GETULIO VARGAS FOUNDATION

SÃO PAULO SCHOOL OF ECONOMICS – EESP

EWERTON CHAVES JOHN

THE EFFECT OF THE CONSTRAINTS FOR THE DISCHARGE OF DIESEL OIL AT THE MARITIME TERMINALS ON THE BRAZILIAN POTENTIAL GDP

SÃO PAULO

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Thesis submitted to the São Paulo School of Economics of the Getulio Vargas Foundation, in fulfilment of the requirement for the Master's degree in Agribusiness

Field of Study: Economics and Agribusiness Management

Advisor: Prof. Dr. Felippe Serigati

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I thank my wife Ana de Cantos for the aid and incentive. And my daughter Júlia Castro John, for the incentive, for the readiness to help and to show me, by her example, how rewarding the academic life can be.

RESUMO

Esta dissertação desenvolve um estudo relacionado à segurança energética do país. Com foco principal na insuficiência da estrutura portuária o trabalho analisa a possibilidade desta carência estrutural causar impactos macroeconômicos de proporções relevantes por conta de um “apagão” no setor de transportes, pelo desabastecimento de óleo diesel. A demanda por óleo diesel é projetada a partir do crescimento estimado do PIB e da elasticidade-renda da demanda por óleo diesel. A oferta é estimada a partir da capacidade de refino doméstica somada a capacidade importação via os terminais marítimos. Os resultados apontam para um esgotamento da capacidade portuária para aumentar as importações. Em consequência da recessão entre os anos de 2014 e 2017 as refinarias operaram em 2017 com apenas aproximadamente 80% da capacidade de refino declarada. Entretanto, mantidas as projeções de crescimento econômico, a demanda por óleo diesel deveria ultrapassar a capacidade de oferta no ano de 2025, no cenário de crescimento mais moderado ou em 2021, no cenário de crescimento econômico mais acelerado. Em vista do iminente risco de “apagão” no setor de transportes, por conta de uma crise de desabastecimento de óleo diesel, o trabalho propõe políticas de curto prazo para contenção do problema. Propõe, ainda, políticas de médio e longo prazos para a efetiva mitigação do risco de desabastecimento de óleo diesel na economia brasileira.

Palavras chave: portos; logística; diesel; petróleo; biocombustíveis; pib; segurança; energética; crescimento econômico; desenvolvimento econômico; apagão

ABSTRACT

This master’s thesis develops a study on the country's energy security. With the main focus on the insufficiency of the port structure, the study evaluates the possibility that this structural deficiency may cause significant macroeconomic impacts due to a "blackout" in the transportation sector. The “blackout” should result from the shortage of diesel oil. The demand for diesel oil is projected based on the estimated GDP growth and the income elasticity of the demand for diesel oil. The supply is estimated from the sum of the domestic refining capacity and the import capacity through the maritime terminals. The results indicate a depletion of port capacity to increase imports. Because of the economic recession in the Brazilian economy between the years 2014 and 2017, the refineries operated in 2017 with approximately 80% of their declared refining capacity. However, once maintained the projections for economic growth, the demand for diesel oil should exceed the supply capacity in 2025, in a more moderate growth scenario, or in 2021, in a scenario of faster economic growth. In face of the imminent risk of a "blackout" in the transportation sector arising on account of the shortage of diesel oil, this study proposes short-term policies to curb the problem. It proposes also medium and long-term policies for the effective mitigation of the risk of diesel oil shortages in the Brazilian economy.

Key Words: ports; logistics; diesel; oil; petroleum; biofuels; gdp; energy security; economic growth; economic development; blackout

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1. INTRODUCTION

This research develops an analysis of the country´s energy security. The study focus on the deficiency of the port logistics structure. It deals with the possibility that said structural deficiency might cause significant macroeconomic impacts, still not estimated yet. The aim is to estimate the actual dimensions of such impacts based on the proposed research, particularly focusing on the supply of diesel oil, which is the most relevant input in the Brazilian energy matrix.

In order to introduce, typify and establish the problem that motivates this work, the following sections develop a thematic discussion around conjunctural facts that lead to what may be the imminence of a “fuel blackout”.

1.1. Pre-crisis scenario

Brazil entered the 21st century in a favorable conjuncture of strong world growth. At the same time, being a commodity exporting country, Brazil also benefitted from the increase in the prices of said commodities, as explained by Serigati and Possamai (2016, p. 225).

As shown in Chart 1, between the years 2000 and 2013, Brazil grew 3.6% a year in average, accumulating a real growth rate of 51% in said period of fourteen years. This accumulated percentage is equivalent to an increase of R$ 2.43 trillion in the annual flow of goods and services produced in the Brazilian economy (BACEN, 2017, p. I.23). The product increase between the years 2000 and 2013 is greater than the sum of the overall volume of goods and services produced in the year 2017 in the state of São Paulo (SEADE, 2018).

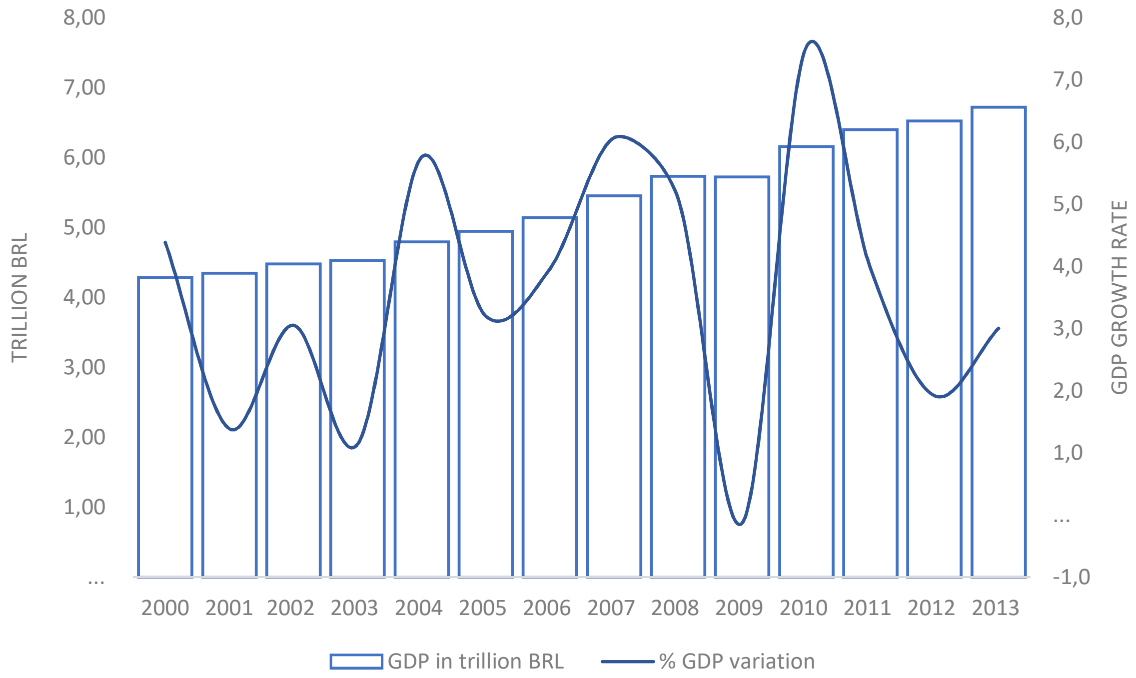


Chart 1 – GDP growth from 2000 to 2013, expressed in 2016 values
Source: BACEN, 2018

The cut-off year was 2013 because it was the last year when the Brazilian gross domestic product (GDP) had a strong growth in the positive cycle interrupted at the outset of the 2010 decade and marked the beginning of the crisis (SERIGATI; POSSAMAI, 2016, p. 267). Taking still into account the same period – 2000 to 2013 – the consumption of fuels derived from petroleum in Brazil grew 47%, while the consumption of fuels in general enlarged by 53%, the one of type-C gasoline increased by 83% and of diesel oil by 67% (ANP, 2017).

The oil price, as happened with the price of the majority of commodities, experienced expressive increases during the upward period of the super-cycle, jumping from US$ 30.00 per barrel, in the year 2000, to US$ 140.00 per barrel, in 2008 (SILVA; MATOS, 2016, p. 716). This behavior is better explained in Chart 2.

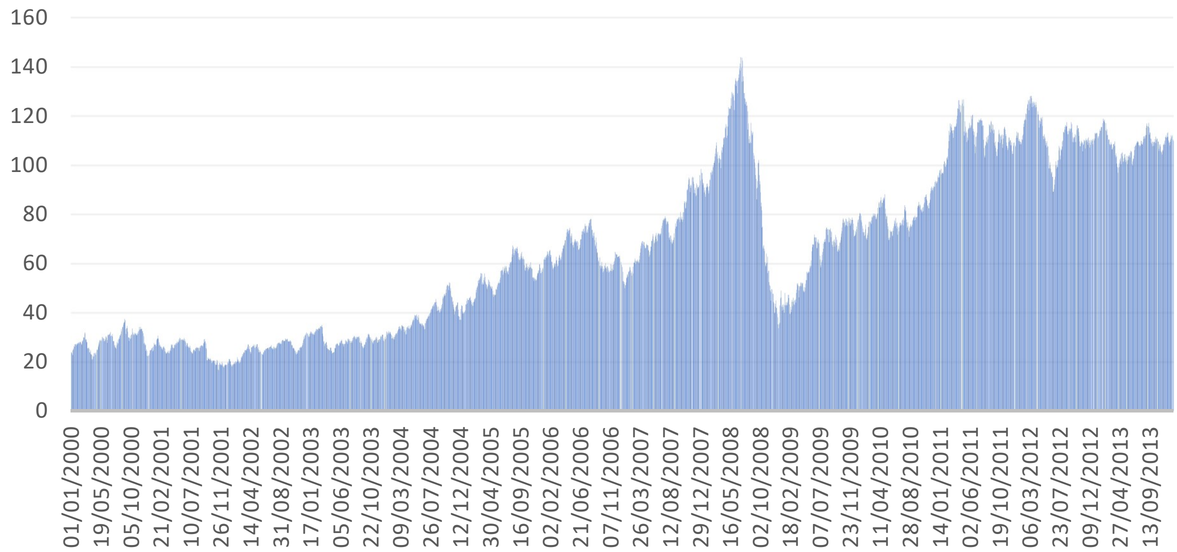


Chart 2 – Brent Crude Oil Price (FOB) - US$
Source: IPEA, 2017

It should be noted that, despite the variation in the international oil price, between the years 2011 and until the end of 2014 the Brazilian government, major and controlling shareholder, forced Petróleo Brasileiro S.A. (Petrobras) to execute a policy of artificially low prices in the Brazilian domestic market. In said period, as explained by Bistafa and Gurgel (2016), Petrobras could not pass on the increases in the prices of crude oil and petroleum products bought in the international market.

The booming pace of the Brazilian economy, impelled by the world economy, motivated Petrobras to take a strategic position consistent with the prospects at the time. The company should have to face the growing demand for fuels. Besides the growing demand, there was also an increase in the supply of crude oil with the opportunity created for the exploration of the discovered pre-salt oil reserves.

Officially announced in 2007, those pre-salt oil reserves created the expectation of having potential to double the Brazilian oil reserves in the 15 years following the announcement – which should be in 2022 (GAIER, 2007). The confirmed oil reserves in Brazil at the end of 2006 amounted to 11.46 billion barrels of oil equivalent, comprehending 9.48 billion barrels of petroleum and LNG[1] and 11,843 billion cubic feet of natural gas (Petrobras, 2007).

[1] LNG means liquefied natural gas. It is produced with the natural gas and condensed to liquid state under normal surface temperature and pressure (PETROBRAS, 2007, p. 10).

In 2006, the year when the pre-salt layer was discovered, Petrobras invested US$ 14.6 billion. For the next 5 years following 2006, it announced annual average investments of US$ 17.42 billion. According to the plan, it should invest US$ 87.1 billion between 2007 and 2011. In 2011, Petrobras Business Plan for 2012 – 2016 had already expanded to contemplate investments around US$ 236.5 billion, equivalent to an average of US$ 47.3 billion in each of these five years (Table 1).

Table 1 – Petrobras Business Plan - 2012 – 2016 - US$ 236.5 billion

Segments	Investments	%
E & P	141.8	60.0
Refining, Transport and Commercialization (RTC)	**65.5**	**27.7**
Gas & Energy	13.8	5.8
Petrochemical	5.0	2.1
Distribution	**3.6**	**1.5**
Biofuels	3.8	1.6
Corporate	3.0	1.3
Total	236.5	100.0

Source: Petrobras, 2012

It is seen from the announced investments that the segments of Refining, Transport and Commercialization (RTC) should receive 27.7%, and the Distribution one, 1.5%. These segments are relevant in order to determine the fuel supply in the Brazilian domestic market, since they embody the refineries and the maritime terminals.

The business area that, in Petrobras, is named Refining, Transport and Commercialization (RTC) is the one that operates the refineries, which process the crude oil, both Brazilian and imported, to manufacture the derivatives. This segment is also in charge of the sale and purchase of oil and petroleum products in the domestic market and in the international market. The coordination and transport infrastructure for the oil and its derivatives, through a coordinated network of commercialization centers, storage facilities, pipelines, sea terminals and vessels, lies with this area. By virtue of the provisions of Law 9,478, known as “The Oil Law”, it is necessary that another company, otherwise than Petrobras, operate and manage the logistics network for oil, petroleum products and natural gas. To meet said legal requirement, Petrobras

established a wholly owned subsidiary, Petrobras Transportes S.A. – Transpetro, which is the operator of said logistics. Transpetro must provide services not only to Petrobras, but also to other companies in the market that may need to share this infrastructure (PETROBRAS, 2007, p. 84).

In the distribution segment, Petrobras Distribuidora is the main distributor of petroleum products in the domestic retail market. Petrobras distribution company also serves other wholesalers. In 2016, the company held 30% of the Brazilian petroleum product distribution market (PETROBRAS, 2017, p. 88).

1.2. Current scenario

The mentioned investment plan of US$ 236.5 billion, for the five-year period from 2012 to 2016, was designed by Petrobras against an economic scenario background that ceased to exist as from 2013. The investment views and prospects changed with the new conjunctural basis.

