations & Production Management*, 15:80–116, 1995.

[30] P. B. Marlow and P. Casaca. Measuring lean ports performance. *International Journal of Transport Management*, 1(4):189–202, 2003.

[31] Maranzana Nicolas. *Amélioration de la performance en conception par l'apprentissage en réseau de la conception innovante.* Thèse de doctorat, Université de Strasbourg, Strasbourg, France, 2009.

[32] A. Kehal. Évaluation de l'efficience technique des producteurs d'électricité par les méthodes stochastic frontier analysis (sfa) et data envelopment analysis (dea). Master's thesis, Ecole Nationale Polytechnique, 2018.

[33] J. M. Gleason and D. T. Barnum. Toward valid measures of public sector productivity: Performance measures in urban transit. *Management Science*, 28(4):379–386, 1982.

[34] Peter Drucker. *Management.* Routledge, 2012.

[35] A. Elouidani and A. Kada. Déterminants de la performance portuaire : Cas du port d'agadir. *Journal of Business And Economics*, 3(2):113, 2015.

[36] P. G. Devine and T. M. Ostrom. Cognitive mediation of inconsistency discounting. *Journal of Personality and Social Psychology*, 49(1):5–21, 1985.

[37] W. Nicholson. *Microeconomic Theory: Basic Principles and Extensions.* Thomson South Western, Canada, ninth edition edition, 1995.

[38] I. Temiz and V. Efecan. A survey of data envelopment analysis in container terminals. *Mersin University Journal of Maritime Faculty*, 2022.

[39] J. Tongzon. Efficiency measurement of selected australian and other international ports using data envelopment analysis. *Transportation Research*, A(35):107–122, 2001.

[40] T. D. Heaver and L. E. Henriksson. Strategy, structure and performance: A framework for logistics research. *Logistics and Transportation Review*, 31(4):285–308, 1995.

[41] G. Chow, T. D. Heaver, and L. E. Henriksson. Logistics performance: definition and measurement. *International Journal of Physical Distribution and Logistics Management*, 24(1):17–28, 1994.

[42] K. Culliane, D. Song, P. Ji, and T. Wang. Container port production efficiency: A comparative study of dea and sfa approaches. In *WCTR2004*, Istanbul, 2004.

[43] Marc Isabelle. *L'optimum de Pareto et la théorie du bien-être social.* Paris, 2002.

[44] S. Ben Farah. Evaluation de l'efficacité technique des exploitations oléicoles en tunisie (cas de chbika). Mémoire, Université de Laval, Laval, Québec, 2018.

[45] N. Amara and R. Romain. Mesures de l'efficacité technique : Revue de la quebec. Technical report, Centre de Recherche en Économie Agroalimentaire, Faculté des Sciences, 2000.

[46] S. Yükcü and G. Atağan. Etkinlik, etkililik ve verimlilik kavramlarının yarattığı karışıklık. *Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi*, 23(4):1–13, 2009.

[47] V. Çağlar and E. Oral. *Türk Özel Limanlarının Etkinlik Verimlilik Analizi*. Dokuz Eylül Üniversitesi Yayınları, 2011.

[48] W. H. Greene. The econometric approach to efficiency analysis. In H. O. Fried, C. A. K. Lovell, and S. S. Schmidt, editors, *The Measurement of Productive Efficiency and Productivity Change*. Oxford University Press, New York, 2008.

[49] S. Hanafi. *Approche d'évaluation de la performance des systèmes irrigués à l'échelle des exploitations agricoles : Cas du périmètre irrigué de Borj Toumi (vallée de la Medjerda-Tunisie)*. PhD thesis, AgroParis Tech, 2011.

[50] Laure Latruffe and Laurent Piet. Does land fragmentation affect farm performance? a case study from brittany. ffhal-01208908f, 2013. [University works] auto-saisine, 24 p.

[51] Isabelle Piot-Lepetit and Pascal Rainelli. Détermination des marges de manœuvre des élevages à partir de la mesure des inefficacités. *Production animale*, 9(5):367–377, 1996.

[52] L. Albouchi, M. Bachta, and F. Jacquet. Estimation et décomposition de l'efficacité économique des zones irriguées pour mieux gérer les inefficacités existantes. In M. S. Bachta, editor, *Les instruments économiques et la modernisation des périmètres irrigués*, 2005.

[53] Dany Vyt. Mesure de la performance commerciale : régression vs dea. une approche catégorielle. Document de travail, 2014.