There was deep change in the macroeconomic environment. There was also a change of the actors in charge of interpreting this reality and taking the strategic actions required for ensuring the traverse through the down period of the commodity super-cycle without impairing the productive activities in the country's economy, in the middle and long terms.

The international oil market also bore structural changes with the introduction of new producing countries. These newcomers weakened the market power of the traditional producers, members of the Organization of the Petroleum Exporting Countries (OPEC). In 2014, the global oil supply overcame the demand and the price of the commodity began to deteriorate. To bar the entry and even force the exit of new suppliers in the market, OPEC adopted a strategy of protecting its market share. The strategy consisted of not reducing their production volume, as it had been traditionally done in situations of excess supply. The maintenance of the production increased the downward pressure on the price, constraining the competitors who had higher production costs. Keeping the oil at a low price should eliminate the suppliers with higher production costs and protect OPEC market share (BEHAR; RITZ, 2017).

In view of all those recent alterations in the country's economic scenario and in the world economic situation, projects that were feasible when the oil price was above US$ 100.00 per barrel, became far less attractive – and some of them have even lost

their viability – with the price below US$ 44.00 per barrel, as occurred with the average price for the year 2016 (U.S. EIA, 2017).

The Brazilian economy growing at an average pace of 3.6%, as seen between 2000 and 2013, was completely different from the negative growing rate between 2013 and 2016. The principal market bases for oil as an input, that is: consumption and price, were deeply modified for the fuel industry when the downward phase of the commodity super-cycle began.

Besides the hardships deriving from the alterations in the market bases, Petrobras plunged into severe financial difficulties. At the same time, the company had its fundraising capacity curtailed in the international markets. The company had its name attached to gross corruption cases. As a consequence of all such factors, the oil company that had been appraised at US$ 270 billion in 2010 was devalued to around US$ 25 billion in 2014 (BISTAFA; GURGEL, 2016).

This new reality raised serious challenges with respect to fuel supply management planning all over the economy. The Brazilian transportation matrix is still fossil fuel-intensive. According to the 2017 National Energy Balance, taking the year 2016 as base, published by Empresa de Pesquisa Energética (Energy Research Company - EPE, 2017), only 20% of the fuel consumed in the Brazilian transportation matrix originates from renewable sources. On the other hand, the country counts on the alternative of exclusive use of biofuel in the majority of the light-duty vehicle fleet because of the high proportion of flex-fuel vehicles. With such flexibility, the planning grows in complexity.

Contributing to the complexity already pointed out, in 2016, Brazil had the largest oil production ever in the history of the country, over 2.3 million barrels per day (114.54 million tons per year).

However, the country has a limited refining capacity of petroleum in general. Specially, such limitation is greater for the refining of heavy oil, which is the type that is mostly prospected in Brazil. With little investments in the expansion of the national petroleum refining capacity, the country is on track for consolidating a situation of net exporter of crude oil and importer of refined petroleum products (EPE, 2017, p. 11).

The total fuel supply for transportation in Brazil is the sum of the Brazilian oil refining plus the national production of biofuels, and the refining of imported crude oil added to the imported refined fuels.

As previously mentioned, the Brazilian transportation matrix is highly dependent on petroleum product fuels, and only 20% of the country's necessity is supplied by renewable fuels (EPE, 2017, p. 25), as shown in Chart 3.

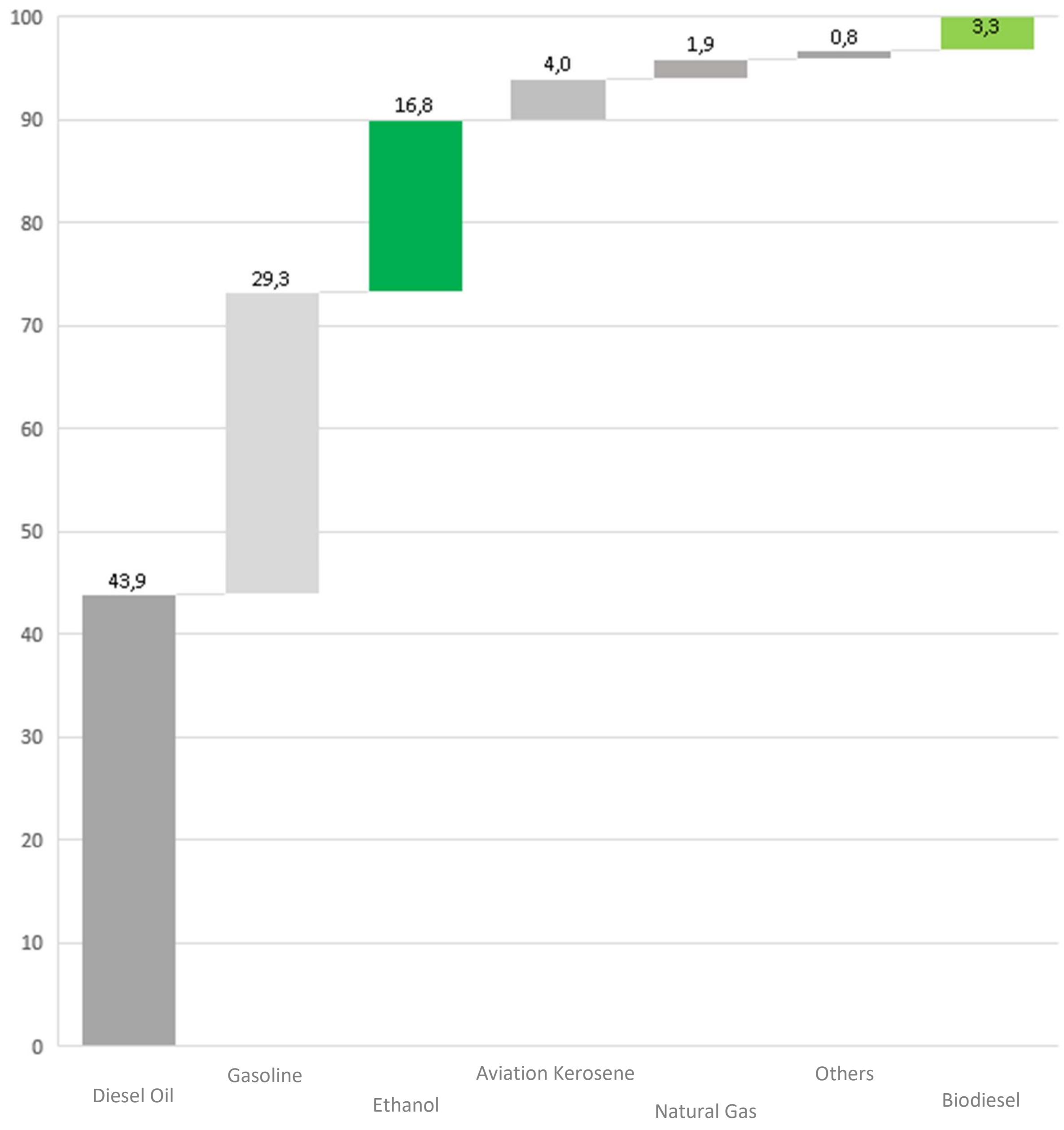
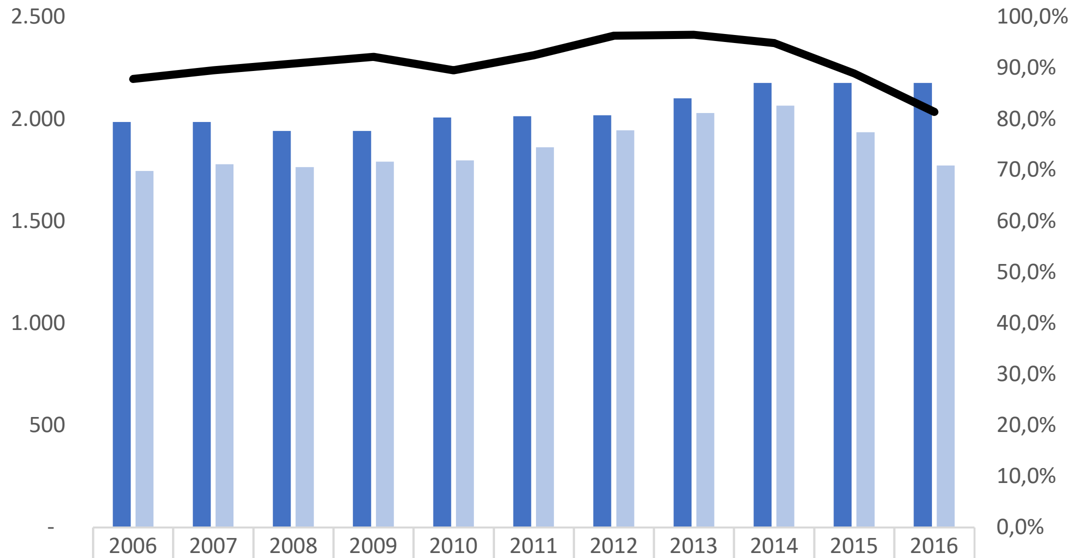


Chart 3 – Energy Consumption in Transportation
Source: EPE, 2017

Diesel oil and gasoline are responsible for 72.2% of fuel demand in the Brazilian transportation matrix, the first supplying 43.9% of the necessities, and the former 23.3%.

At the height of Petrobras optimism period, with the discovery of the pre-salt layer in 2006, the company announced reassuring figures about the investments in the expansion of the Brazilian crude oil refining capacity. This increment in the refined quantity ought to reduce the dependence on imports of light oil and refined oil products.

But these plans to augment the refining capacity were postponed. Actually, in the last 10 years, since the announcement of the investments in the implementation of Abreu e Lima refinery (RNEST), of Rio de Janeiro Petrochemical Complex (COMPERJ), and of all investments to expand the crude oil refining capacity in Brazil, such capacity has only increased by 9.6%, in absolute numbers. This variation in the refining capacity and in the refining effectively as well as the oscillation in the refinery level of utilization is represented in Chart 4.



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Capacity	1.986	1.986	1.942	1.942	2.007	2.013	2.018	2.102	2.176	2.176	2.176
Refining	1.746	1.779	1.765	1.791	1.798	1.862	1.944	2.029	2.065	1.936	1.772
Utilization	87,9%	89,6%	90,9%	92,2%	89,6%	92,5%	96,3%	96,5%	94,9%	89,0%	81,4%

Capacity Refining Utilization

Chart 4 – Installed Capacity of Refining, Effective Refining and Installed Capacity Utilization Rate – in mbd
Source: ANP, 2017

The utilization of the installed refining capacity, which was of 87.9% in 2006, reached 94.9%, in 2014. This actually represented a reduction in the potential capacity to increase the supply. Theoretically, in 2006, it had been possible to expand refining by 12.1%, that is, there was room for refining more 240 million barrels per day (mbd) to reach 100% of capacity. In 2014, however, the possible margin to augment supply

fell to 5.1%. In 2014, therefore, it should have been theoretically possible to increase the supply of refining services by only 111 mbd.

In this same period, from 2006 to 2014, while the growth in the demand exceeded the national capacity development, gasoline imports multiplied 70 folds, from 150 thousand tons in 2006 to the level of 10.3 million tons in 2014. Diesel oil imports have expanded by 218% over the interval in question (ANP, 2017).

In 2018, the refining capacity maintains unchanged in relation to 2014. From 2014 to 2016, the economic activity shrank, as reflected in a decrease of 7.2% in GDP. In same period, the quantity of crude oil processed in the Brazilian refineries fell by 14.2%. The volume of refined crude oil employed only 81.4% of the installed refining capacity in 2016.

Notwithstanding the increase in the prospection of Brazilian crude oil, the supply of fuels in the country continues depending on imports. Said imports of oil and other fuel derived from oil arrive in Brazil solely by sea. This transportation mode is dependent on specialized port terminals to receive the vessels carrying liquid cargoes in bulk. Specialized equipment for discharge and a tank storage structure are required for the liquid bulk delivered.

Moreover, although the country's actual GDP reduced by 7.2% since its peak of R$ 6.76 billion in 2014 (BACEN, 2017) and the end of 2016, it was observed that the Brazilian port terminals for the handling of liquid bulk operated at full capacity. This expansion in the utilization will be demonstrated in the following section, based on data from the National Agency for Waterway Transportation (ANTAQ, 2017).

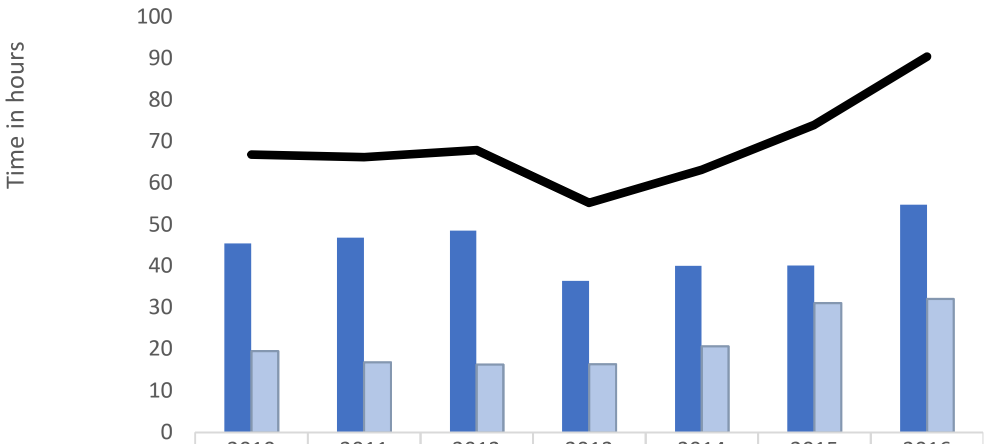
1.3. The scenario on resumption of growth

The economy works in cycles (ALÉM, 2010, p. 296). From 2013, when there was an inflection in the growth curve, the Brazilian economy experienced a cycle of almost three years of recession. In the second quarter of 2017, the country's GDP grew compared to the same period in the previous year, breaking a cycle of 12 quarters without inter-annual growth (IPEA, 2017, p. 1).