[54] F. Chachoua. *La performance des ports algériens : Etude comparative par la méthode d'Analyse d'Enveloppement des Données (DEA)*. PhD thesis, Université Abdelhamid Ibn Badis, 2018.

[55] Jean-Marc Huguenin. *Data Envelopment Analysis (DEA)*. IDHEAP, Lausanne, 2013.

[56] M. Fok, O. Ndoye, and S. Kone. L'agriculture face aux défis de l'alimentation et de la nutrition en afrique : quels apports de la recherche dans les pays cotonniers. In *1ère conférence de la recherche africaine sur l'agriculture, l'alimentation et la nutrition*, page 689, Yamoussoukro, Côte d'Ivoire, juin 2013.

[57] A. Shantha. *Stochastic Frontier Analysis: Theory and Practices.* LAP LAMBERT Academic, University of Malaysia, 2019.

[58] N. G. Kalaitzandonakes, S. Wu, and J. J. Ma. The relationship between technical efficiency and firm size revisited. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroéconomie*, 40(3):427–442, 1992.

[59] T. Coelli, D. S. P. Rao, and G. E. Battese. *An Introduction to Efficiency and Productivity Analysis.* Kluwer Academic Publishers, Boston/Dordrecht/London, 1998.

[60] J. Liu, L. Lu, W. Lu, and B. Lin. A survey of dea applications. *Omega*, 41:893–902, 2013.

[61] Korea Maritime Institute. *A Study on Port Performance Related to Port Backup Area in the ESCAP Region.* Korea Maritime Institute, 2005.

[62] Naeem Malana and Hector Malano. Benchmarking productive efficiency of selected wheat areas in pakistan and india using data envelopment analysis. *Irrigation and Drainage*, 55:383–394, 10 2006.

Appendix

Preliminary Testing using SPSS Software

1. Variables Introduced/Eliminated

Model overview[b]

Modèle	R	R-deux	R-deux ajusté	Erreur standard de l'estimation	Durbin-Watson
1	,531[a]	,282	,184	11432510,740	2,069

a. Prédicteurs : (Constante), terminal, nombre, delai

b. Variable dépendante : tonnage

ANOVA[a]

Modèle		Somme des carrés	ddl	Carré moyen	F	Sig.
1	Régression	1128334392806709,000	3	376111464268903,000	2,878	,059[b]
	de Student	2875450640255551,000	22	130702301829797,770		
	Total	4003785033062260,000	25			

a. Variable dépendante : tonnage
b. Prédicteurs : (Constante), terminal, nombre, delai

Coefficients[a]

Modèle		Coefficients non standardisés B	Coefficients non standardisés Erreur standard	Coefficients standardisés Bêta	t	Sig.
1	(Constante)	-9185487,667	16405178,074		-,560	,581
	délai	1427,016	4543,512	,097	,314	,756
	nombre	337769,930	138407,413	,722	2,440	,023
	terminal	-4914,519	8507,789	-,193	-,578	,569

a. Variable dépendante : tonnage

Statistiques des résidus[a]

	Minimum	Maximum	Moyenne	Ecart type	N
Valeur prédite	-2326321,50	20114030,00	4809371,35	6718137,816	26
Valeur prévue standard	-1,062	2,278	,000	1,000	26
Erreur standard de la prévision	2560897,250	7034511,500	4384449,567	959184,219	26
Valeur prédite ajustée	-2641173,00	27567858,00	4747712,43	7359699,972	26
de Student	-20046898,000	42382464,000	,000	10724645,710	26
Résidu standard	-1,753	3,707	,000	,938	26
Résidu Student	-2,054	4,216	,002	1,060	26
Résidu supprimé	-27500726,000	54804736,000	61658,914	13710959,681	26
Résidu Student supprimé	-2,232	9,394	,192	1,985	26
Distance de Mahalanobis	,293	8,504	2,885	1,728	26
Distance de Cook	,000	1,302	,076	,262	26
Valeur influente centrée	,012	,340	,115	,069	26

a. Variable dépendante : tonnage

Coefficients[a]