An expected effect of the slowdown of the economic activity, as happened between 2013 and 2017, is that it may give rise to idle resources. On August 2017, the use of the installed industrial capacity was 74.1% (IBRE, 2017), 6.6% lower than the historical average of 80.7% (IPEA, 2017).

Nevertheless, as regards the port terminals for discharge of fuels, this did not occur. Otherwise, the terminals were busier than in the period prior to the recession.

According to data from the Management Information System of ANTAQ (2017), with respect to the terminals that load and unload crude oil and petroleum products, their occupancy rates are increasing. The average time that vessels have waited for a mooring berth has increased. The vessels arrive from their international voyages and have to lie at anchor off the ports, at open sea, waiting for a berth at any specialized terminal in order to go alongside. The time the vessels remain moored, unloading or loading their cargoes have also extended. Consequently, total stay of ships carrying crude oil and petroleum products has increased as shown in Chart 5.



	2010	2011	2012	2013	2014	2015	2016
Wait	45,4	46,8	48,5	36,4	40,0	40,1	54,7
Berth	19,5	16,8	16,3	16,4	20,7	31,1	32,1
Stay	66,8	66,2	67,9	55,2	63,1	74,0	90,4

Wait Berth Stay

Chart 5 – Average times at Wait, at Berth and of Total Stay of vessels calling the terminals for loading/unloading crude oil and petroleum products in the Brazilian ports, from 2010 to 2016
Source: ANTAQ, 2017

Another foreseeable consequence of the slowdown in the economic activity is the reduction, delay and cancellation of investments. Under this prism, with regard to the investments to increase the fuel supply in the short and middle runs, the effect was as expected. Petrobras, historically the main responsible party for any expansion in the fossil fuel production capacity in the country, has drastically curtailed its investments.

Such combination of factors is cause for concern: even going through a period of almost three years of recession, the utilization of the imported fuel discharge capacity is in the process of becoming saturated. Additionally and concomitantly, the investments in the national production do not point to an enlargement of the supply capacity in the short and middle runs.

In view of all above, changes in the basis of the petroleum market have become evident. These changes have brought about questionings and controversies on the viability of investments in the pre-salt oil prospection and refining. Even if it may prove feasible, or if a decision is taken for intensifying the exploration of the pre-salt level oil for strategical or political reasons, a significant expansion of the refined fuel supply in the country is not evident. Hence, it becomes relevant to assess the capacity to increase the refined fuel supply of the Brazilian refineries and determine which works might generate an important expansion in this capacity in the short and middle runs.

The macroeconomic foundations and the international environment consistently point out to the resumption of the economic growth. The Business Confidence Index, issued by IBRE/FGV, has demonstrated a steady although discreet growth. This index is a predecessor of investments. The world economy is having favorable results, with excess of liquidity. Part of such international liquidity should transform into investments in Brazil. The inflation rates and consequent interest rates are at historically low levels for the country. The average actual income has also risen. These indexes suggest probable resumption of the consumption level of the families (IPEA, 2017, p. 5).

Upon the resumption of the economic growth, there will be need for increase in the fossil fuel supply for domestic consumption. The refineries have a limited refining capacity. Considering such limitation, immediate increase of fuel supply may only be viable through the increase of imported quantities.

Because of the characteristics of the products and the location of suppliers, said imports will continue to be made by sea. These products will have to be unloaded and stored in port terminals specialized for such purpose.

1.4. Research Problem and Objectives:

Assuming that the resumption of the Brazilian economy’s growth as from the year 2017 will remain, this study intends to answer the following question:

- What is the impact of the capacity constraints for the discharge of diesel oil at the maritime terminals on the Brazilian GDP growth?

This study general objective is to estimate what is the maximum supply reachable of diesel oil with the infrastructure available in the country. The available supply channels consist of refineries and port terminals. And based on such maximum supply possible, to estimate if it meets the demand expected in the scenarios of projected economic growth.

To reach the general objective, the pursuit of the following objectives is specifically intended:

- To map the total refining capacity as declared by the Brazilian crude oil refineries;
- To estimate what is the actual capacity for the discharge of diesel oil in the Brazilian sea terminals;
- Finally, based on the estimate for the maximum diesel oil supply capacity, calculate if it would be sufficient to meet the demand expected in the projected scenarios of Gross Domestic Product growth.

2. LITERARY REVIEW

The depletion of the crude oil refining capacity in the country and the physical limitation to the increase of imports because of the exhaustion of the fuel discharge capacity available for the maritime terminals can lead to a negative supply shock. In the event that an increase in the demand for fuels is not satisfied, this will represent a negative productivity shock (Além, 2010, p. 298).

The economy's lack of capacity to supply the necessary inputs for a sustainable growth can hold back the potential growth of the country. The fuel consumption is adherent to the concept of income elasticity of demand. Mohammadi and Parvaresh (2014) have demonstrated a stable relation between energy production and consumption. They have also found a bidirectional causal relation between energy consumption and production. An increase in the production leads to an increase in the demand for energy. And an increase in energy supply spurs an increase in the production. Oil and petroleum products are responsible for more than one third (36.5%) of total energy supplied in Brazil (EPE, 2017).

A change in the economy's level of income will be reflected in the quantity demanded of fuel. Fuels can be considered as normal goods, defined as those goods whose demand increases as the income rises. They are goods whose income elasticity of demand is positive (VARIAN, 1947, p. 300).

According to *BP Statistical Review of World Energy 2017* (BP, 2017), between the year 2006 and 2016, Brazil expanded oil consumption by 40%, while it increased its refining capacity by 18% only. It should be noted that, on analysis of *Forms 20F* annual records, Petrobras declares that the refining capacity increased from 1,986 mbd to 2,176 mbd in this same period, that is, 9.6% and not 18% as informed by BP.

The *Form 20-F* Annual Reports of compulsory publication to companies listed in the North American stock exchanges show that the last investments by Petrobras with potential to generate a significant increase in the refining capacity in Brazil were the refineries of Abreu e Lima – RNEST, in the northeast region, and Rio de Janeiro Petrochemical Complex – COMPERJ.

The refinery Abreu e Lima, which construction was announced in 2004, started operations only at the end of 2014, with approximately one third of the originally announced capacity. In 2016, it was authorized to refine around 50% of the projected

210 thousand barrels daily. Two hundred ten thousand barrels per day are equivalent to 10.5 million tons per year.

The construction of the COMPERJ complex was interrupted for lack of funds, and at the time this study was prepared, in 2017, Petrobras was said to be building a business model in the rush to attract investors to finance and finish the first refining unit of the project.

Comparing the Brazilian agribusiness growth with the international conjuncture between the years 2015 and 2017, Serigati and Possamai (2016) incorporated the influence of the financial markets in the formation of the commodity prices. Although they have focused in agricultural commodities, one may not rule out that said financial market forces that pressed the price of the agricultural commodities have acted also with similar force and in the same direction on the crude oil quotations.

In this same work, the authors call attention to the fact that the prices of all commodities have started to have a downward trend as from 2012. Said trend should not mean a crisis but, otherwise, the return to normal quotations. As a result of the weakening of the upward pressure originating from the financial market, the commodities ought to be resuming their normal price levels.

The analysis and the results of Serigati and Possamai (2016) reinforce the expectation that the crude oil price will remain at levels lower than those observed between 2011 and 2013. This favors an expansion of demand for fuels derived from crude oil.

When studying the macroeconomic and sectoral impacts of the development of the pre-salt level, in the manner designed in the 2015-2016 Business and Management Plan of Petrobras, Bistafa and Gurgel (2016) provided information that help to foresee how the sugar-alcohol sector can act in case of the negative supply shock investigated in this study.

Bistafa and Gurgel (2016) concluded that the premature development and exploration of the pre-salt level should result in costs higher than the benefits gained by the Brazilian economy, in the long term. Particularly in relation to the sugar-alcohol sector, said costs should firstly be represented by the direct fuel competition for light vehicles. Still, in view of the disproportionate relocation of funds to the pre-salt sector, the economic activity should tend to decrease in the country, reducing the demand for fuels, among them the ethanol.

In addition to the discussion on the impacts of the pre-salt sector over the ethanol sector, Bistafa and Gurgel (2016) also analyzed the effects of the gasoline price control policy, occurred in Brazil between the years 2011 and 2014. This policy kept the domestic price 15% lower than the international price, in average. Such policy should have had a greater negative impact on the ethanol sector than all five estimated scenarios of the pre-salt impact on the ethanol sector. In view of said policy that kept the domestic prices 15% lower than the international prices, between 2011 and 2014, ethanol producers should become vulnerable, terminated a number of employees and the like, and even went bankrupt.

Chart 6 outlines in a rudimentary manner, just for a notion of magnitude, the idea of gasoline domestic price lower than the international price between the years 2011 and 2014. To make it simpler and render visualization more direct, the price for regular gasoline in the USA will be deemed as the international price. A 15% discount is applied all over the period from 2011 to 2014 in order to draw the gasoline theoretical price line in Brazil.

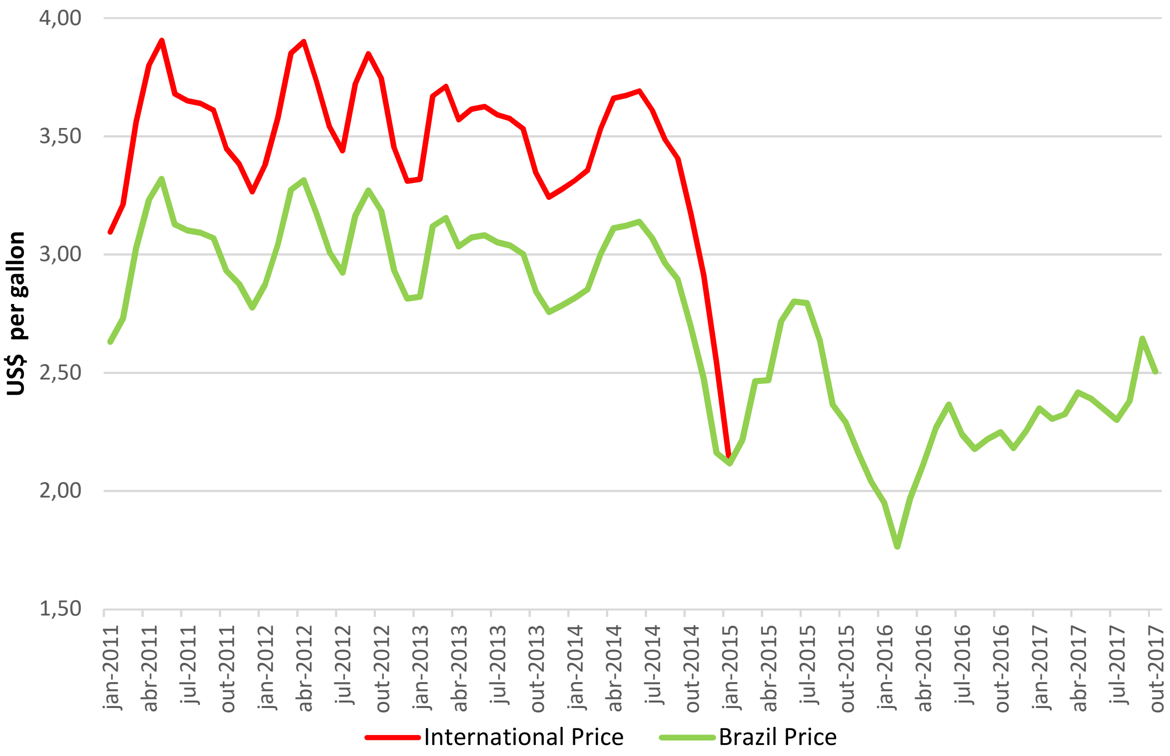


Chart 6 – Outline of gasoline prices artificially 15% lower than the international market between 2011 and 2014 and converging to the same price in 2015
Source: EIA, 2017

The illustration stands out that, in dollars, the international price for gasoline is lower than the price charged domestically during the government intervention. Between 2016 and 2017, the decrease in the gasoline international price was still more significant than the 15% reduction that would have impaired the ethanol producers between 2011 and 2014.

The insights of Bistafa and Gurgel (2016) on the catastrophic effect on the Brazilian market of a 15% reduction in the national gasoline price in relation to the international quotation contribute for the construction of the scenarios. In a scenario of continued low quotations of fossil fuel prices, these studies do not permit to discard the idea that it will not be possible to count on an increase in the supply of Brazilian ethanol. In a scenario where the ethanol remained competitive, the increment in the internal production of ethanol could ease the pressures of volumes of fuel imports through the port terminals.

Empresa de Pesquisa Energética (EPE), in its Ten-Year Energy Expansion Plan 2026 (PDEE) (EPE, 2017, p.164), emphasizes the need of investments in the refining park and in the logistics infrastructure to face the growing demand for diesel oil.

EPE used the Oil Products Supply Planning Model (Plandepe), developed by itself, which allows analyses on the refining park and on the flows of crude oil and its derivatives in different scenarios. EPE concluded that the oil refining capacity in Brazil should reach 2.5 million barrels per year in 2026, representing a modest increment of the order of 8% on the refining capacity observed in the year 2017. Consequently, the study concluded that the Brazilian production of petroleum-products would not vary much until the year 2026.

Even when considering the enlargement of the production of diesel oil at RNEST, with the timely delivery of two more stages as planned, in 2018 and 2023, the PDEE plan predicts that the country will remain as net importer of diesel oil until the end of the studied period, the year 2026.

According to this EPE study, published in 2017, the maximum volume of diesel oil imports in the period from 2017 to 2026 should be 6.2 million tons, in the year 2026. Such amount should be lesser than the historical maximum of 9.5 million tons imported in 2014. In the same year of PDEE publication, the diesel oil imports totaled 11.0 million tons, exceeding by more than 77% the maximum volume projected, which should be reached in 10 years only.

With regard to biodiesel, EPE also projects a worrying situation with regard to the supply capacity. According to PDEE, the installed production capacity of 7,535 million liters in 2017 will increase to 8,745 million liters in 2026. Nevertheless, the mandatory consumption that was 4,358 million liters in 2017 will escalate to 10,368 million liters in 2026, representing a deficit of 1,623 million liters in the national biodiesel productive capacity in the year 2026 (EPE, 2017, p.211).

Luz (2015), proposed an econometric model to estimate the demand of diesel oil for the next 10 years – from the date of this study - in Brazil. The author carried out an ample literature review, which we quote in Table 2 in a simplified manner.

Table 2 – Literature Review by Luz (2015) to propose a model to predict the consumption of diesel oil for 10 years in Brazil

Year	Author	Model / Methodology			Diesel Consumption Regressors	Remarks
1986	Castro	Econometric	Cross Section	Data on Municipalities	Salaries, Inhabitants & Agriculture Sector	Consumption is the main component of the diesel demand
1989	Castro	Econometric	Cross Section	Data on Municipalities of 1980	GDP, (price in some periods...)	Focus on passengers/included gasoline and ethanol/used 1 year record on diesel consumption for the prediction
1996	Moreira	Econometric	Time Series	Regional top down - National and Regional Model	Regional Consumption & GDP (price Is exogenous ())	Restrictions to the regression coef. to assure congruence with national C ttl. - Part of one Cobb D where the GDP and (f) of N, K and Diesel + PTF
2007	Pock	Dynamic Equation (70´s)	Panel Data	14 European Countries, 1990 to 2014	Km´s driven by car, l/Km, N Cars - l/KM = f(Y)	Focus on total fleet, with light diesel vehicles (Europe), mature economies
2008	Borba	Technical Economic	Fuel Consumption Projection Model of the International Energy Agency	Eight "regions" of Brazil	Vehicle fleet disaggregated per type; average fleet performance for each mode, annual average KM, average occupancy factor per mode (and CO2 emission factor)	Focused on demand for energy and CO2 emissions
2011	Hyndman, Athanasopoulos and Shang	* On disaggregation	data (by Borba 2008)	====>	"Less sophisticated models, as the one of historical proportions, have satisfactory results in the disaggregation of data"	
2011	Santiago, Mattos and Perobeli	Integrated-Econometric (Econometric + IP Hybrid = EC-IP)	Input-Product Model	National Data	EC=> C, I, M e X + Input-Product Matrix	Study projected a greater diesel demand if the crisis started in 2008 were long rather than if it were short (2.4% and 2,5% yearly)
2015	Luz and Ribeiro	Econometric Model	Topdown	Brazil	GDP and Price	Diesel demand projection - National and Regional

Source: Luz, 2015

After a careful and detailed analysis, Luz (2015) established in his work that the econometric time-series models should be the ones most aligned with the purpose of his study.

The models proposed by Luz (2015) estimated the national consumption and, from the country´s aggregate value, they segmented the forecast per region. In other words, a top down approach was carried out to attain the regional projections.

The models were based on 5-year sample historical data. The author justifies his choice of period on the data contemporaneity, which, therefore, should minimize the risk of structural breaks.

Ten econometric models were tested. For selecting the ones employed for the (national and regional) forecasts, both the results of the projections made from them and the parsimony were taken into consideration.

The author points out, among the relevant conclusions of his study, the fact that the inclusion of the agricultural sector GDP and family consumption does not improve the predictive properties of the model. He remarks that the inclusion of the agricultural sector GDP contributes to the explanation of the seasonal variation of diesel consumption. This contribution is supplied by the presence of dummy variables in the model.

The impact of the occasional activation of thermal power plants has also been underlined as an important factor to impose adjustments to the model. The activation of thermal power plants is made as a contingency resource, in hydric stress situations where the hydroelectric generation decreases, and their consumption of diesel oil affects the model's premises.

Luz (2015) study reaffirmed what had already been consolidated in the literature towards having the GDP as the main driver of the demand for diesel oil. The addition of the 'price' regressor improved the performance of the models compared to models without said variable. It is worth of note the author's observation that the best performance of the models including the price variable has only occurred in the tests within the sample. Outside the sample, the most parsimonious models, without the presence of the price, performed better.

Once having defined and tested the models, Luz (2015) made the projections. The Base Scenario assumed a GDP annual average growth of 2.5% and zero growth in real terms in the diesel oil price. In the Alternative Scenario, GDP average growth should be 1.6% while the price of the diesel oil should be 2%, also in real terms.

Both scenarios indicated growth in the consumption of diesel oil for the next 10 years as from the projection.

3. METHODOLOGY

To estimate the impact that a possible crisis of diesel oil supply shortage can have on the potential growth of the country, it is first necessary to investigate the potential growth of the product being projected.

Based on said growth projection, estimate what should be the demand for diesel oil in this scenario.

And, finally, estimate what is the potential capacity of the diesel oil supply to face the projected demand.

3.1. Projecting the growth of the gross domestic product

This study used as source for the projections the GDP growth predictions established by the Central Bank through the Focus research. This is a survey where agents from multiple market sectors take part contributing with their perceptions of the economy. Companies and universities, as well as financial market companies, can participate in the respondent universe. The Central Bank requires from the entity interested in participating that it has a team specialized in macroeconomic projections (BACEN, 2017).

The horizon of the projections of the Focus research spanned until 2021. From 2021 to 2028, the GDP growth rate was stabilized at 2.65%, which is the rate projected by the research for the year 2021.

3.2. Projecting the demand for diesel oil

The projection of the demand for diesel oil was estimated based on the application of the elasticity of consumption of diesel oil in relation to the GDP. The considered elasticity is the resultant of the recently presented time-series econometric model (2015).

The study used a parsimonious model without prejudice to the predictive capacity in relation to more complex models.

There are three implicit presuppositions in the model. The first is that no substitute goods may affect the demand for diesel oil within the analyzed period. The second premise concerns the technical advance, which will have null effect in the model. Based on the assumption that technical progress tends to be proportional to

the income, if the diesel consumption per kilometer falls because of the technical progress, the demand will increase as a consequence of the higher income. And, finally, the model assumes the premise that there is a constant elasticity of demand.

The elasticities to be used are as obtained from the application of the model where the impacts of the GDP variation on the diesel demand were taken in consideration. The model included an error correction mechanism. The models included dummy variables to catch the effects of seasonality and, by definition, also the error term.

The models as proposed by Luz (2015) are:

$$\Delta Die_t = c + \beta_1 \Delta PIB_t + \alpha Die_{t-1} + \beta PIB_{t-1} + \phi_2 2^o tri + \phi_3 3^o tri + \phi_4 4^o tri + \varepsilon_t \quad (1)$$

$$\Delta Die_t = c + \beta_1 \Delta PIB_t + \phi_2 2^o tri + \phi_3 3^o tri + \phi_4 4^o tri + \varepsilon_t \quad (2)$$

$$\Delta Die_t = c + \beta_1 \Delta PIB_t + \delta \Delta Pre_t + \alpha Die_{t-1} + \beta PIB_{t-1} + \delta \Delta Pre_{t-1} + \phi_2 2^o tri +$$

$$\phi_3 3^o tri + \phi_4 4^o tri + \varepsilon_t \quad (1p)$$

$$\Delta Die_t = c + \beta_1 \Delta PIB_t + \delta \Delta Pre_t + \phi_2 2^o tri + \phi_3 3^o tri + \phi_4 4^o tri + \varepsilon_t \quad (2p)$$

Where:

ΔDie_t : diesel sales log

c : constant

β_1 : short-term impact of the GDP change on diesel consumption

ΔPIB_t : GDP variation, in log

$-\alpha$: coefficient of adjustment

$\phi_2 2^o trim$, $\phi_3 3^o tri$ e $\phi_4 4^o tri$: dummy variables

ε_t : error term

The prediction of the demand for diesel oil in this research used the elasticity disclosed from the econometric model 1, with price (ECM 1p):

$$\Delta Die_t = c + \beta_1 \Delta PIB_t + \delta \Delta Pre_t + \alpha Die_{t-1} + \beta PIB_{t-1} + \delta \Delta Pre_{t-1} + \phi_2 2^o tri + \phi_3 3^o tri + \phi_4 4^o tri + \varepsilon_t$$

The projections with the model are based on natural logarithm and, later, converted to tons by the exponential function. The direct use of the natural logarithm changes on the cubic meter volumes generates distortions, particularly in case of greater percentage changes. This is a remark of the model's author.

This study has elected to apply directly the elasticity resulting from the model. The elasticity was applied on the percentage of change predicted in the GDP and it was increased and decreased over this variation by standard deviations of 1.96 to generate the estimates for diesel demand within the confidence interval.

3.3. Projecting the capacity of diesel oil supply

The supply of diesel oil in Brazil occurs through either domestic refining or maritime imports. The energy sector is highly regulated and controlled by the government. The fuel industry is highly concentrated and the government is the major partner of the largest company in the sector, Petrobras.

ANP, National Agency of Petroleum, Natural Gas and Biofuels, created by Law no. 9,478 of August 6, 1997 (BRASIL, 1987), is the entity that regulates all activities integrating the chain of petroleum, natural gas and biofuels.

ANP keeps a monthly updated data record on refining, imports and sales of diesel oil.

The agency maintains strict control over the quantities produced per refinery and the declared operational capacity of each.

The data on refining and refining capacity, components of diesel oil demand, will be considered according to ANP data.

The import supply capacity will be studied based on the port movement data provided by the National Waterway Transportation Agency (ANTAQ, 2017), crosschecked with ANP data and, still, crosschecked with the data of the Foreign Trade Information Analysis System (Alice Web). Alice Web is fed with data from the Integrated Foreign Trade System (SISCOMEX) and falls under the responsibility of the Ministry of Industry, Foreign Trade and Services (MDIC).

A significant volume of port data was accessed and scrutinized to support the analyses that will follow in this work. The downloaded port data include all cargo operations in every Brazilian port, from January 2010 to December 2017.

Such bulk of information cannot be dealt with using the most popular software applications for electronic spreadsheet or management purposes. The database had to be assembled through the R-Studio program.

4. RESULTS

4.1. GDP projected growth

In 2018, the Central Bank of Brazil foresaw a short-term average growth over 3% in the second, third and fourth quarters. Although presenting lower percentage rates in the first periods, the bank Itaú also indicated a product growth for same quarters. The private bank extended the three-month projection until the last quarter of 2019, as shown in Table 3.

Table 3 – Projection for GDP percent growth on the previous year quarter according to Bacen and Itaú

		Bacen	Itaú
Year	Quarter	ΔGDP	ΔGDP
2018	2	2.73	2.40
2018	3	3.09	2.80
2018	4	3.40	3.00
2019	1	3.15	3.80
2019	2	N/A	3.70
2019	3	N/A	3.70
2019	4	N/A	3.70

Sources: Central Bank, 2018 and Bank Itaú, 2018

From 2018 to 2022, the Market Expectations System of BACEN also projected uninterrupted growth of the gross domestic product. The system has projected an average rate of 2.74% a year. This growth estimated by the bank should reach its period peak in the year 2019, with a growth of 3.08% and, in the years to follow, it should lose impetus a little and reach 2022 with an estimated growth of 2.63%. OECD, the Organization for Economic Cooperation and Development, also disclosed long-term forecasts for the Brazilian GDP growth, as listed in Table 4.

Table 4– Projection for the Brazilian GDP growth from 2018 to 2028 according to Bacen and OECD

Year	Bacen ΔGDP	OECD ΔGDP
2018	2.74	2.76
2019	3.08	2.63
2020	2.65	2.54
2021	2.62	2.50
2022	2.63	2.49
2023	N/A	2.50
2024	N/A	2.54
2025	N/A	2.59
2026	N/A	2.64
2027	N/A	2.68
2028	N/A	2.72

Sources: Bacen, 2018 and OECD, 2018

For the reasons listed in the Methodology, the predictions for the GDP growth rate considered in this study were generated based on the Focus research. The research methodology and the technical resource of disclosing the standard deviation together with the result were deemed adherent to the purpose of this study. From the projections within a confidence interval, the predictions of the demand for diesel oil and any policy recommendations will be more assertive.

The Brazilian GDP growth rates until the year 2021 as disclosed in the FOCUS research report (BACEN, 2018) are found on table 5, in the next section.

4.2. The demand for diesel oil

The demand for diesel oil was projected from the elasticity revealed by the econometric model recently developed and tested by Rafael Luz (2015).

The study used elasticity resulting from the price econometric model.

From the growth rate predicted by Focus research, another two rates were derived by deducing and adding standard deviations of 1.96, in order to create a confidence interval for the projections. Thus, three projections were built, for percent change, additional tonnage and total demand for diesel oil, for 2018 and the following 10 years.

The projections resulting from the application of the elasticity to the three confidence interval values of the GDP growth rate forecast were named “minimum”,

"average" and "maximum". "Average" refers to projections originating from the use of the elasticity in the center of the growth rate prediction. "Minimum" and "maximum" are those deduced and added by a standard deviation, respectively.

For the years 2018 and 2021, the percent variation, the additional volume and total volume of the demand for diesel oil were estimated based on the Focus research projections. The additional volume, or the change in the volume of diesel demand, in tons, is estimated based on the volume demanded in 2017. From 2023 to 2028, the projections are only based on the repetition of the last estimate of growth disclosed by the Focus research. Said rate is 2.65%, with a standard deviation of 0.50%. The study elected this definition of rate of growth to the most remote period for being coherent with the trend to a long-term economic balance.

Find below the Tables with the results of the projections. The first is Table 5 that shows the input data of the GDP growth rate for the scenarios to be outlined.

Table 5 – Input data

Year	Focus Δ%GDP	Standard Deviation	Minimum	Maximum
2018	2.83%	0.47%	1.91%	3.75%
2019	3.01%	0.52%	1.99%	4.03%
2020	2.66%	0.48%	1.72%	3.60%
2021	2.65%	0.50%	1.67%	3.63%
2022	***2.65%***	***0.50%***	***1.67%***	***3.63%***
2023	***2.65%***	***0.50%***	***1.67%***	***3.63%***
2024	***2.65%***	***0.50%***	***1.67%***	***3.63%***
2025	***2.65%***	***0.50%***	***1.67%***	***3.63%***
2026	***2.65%***	***0.50%***	***1.67%***	***3.63%***
2027	***2.65%***	***0.50%***	***1.67%***	***3.63%***
2028	***2.65%***	***0.50%***	***1.67%***	***3.63%***

Source: BACEN. 2018

From the above-tabulated parameters, the study projected the growth rate for the diesel oil demand, as per Table 6.