Modèle		Coefficients non standardisés B	Coefficients non standardisés Erreur standard	Coefficients standardisés Bêta	t	Sig.	Corrélations Corrélation simple	Corrélations Partielle	Corrélations Partielle	Statistiques de colinéarité Tolérance	Statistiques de colinéarité VIF
1	(Constante)	-9185487,667	16405178,074		-,560	,581					
	délai	1427,016	4543,512	,097	,314	,756	-,273	,067	,057	,341	2,936
	nombre	337769,930	138407,413	,722	2,440	,023	,503	,462	,441	,373	2,680
	terminal	-4914,519	8507,789	-,193	-,578	,569	,285	-,122	-,104	,294	3,406

a. Variable dépendante : tonnage

Diagnostics de colinéarité[a]

Modèle	Dimension	Valeur propre	Index de condition	Proportions de la variance			
				(Constante)	délai	nombre	terminal
1	1	3,491	1,000	,00	,00	,01	,00
	2	,441	2,814	,00	,05	,05	,03
	3	,056	7,885	,00	,01	,86	,55
	4	,012	16,776	,99	,94	,08	,41

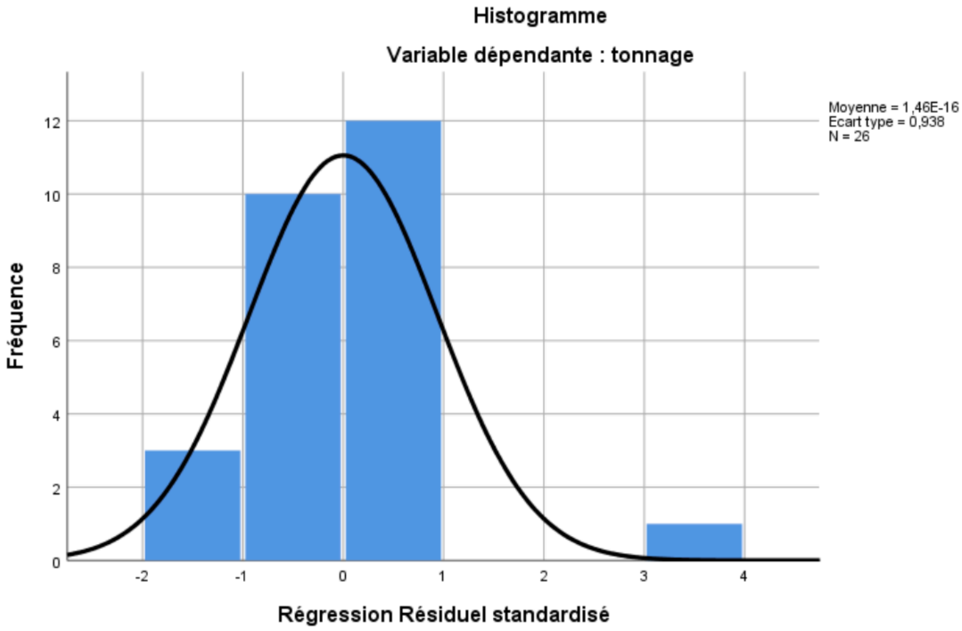
a. Variable dépendante : tonnage

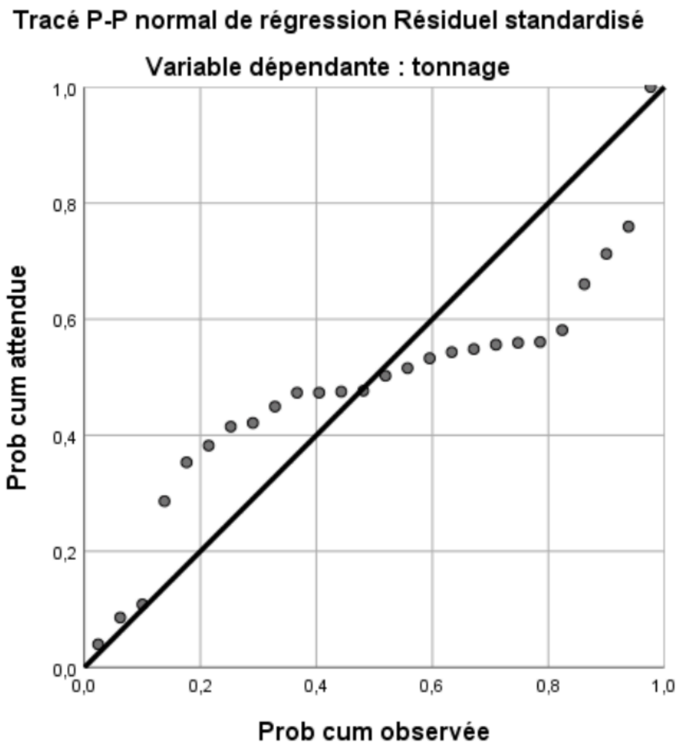
Statistiques des résidus[a]