Table 6 – Projection of variation in the rate of demand for diesel oil

FOCUS + ECM 1p			
Δ%Diesel			
Year	Minimum	Average	Maximum
2018	1.73%	2.56%	3.39%
2019	1.80%	2.72%	3.64%
2020	1.55%	2.40%	3.26%
2021	1.51%	2.40%	3.28%
2022	*1.51%*	*2.40%*	*3.28%*
2023	*1.51%*	*2.40%*	*3.28%*
2024	*1.51%*	*2.40%*	*3.28%*
2025	*1.51%*	*2.40%*	*3.28%*
2026	*1.51%*	*2.40%*	*3.28%*
2027	*1.51%*	*2.40%*	*3.28%*
2028	*1.51%*	*2.40%*	*3.28%*

Source: Bacen, 2018. Prepared by the author (projection by the author starting in 2022)

Obtained the projection of variation in the annual rate of demand for diesel oil, it was applied on the volume of the demand of the year 2017, of 46.2 million tons. On application of the demand variation rate on a known constant, Table 7 informs the prediction of total volume that has to be supplied annually from the year 2018 and in the following 10 years to reach the demand projected.

Table 7 – Projection of total annual demand for diesel oil

FOCUS + ECM 1p			
Total volume of the demand for Diesel (T)			
Year	Minimum	Average	Maximum
2018	46,969,784	47,354,297	47,738,810
2019	47,815,091	48,642,826	49,477,646
2020	48,558,213	49,812,511	51,088,205
2021	49,291,286	51,005,819	52,764,674
2022	50,035,427	52,227,715	54,496,158
2023	50,790,802	53,478,882	56,284,460
2024	51,557,580	54,760,022	58,131,446
2025	52,,335,935	56,071,853	60,039,041
2026	53,126,040	57,415,111	62,009,234
2027	53,928,073	58,790,547	64,044,080
2028	54,742,215	60,198,933	66,145,699

Source: Prepared by the author

Total demand is informed within the confidence interval generated and can be better seen in Chart 7.

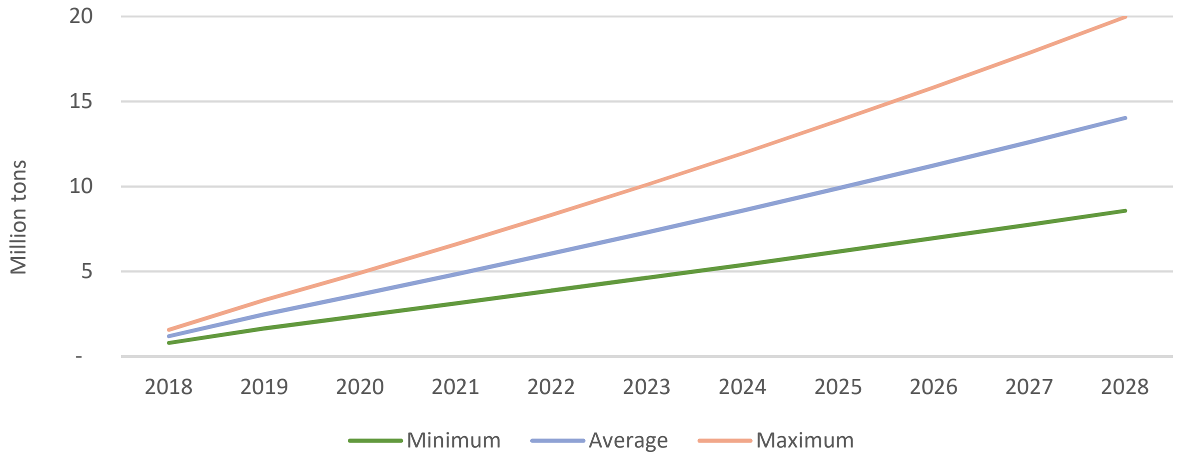


Chart 7 – Total annual demand predicted for diesel oil (minimum, average and maximum)

The annual additional volume to be introduced in the Brazilian market in order to reach the total demand predicted for the following years was estimated based on the fuel demanded volume in 2017.

Find in Table 8 the projection of the additional quantities that will be demanded in the following years:

Table 8 – Additional quantities of diesel to be demanded from 2018 to 2028

FOCUS + ECM 1p			
Increment in the Diesel demand (Tons on 2017)			
Year	Minimum	Average	Maximum
2018	796,741	1,181,254	1,565,767
2019	1,642,049	2,469,784	3,304,604
2020	2,385,170	3,639,468	4,915,162
2021	3,118,244	4,832,777	6,591,632
2022	*3,862,384*	*6,054,672*	*8,323,115*
2023	*4,617,759*	*7,305,839*	*10,111,418*
2024	*5,384,538*	*8,586,980*	*11,958,403*
2025	*6,162,892*	*9,898,811*	*13,865,998*
2026	*6,952,997*	*11,242,068*	*15,836,192*
2027	*7,755,031*	*12,617,504*	*17,871,037*
2028	*8,569,172*	*14,025,891*	*19,972,656*

Chart 8 contributes for the perception of the concept of relative magnitude along the following years.

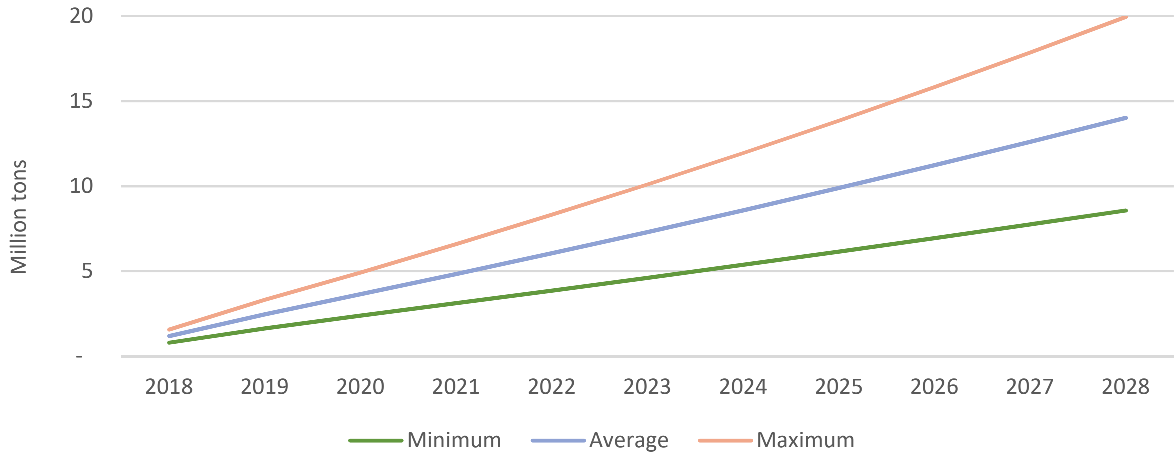


Chart 8 – Additional quantity of diesel oil to be demanded from 2018 to 2028

4.3. Domestic refining supply capacity

Brazil counts on 18 petroleum refineries. Together, they have capacity to refine approximately 120 million tons of crude oil per year. The list of refineries and the participation of each in this component of the fuel supply can be seen in Chart 9.

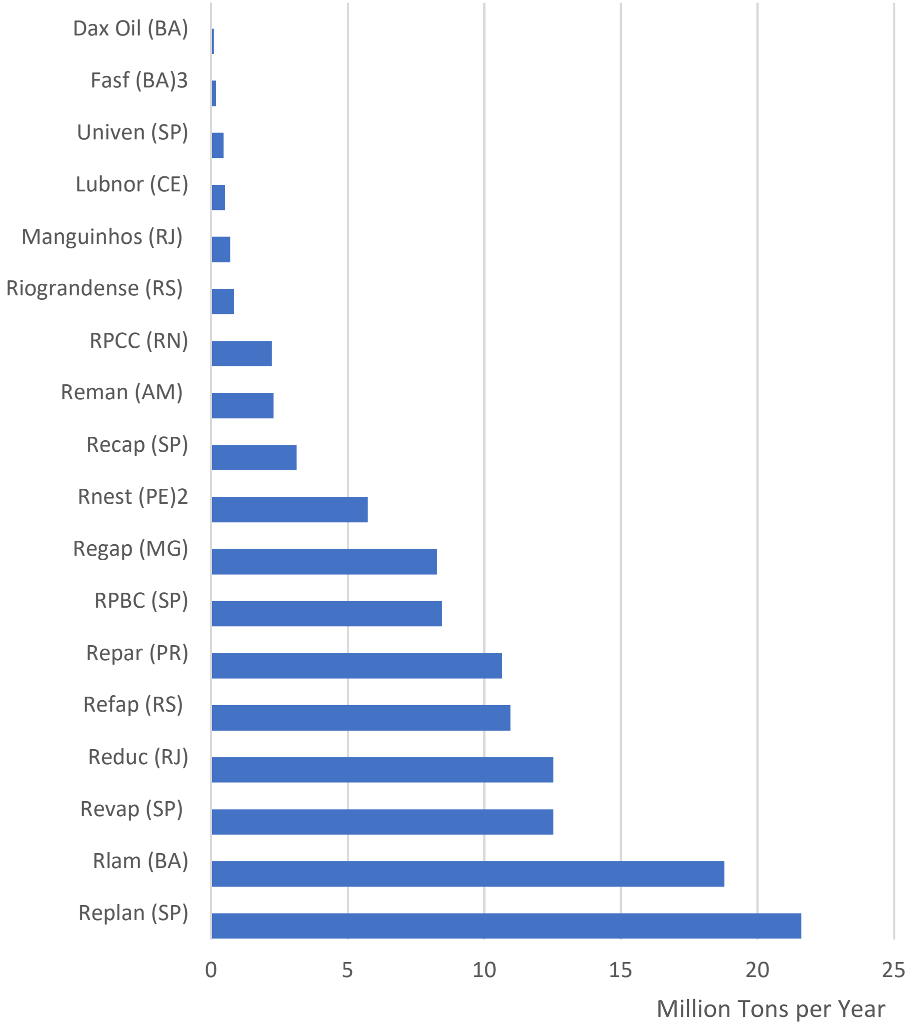


Chart 9 – Refining Capacity, according to the refineries, as of 2016
Source: ANP

As can be seen in chart 9, the difference as regards the capacities of some refineries exceeds 20 million tons per year. The 10 largest plants are responsible for 93.9% of the refining capacity and the other 8 small ones share the remaining 6.1% participation.

The refineries are present in only 10 of the 21 states of Brazil, according to Table 9.

Table 9 – Refining Capacity per State

State	Million T	% Share	% Accum.
SP	46,188	38.49%	38.49%
BA	19,086	15.91%	54.40%
RJ	13,227	11.02%	65.43%
RS	11,810	9.84%	75.27%
PR	10,650	8.88%	84.14%
MG	8,269	6.89%	91.04%
PE	5,727	4.77%	95.81%
AM	2,286	1.91%	97.72%
RN	2,224	1.85%	99.57%
CE	517	0.43%	100.00%
Total	119,985	100.00%	

Source: ANP

Southern and southeastern states have more than three fourth of the refining capacity in the country.

Refining capacity has been kept constant in the last years. In view of the recent past economic recession, the level of utilization of the installed refining capacity dropped to 81.4% in 2016, according to chart 4 illustrated in section 1.2 of this study.

With regard to the diesel oil, the production history in the last years is shown in Table 10.

Table 10 – The history of diesel oil refining (million tons)

REFINERY	2010	2011	2012	2013	2014	2015	2016	2017	Average
REPLAN	8.4	9.2	9.8	10.2	10.3	10.2	8.3	7.1	9.5
RPBC	4.0	4.1	4.5	4.5	4.7	4.1	3.6	3.5	4.2
REPAR	3.7	4.3	4.2	4.7	4.8	4.8	3.8	3.5	4.3
RLAM	4.5	3.9	4.0	4.7	5.0	4.6	3.9	3.4	4.4
REGAP	2.8	2.6	2.9	2.8	2.9	3.3	3.3	3.3	3.0
REFAP	3.7	3.7	3.7	4.5	4.2	4.2	3.9	3.2	4.0
REVAP	2.6	3.5	3.7	4.2	4.4	4.1	3.3	3.0	3.7
RNEST	-	-	-	-	0.0	1.9	3.0	2.6	2.5
REDUC	2.9	2.9	2.9	3.3	2.8	2.5	2.6	2.3	2.9
RECAP	0.8	0.9	1.2	1.3	1.4	1.0	1.3	1.2	1.1
REMAN	0.6	0.6	0.6	0.7	0.7	0.6	0.6	0.5	0.6
RIOGRANDENSE	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
RPCC	0.5	0.5	0.5	0.5	0.4	0.2	0.2	0.3	0.4
LUBNOR	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
DAX OIL	-	-	0.0	0.0	0.0	0.0	0.0	0.0	-
UNIVEN	-	-	-	-	-	-	-	-	-
MANGUINHOS	-	-	-	-	-	-	-	-	-
TOTAL	34.9	36.6	38.4	41.8	41.9	41.7	38.2	34.2	40.8

Sources: ANP. Prepared by the author

In 2014, when the utilized refining capacity was 94.9% of the installed capacity, the national industry park even delivered almost 42 million tons of diesel oil.

4.4. Import supply capacity

This section sets out a general panorama of the situation of liquid bulk discharges in the country. Below, find the details about the study on the capacity of the main port of discharge for diesel oil in 2017, the port of Paranaguá.

At the end of the section, the analysis results are presented in relation to the other major ports responsible for the diesel oil entry in the country.

4.4.1. A panorama of the diesel oil unloading in Brazil

Such portion of the demand for petroleum-derived fuels that exceeds the production, or domestic refining, must be supplied by imports. Regular imports of petroleum-derived fuels are solely carried out by the sea mode. Such constraint is due to the physical characteristics of the products, the low aggregate value and the location of the exporting countries.

These fuels enter the country through port terminals that are specialized in receiving and unloading tanker vessels. Additionally to the infrastructure required for

mooring and unloading the ships, these terminals must also have a tank storing structure to receive, segregate, store and, later, forward the imported products to their destinations. Said shipment of imported products can be made on trucks, trains, vessels (coastal trading, inland shipping and port support vessels) or through pipelines.

According to ANP (2018) figures, imports of petroleum and petroleum products have evolved since the year 2000 as shown in chart 10.

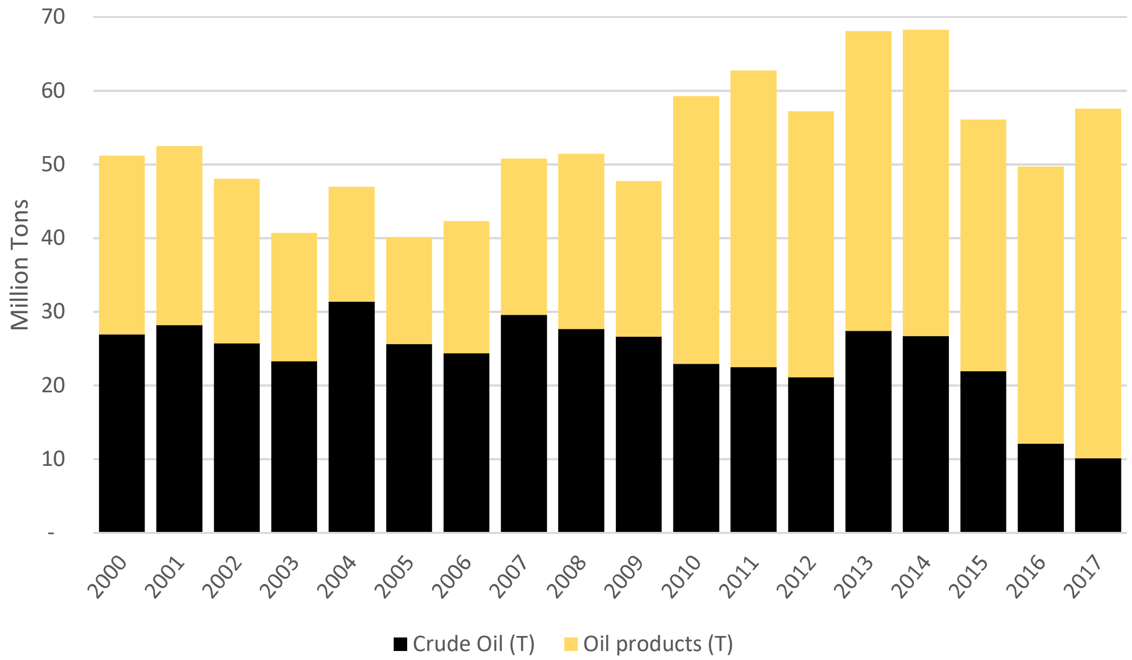


Chart 10 – Imports of crude oil and petroleum products from 2000 to 2017
Source: ANP. Prepared by the author

Chart 10 demonstrates two clear movements concerning the imports: the import of crude oil is diminishing, while the import of its derivatives is expanding. The quantity of imported petroleum in 2017 is less than half the number imported in 2000. This effect is due to the increase in prospection and refining of the national petroleum in the last years. The share of the national petroleum in total refining volume jumped from 77%, in 2007, the year of the official announcement of the discovery of the pre-salt layer reserves, to 90%, in 2016. This represents an additional contribution of more than 9 million tons of Brazilian petroleum per year. The quantity of imported oil used in the refining of petroleum products in Brazil is less than the quantity exported by Brazil. However, due to technical reasons concerning some refineries, there is still necessity of using the imported petroleum.

The exploration of the national petroleum and the importation of foreign oil to cause impact on the supply of the fuel focused in this study (diesel oil) go through the bottleneck of the refining capacity. The study regarding the supply capacity will focus only its limiting factors with regard to the diesel oil: the capacity of refining and the capacity of importing already refined diesel oil. The evolution of the diesel oil imports can be seen in Chart 11.

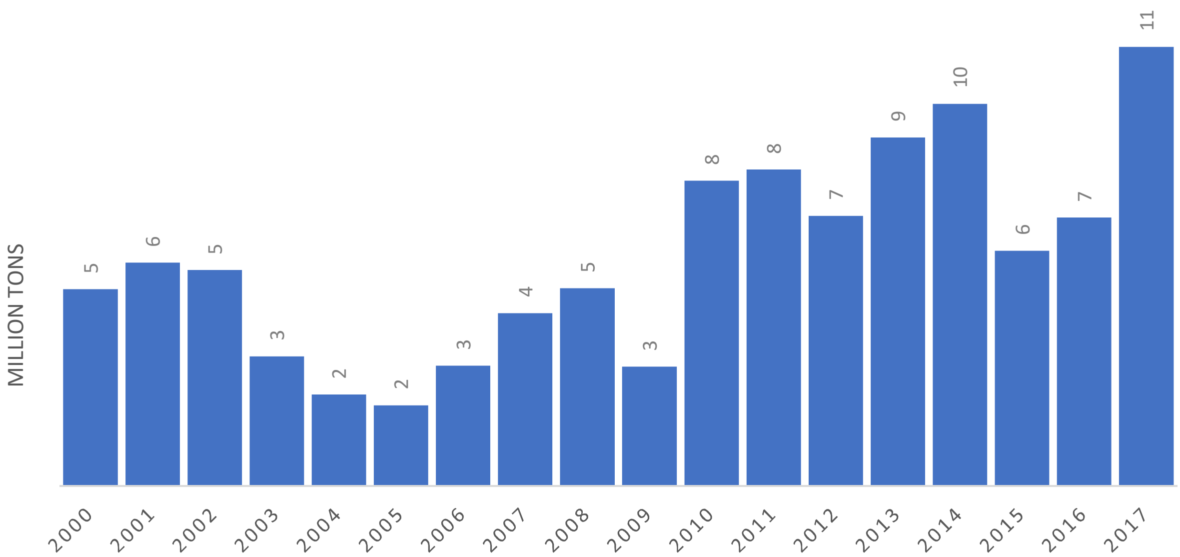


Chart 11 – Diesel oil imports from 2000 to 2017
Source: ANP

ANTAQ keeps analytical records of all movements of goods and vessels in the Brazilian ports. The access to information is detailed in what the agency names as the "5 dimensions".

The dimensions are: period, facilities, merchandise, container and carriage. The metrics are divided in movement and carriage, and they quantify the different specifications made in the dimensions in tons or in number of moorings. The dimensions are sectioned in different other options, allowing more detailing in the researches. From these dimensions and metrics, it is possible to extract researches on the port movement directly in the website or to download the database.

In the carriage dimension, it is possible to divide the data as to the type of navigation. For the study on import volumes, the deep-sea navigation is what matters in this classification, that is, the one where the vessels sail beyond the national borders. In ANTAQ classification, as regards the direction, the deep-sea navigation can refer to unloaded volumes or to loaded volumes. Import volumes are those unloaded. In brief,

in ANTAQ classification, import cargo refers to volumes unloaded from deep-sea navigation.

ANTAQ database detailing is not ideal for the merchandise dimension: it is only possible to detail the merchandise data up to four-digit level of the Common External Tariff (TEC). In the case of diesel oil, which receives the TEC classification code 2710.19.21, it is grouped with all merchandises of the group 27.10.

TEC position 27.10 covers “Petroleum oils or oils obtained from bituminous minerals, other than crude; preparations not elsewhere specified or included, containing by weight 70% or more of petroleum oils or oils obtained from bituminous minerals, these oils being the basic constituents of the preparations: waste oils.”

Among other products, this position 27.10 also includes petrochemical naphtha and gasoline. Both are, after the diesel oil, the merchandises that move the greatest volumes of import cargo in said class.

Nevertheless, ANP releases the segmentation of imports per product. In 2017, the imported total of diesel oil according to ANP figures was 10.9 million tons. Petrochemical naphtha and gasoline corresponded to 7.8 and 3.3 million tons, respectively. These three merchandises – diesel oil, petrochemical naphtha and gasoline – cover 92% of the volume of imported cargo disclosed by ANTAQ under the position 27.10. Diesel oil represents 46%, petrochemical naphtha another 33% and gasoline corresponds to 14% of the total merchandises classified under the position 27.10, and unloaded in the Brazilian ports in the year 2017.

The imports of petroleum products covered by TEC position 27.10 in 2017 concentrated 98% of their volumes in only 10 ports, and the complementary 2% of the volume were sprayed among the other six ports. Among said 10 ports, the main five were responsible for 78% of total volume of imports.

As can be seen in chart 12, among said 10 ports responsible for 98% of total imports, six are located in the southern and southeastern regions. In total, the ports lying in these two regions were responsible for 58% of the quantity of light oil products imported in 2017. Salvador port complex was responsible for more than 17%, Recife for 11% and Itaqui for 10%. The ports of the southern and southeastern regions, plus the three former ports, concentrated 95% of all import discharge of said petroleum products.

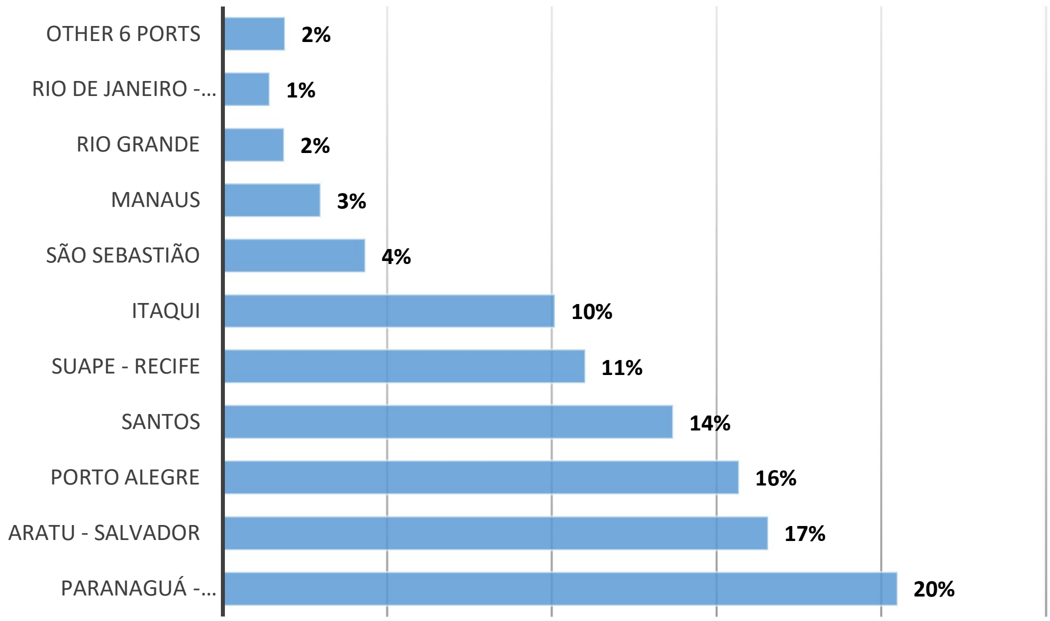


Chart 12 – Port participation rate in the discharge of 27.10 cargo imports
Source: ANTAQ, 2018.

In section 4.3 on the domestic refining supply capacity, it had already been pointed out that the southern and southeastern regions also concentrated three fourth of the petroleum refining capacity in Brazil. This concentration of fuel supply sources, namely: refineries and ports, help to explain the volumes of fuels carried in the coastal trading navigation and other modes of transportation inside borders.

For every 100 tons of those cargoes covered by the position 27.10 and moved as imports through the Brazilian ports, there are other 166 tons that were moved by coastal navigation or inland navigation, that is, loading and unloading between Brazilian ports only.

Added to the other 4 million tons of exports of goods in said same position, the Brazilian ports moved in 2017, among import, export, cabotage and inland waterways, 68 million tons only of liquid petroleum products classified under the position 27.10, in TEC.

Diesel oil import competes for mooring space in the Brazilian ports, with not only cargoes of the same class carried in other modes of navigation or in other direction (cabotage, deep sea going shipments), but also with crude petroleum oils and other liquid cargoes in bulk, in large part from the terminals.

Based on MDIC numbers, accessed through the ALICEWEB system, it is possible to identify in which ports the fuel importation was registered.

ANTAQ data provide information about the quantities that were actually discharged in each port. However, the maximum detailing level is the fourth position in the code of the Mercosur Common Nomenclature (NCM). Said constraint impedes that an accurate data for diesel oil or any other specific cargo discharged may be obtained from said databases.

MDIC, otherwise, brings information about the port of clearance, which, as a rule, is the merchandise port of discharge. MDIC data is provided up to the eighth NCM code position, allowing the individual identification of diesel oil, gasoline, petrochemical naphtha and other products.

Usually, the port of clearance stated in MDIC statistics is the port of discharge; however, in some cases the importers have been adopting the practice of nationalizing the imported diesel oil at a port and not discharging all cargo in said port, proceeding with same, already cleared, to be discharged in other Brazilian ports. Importers avail of this strategy to optimize the cost of ocean freight, once they can carry more cargo in a same voyage, or even employ larger vessels. By carrying more cargo or in larger vessels to serve importers in different ports on one same trip, the freight cost is optimized when compared to the cost they would have employing smaller vessels or bringing less cargo to supply one sole port per voyage. There is an important time gain and the risks of delay are mitigated when the nationalization of the entire cargo is made already in the first Brazilian port. This avoids the repetition of the customs procedure at each port of discharge and eliminates the possibility of delays that can derive from said bureaucratic procedure.

Together, MDIC (2018) numbers and those of ANTAQ (2018) allow the identification of the ports through which the supply of imported diesel oil is arriving at the Brazilian market.

Chart 13 outlines the distribution of the import volumes specifically for diesel oil in the different Brazilian ports. The effects, mainly of the exclusion of more than seven million volumes of petrochemical naphtha, are demonstrated. When one separates said volume, which is mainly discharged in the ports of Aratu-Salvador, Porto Alegre, São Sebastião and Rio Grande (to satisfy the petrochemical poles of said regions), the discharge of diesel oil becomes even more concentrated.