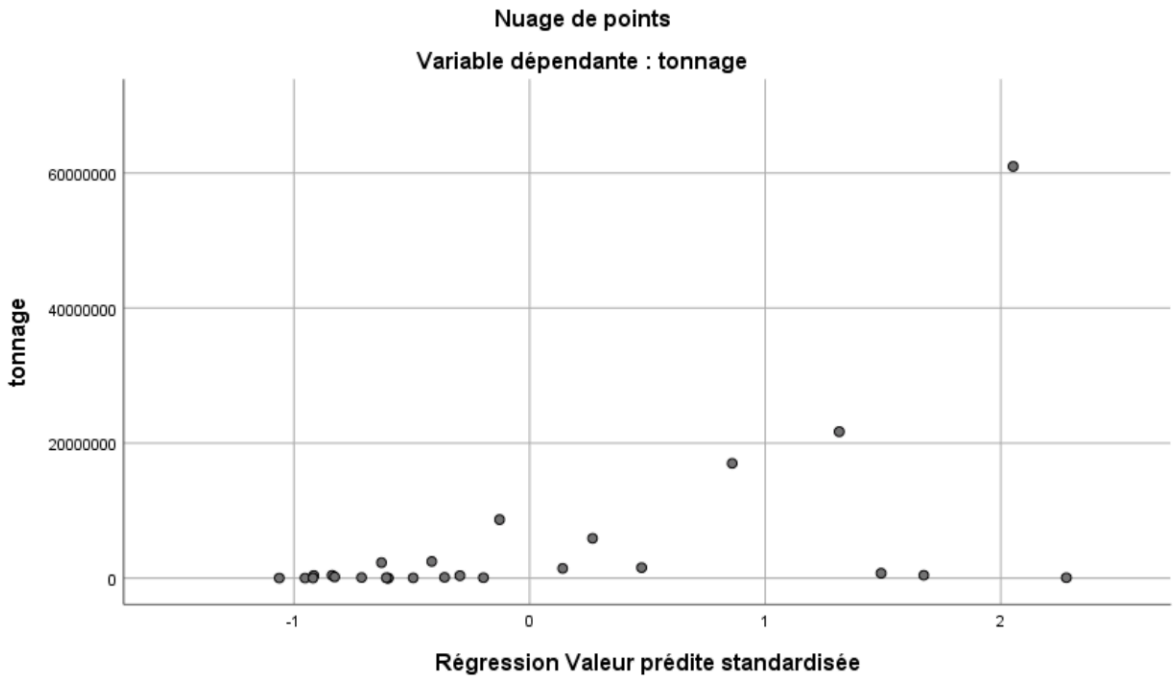
	Minimum	Maximum	Moyenne	Ecart type	N
Valeur prédite	-2326321,50	20114030,00	4809371,35	6718137,816	26
Valeur prévue standard	-1,062	2,278	,000	1,000	26
Erreur standard de la prévision	2560897,250	7034511,500	4384449,567	959184,219	26
Valeur prédite ajustée	-2641173,00	27567858,00	4747712,43	7359699,972	26
de Student	-20046898,000	42382464,000	,000	10724645,710	26
Résidu standard	-1,753	3,707	,000	,938	26
Résidu Student	-2,054	4,216	,002	1,060	26
Résidu supprimé	-27500726,000	54804736,000	61658,914	13710959,681	26
Résidu Student supprimé	-2,232	9,394	,192	1,985	26
Distance de Mahalanobis	,293	8,504	2,885	1,728	26
Distance de Cook	,000	1,302	,076	,262	26
Valeur influente centrée	,012	,340	,115	,069	26

a. Variable dépendante : tonnage

2. Graphics


Histogramme
Variable dépendante : tonnage
Moyenne = 1,46E-16
Ecart type = 0,938
N = 26
Fréquence
0
2
4
6
8
10
12
-2
-1
0
1
2
3
4
Régression Résiduel standardisé


Tracé P-P normal de régression Résiduel standardisé
Variable dépendante : tonnage
Prob cum attendue
0,0
0,2
0,4
0,6
0,8
1,0
Prob cum observée


Nuage de points
Variable dépendante : tonnage
tonnage
60000000
40000000
20000000
0
-1
0
1
2
Régression Valeur prédite standardisée