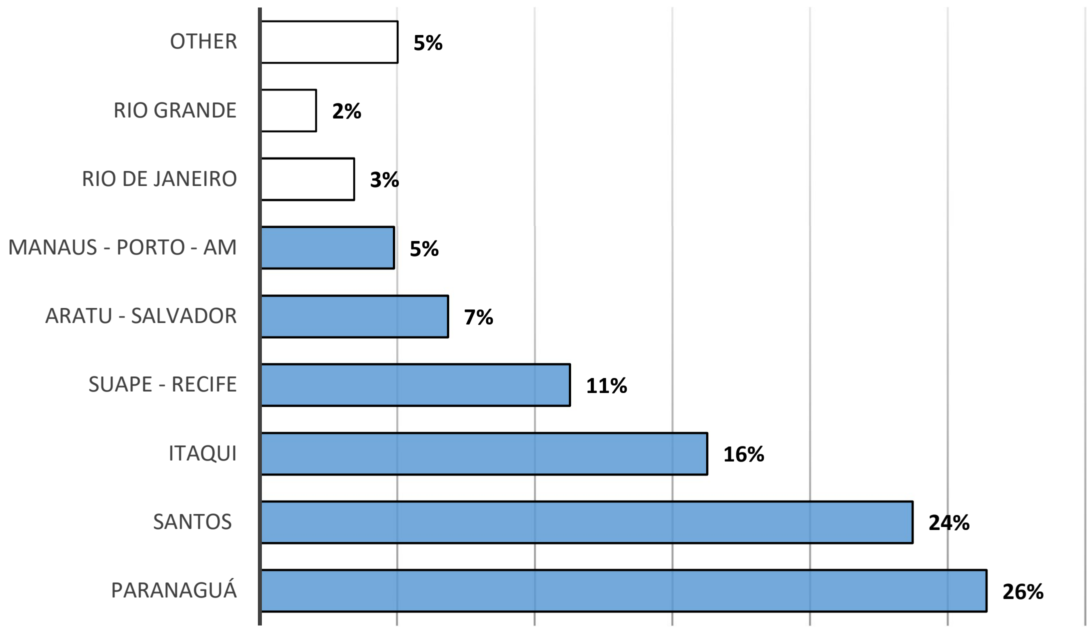


Chart 13 – Port participation rate in the volumes of imported diesel oil discharged in 2017
Source: ANTAQ, 2018

About 90% of the imported diesel oil supply arrived at Brazil through six ports only, in 2017: Paranaguá, Santos, Itaqui, Suape, Aratu and Manaus. For emphasis, said ports are marked with blue filled bars in chart 13.

Given the above numbers, it follows the study of the historical movement of the six ports that were responsible for about 90% of the diesel oil importation in 2017. Based on this survey, it will be possible to estimate what the capacity of response of said ports would be in case of an increase in the demand for imported diesel oil.

The problem regarding the concentration of the movement of some goods in a few ports, according to Caixeta and Martins (2001, p. 55), is a matter to be faced at federal level. Said imbalance should be mitigated through regulatory mission, technical monitoring and competition among the ports. The authors pondered the importance of a competition policy among ports, taking into account the large distances traversed by the trade flows.

Caixeta and Martins (2001) warn that, besides the large distances between the ports, the inexistence of proper facilities for each specific cargo type in the possible alternative ports appears as a barrier to competition. The frequency of ships' calls, the

chains of land carriage and movement of goods connected to the ports also have a determining role in any possible competition among the ports.

In brief and with a focus on the transportation of goods, the Law 12,815, published on June 5, 2013 (BRASIL, 2013), known as the new "Port Law", defined the "Organized Port" as the public port. Port traffic and operations within the limits of the Organized Port fall under its jurisdiction. The Organized Port consists of port facilities intended for the handling and storage of merchandises.

Said Law also defined the Private Use Terminals (TUP) as the port facilities exploited outside the Organized Port area.

In this study, when not otherwise specified, the term "Port" is employed with emphasis in the geographic location and not in the exploitation regime. The term "Port" is used when referring to a "Port Complex", and embodies the Organized Port and the Private Use Terminals. And the word "Terminal", in this study, refers to a "port facility" as defined in said Law.

In one perspective, a port can be described as a system with several terminals specialized in certain types of cargo. Irrespective of the size and total declared movement capacity of the port, in order to check the capacity to handle any specific cargo segment, it is necessary to detail the system. It must be known which terminal(s) specifically gathers (gather) the required characteristics to handle a determined cargo segment.

With regard to the diesel oil, the port segment of which is the one specialized in the movement of liquid bulk cargo, the degree of specificity is high for port facilities. A terminal that operates general cargo, for instance, can occasionally operate solid bulk cargoes or containers, and vice-versa. Liquid bulk cargoes cannot be operated (from the port or to the port) in a terminal that is not specialized in liquid bulk. Not in a manner that is economically acceptable at a minimal level.

In the ports, vessels carrying such cargoes can only moor at certain specialized terminals. Each specialized terminal has one or more positions for ships to berth at and operate. Those positions alongside which the vessels moor to operate are called mooring berths.

In the case of liquid bulk vessels, some ports are able to have the ships operated without being moored, as it is the case of Tramandaí (which appears in the statistics as Porto Alegre Port Complex). In such operations, the vessels lie at anchor or are moored to the so called "floating buoys", and their loading and unloading operations

are carried out through flexible pipelines connecting the ship's tanks to the storage shore tanks in the port facility. There are also transshipment operations, which are performed directly from one vessel to another vessel or barge. The limitation in the capacity to load or unload vessels from terminals that can operate cargoes off the berth is equivalent to the limitation in the number of berths at conventional terminals; and, therefore, this study treats these terminals indistinctly.

4.4.2. Paranaguá – Capacity to increase the discharges of diesel oil

The port of Paranaguá was responsible for 26% of total imported diesel oil in the year 2017. Located in the state of Paraná, in the Southern Region, the port of Paranaguá moved a total of 53 million tons in 2017, handling mainly grain cargoes, containerized cargoes, petroleum products and sugar.

Chart 14 indicates the participation rate of the petroleum products compared to other cargoes moved in the port of Paranaguá.

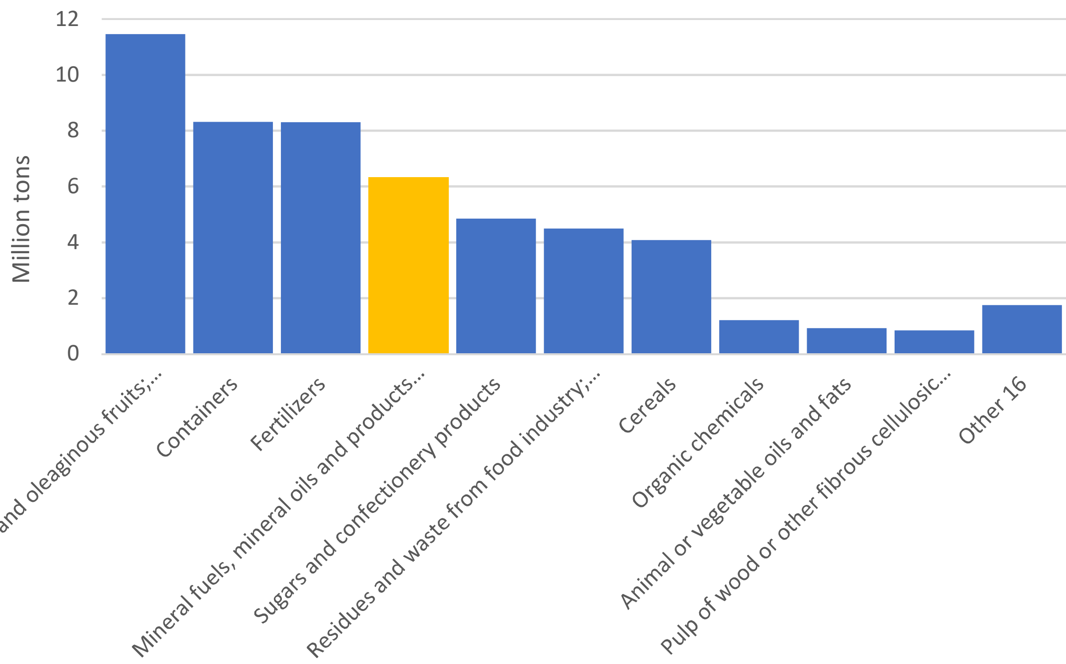


Chart 14 – Main cargoes handled in the port of Paranaguá
Source: ANTAQ, 2018.

The participation rate of the petroleum products in the port of Paranaguá represented 12% of total tons moved, and 13% of total berthing events occurred in said port during the year 2017.

Table 11 details the representativeness of the main cargo groups, in tons and in number of berthing events.

Table 11 – Paranaguá Port Complex – Main cargoes

Ranking	Merchandise group (TEC)	Cargo Volume		Berthing Events	
		Tons	%	Qty	%
1	Seeds and oleaginous fruits; miscellaneous grains, seeds and fruit	11,454,116	22%	191	7%
2	Containers	8,315,843	16%	757	29%
3	Fertilizers	8,305,168	16%	307	12%
4	**Mineral fuels, mineral oils and products of their distillation**	**6,335,839**	**12%**	**354**	**13%**
5	Sugars and confectionery products	4,846,268	9%	161	6%
6	Residues and waste from food industry; prepared animal fodder	4,493,712	9%	97	4%
7	Cereals	4,072,814	8%	89	3%
8	Organic chemicals	1,207,404	2%	86	3%
9	Animal or vegetable oils and fats	916,874	2%	77	3%
10	Pulp of wood or other fibrous cellulosic material	845,196	2%	49	2%
11	Other 16	1,750,427	3%	474	18%
		52,543,661	100%	2.642	100%

Source: ANTAQ, 2018

Based on the exploratory research of ANTAQ database, it was seen that the discharge of petroleum products in the port of Paranaguá occurs only in two terminals specialized for such operations: Petrobras Pier and Cattalini Maritime Terminals.

To assess the actual capacity of said terminals, the study has investigated the total movement of cargoes in both terminals between 2010 and 2017. This movement is illustrated in the series of graphs in Figure 1.

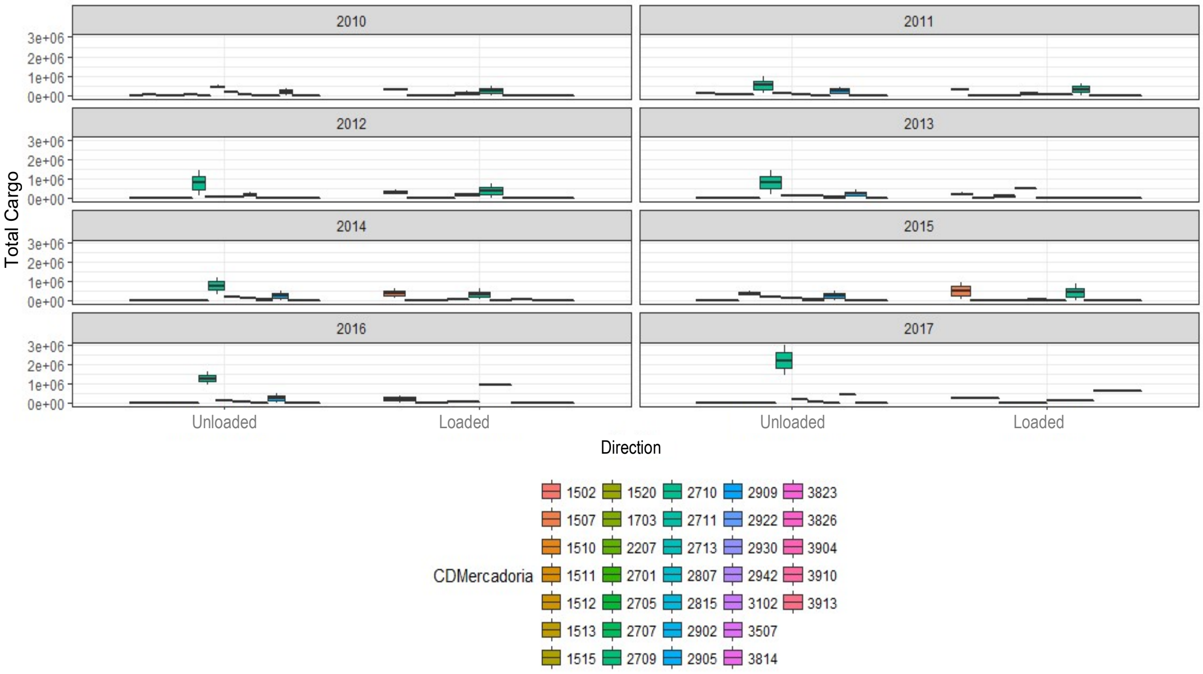


Figure 1 - 2010-2017 historical boxplots of all liquid bulk movement at the terminals of Cattalini and Petrobras, in Paranaguá
Source: ANTAQ, 2018

The petroleum products, covered by NCM 2710, are represented in green and are the sole ones distinguishable in the series of graphs, given the predominance of their volume over the volume of other cargoes competing with them for the mooring berths.

The contribution of Figure 1 is limited to illustrate the diversity of cargoes competing with the one focused in this work for the berthing superstructures. It graphically shows that the increase in the volumes of diesel oil was disproportionate to the movement of the other cargoes. It is also made clear that, in Paranaguá, between 2010 and 2017, no other liquid bulk cargoes matched in volume the volumes seen as from 2011 for diesel oil.

To render the analysis clearer and more simplified, in Figure 2, cargoes were divided in only two groups: cargoes of 2710 group, and cargoes of non-2710 group:

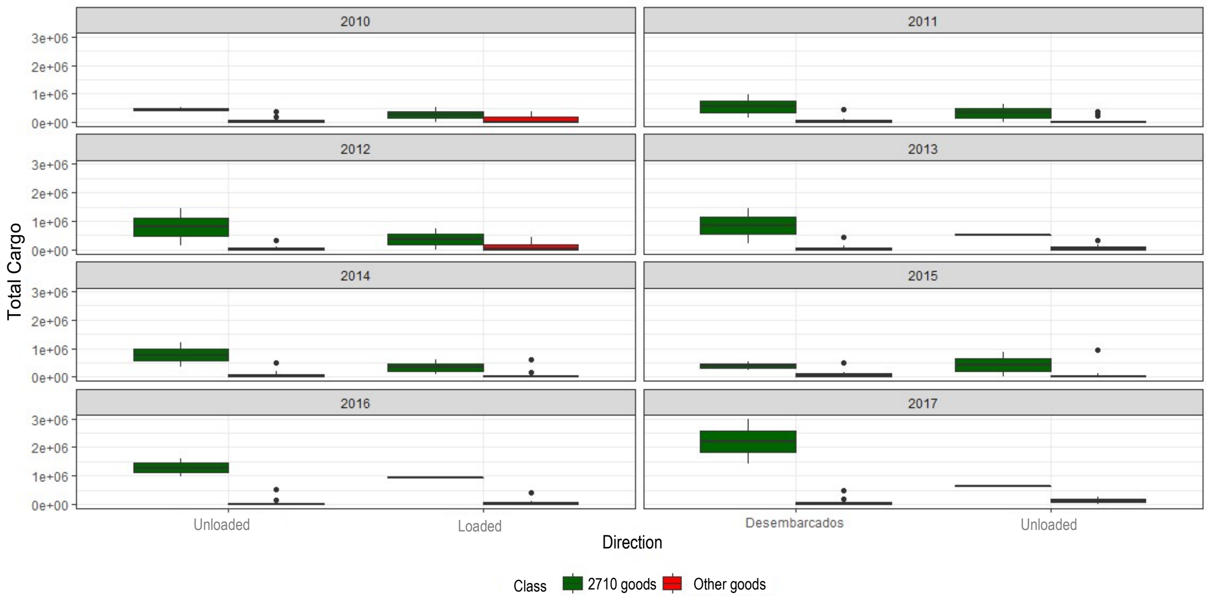


Figure 2 - 2010-2017 historical boxplots of the movement of 2710 cargoes and non-2710 cargoes at the terminals of Cattalini and Petrobras, in Paranaguá
Fonte: ANTAQ, 2018.

From the analysis of the graphs, the predominance of 2710 cargoes over the other liquid cargoes becomes clear. Additionally, it is demonstrated the existence of imbalance between the quantities unloaded and the quantities loaded in the port of Paranaguá. The volumes of unloaded petroleum products have been increasing disproportionate to the loaded volumes of all cargoes together.

Based on this information, it is made clear that all said additional discharge volume is being forwarded by land transportation modes only.

The discharged total of liquid petroleum products in Paranaguá in 2017 is greater than the total annual volumes of loadings and discharges for all liquid products (including petroleum products) in the historical series from 2010 to 2015, as illustrated in Chart 15.

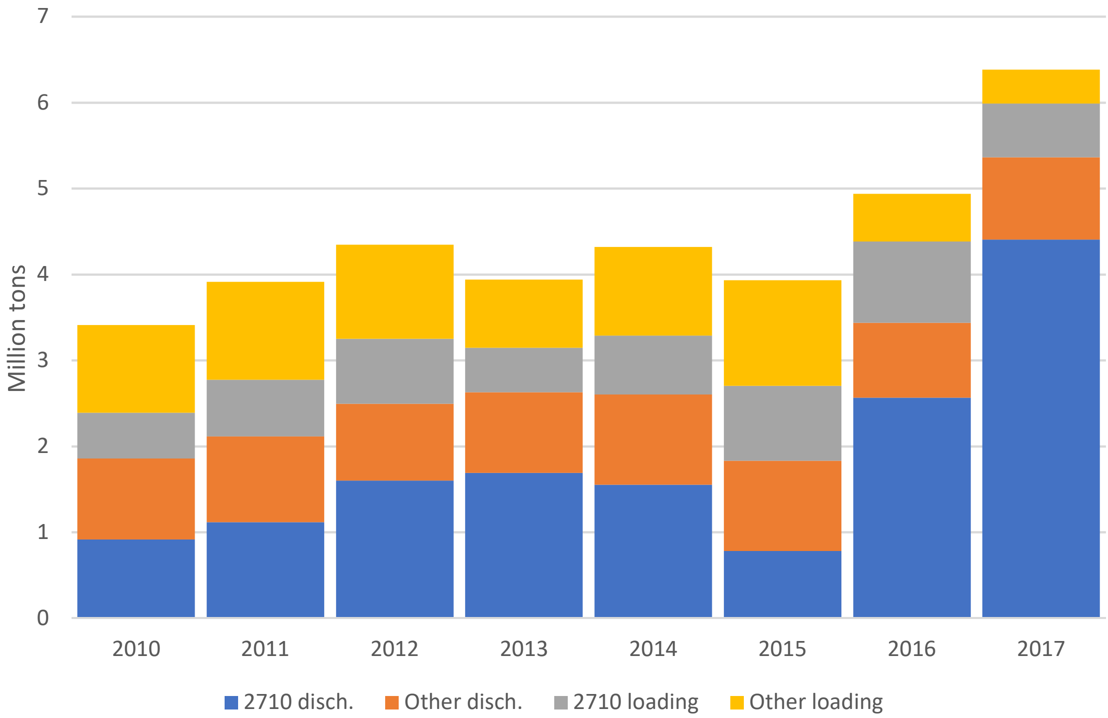


Chart 15 – Discharge of liquid bulk at Cattalini and Petrobras terminals in Paranaguá, from 2010 to 2017
Source: ANTAQ, 2018.

In Paranaguá, it was the task of Cattalini Maritime Terminals to receive the majority of the additional volume in the last years. To meet such increase of 87% in the total demand of the port for volumes of petroleum products, Cattalini managed to expand its operation by 150%. Petrobras Pier increased by 35% its annual movement volume in 2017 compared to the year 2010.

Consequently, Cattalini had its market share increased from 45% in 2010 to 61% in 2017 with regard to port operations of petroleum products.

The division of the operations with petroleum products in Paranaguá presented the following numbers in the last years, as per Chart 16.

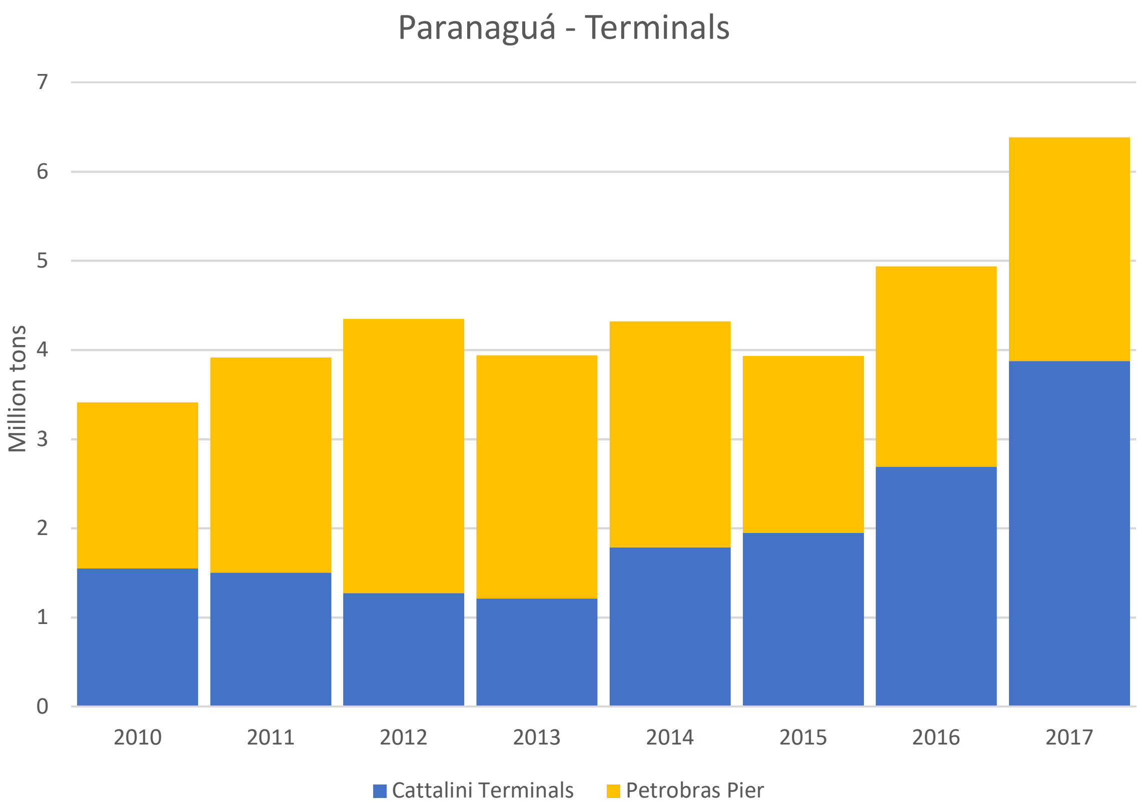


Chart 16 – Division of liquid bulk operation volumes between the terminals operating with petroleum products in Paranaguá
Source: ANTAQ, 2018.

This increment in the operations of both terminals produced the effect of increasing the waiting time that the vessels have to bear prior to getting to the berth and starting cargo operations.

Chart 17 shows an idea of magnitude of the effect that the increase in diesel oil imports had on the port of Paranaguá. The number of hours used by the vessels to operate liquid bulk cargoes in both terminals of said port and the total time waiting for a berth endured by the vessels are plotted on the left axis. On the right axis, the monthly quantities of cargoes moved by the two liquid terminals are plotted.

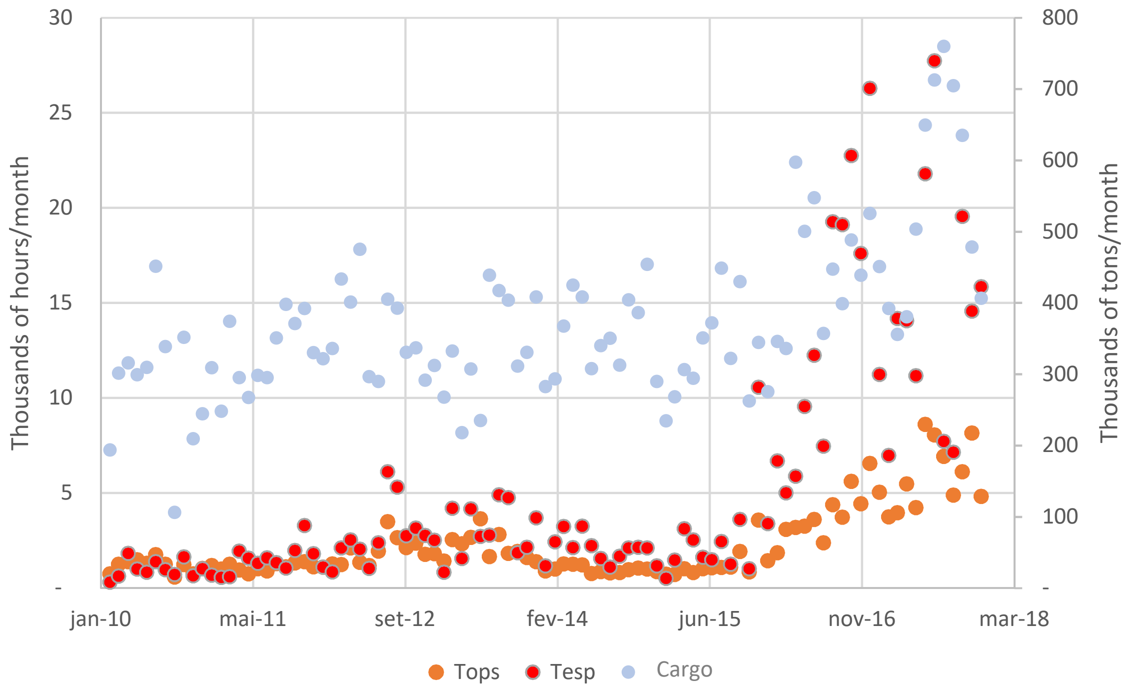


Chart 17 – Cargo operation volume, waiting time for a berth and operating time in the terminals that discharge petroleum products in Paranaguá, from 2010 to 2017
Source: ANTAQ, 2018.

From the analysis of Chart 17, it is seen that the relative proportion maintained by the three metrics between 2010 and 2016 have spaced. Until then, the operating time (Tops) and the waiting time (Tesp) on each month were in the interval that has as top limit 5,000 monthly hours. The cargo oscillated around a line that can be estimated at 350,000 tons a month.

From 2016, with the increase in the quantities of imported diesel oil, the total tonnage of liquids moved rises, as represented in the chart. They even overcome the line of 750,000 tons a month little before the September 2017 mark. Total vessel waiting time exceeds 27,000 hours a month in same period.

On its turn, the ships' operating time per month, although having increased a lot, stayed far below the increase in the waiting hours. While waiting time reached peaks above 25,000 hours a month, total time of operation has never exceeded 10,000 hours a month.

There are practically no physical limits to the increase in the hours waiting for a berth. The number of vessels that arrive and can position themselves to wait for a berth in the ports is just physically limited by the global vessel fleet. Economically speaking, this limit is certainly more modest.

Waiting time is computed from the time of vessel’s arrival off the port limits until the time of berthing. For statistical purposes, the hours a vessel spends waiting for a berth are computed in the month the vessel moors alongside quay. To exemplify, let us suppose that a vessel has arrived on December 30 and waits two days before getting a berthing space. In this case, the vessel should moor on January 01, and 48 hours of wait would be computed in the indicator for the month of January. Total waiting hours of all vessels that have berthed in a determined month are the total waiting hours accounted for in the indicator for that month.

Cargo operation hours, however, have a clear physical limit. The maximum operating hours of a port is the result of multiplying 24 hours by the number of facilities available for operating said cargo. From said time, one must deduct the unavoidable operational intervals. In the case of maritime terminals, the time spent between the completion of a ship’s operation, its unberthing and the berthing, preparation and beginning of the operation on the next vessel is the largest operational interval that cannot be taken away.

Chart 18 illustrates the increase in the quantity of vessels that wait longer in the historical series and the occurrence of outliers, with a waiting time far removed from the year average.

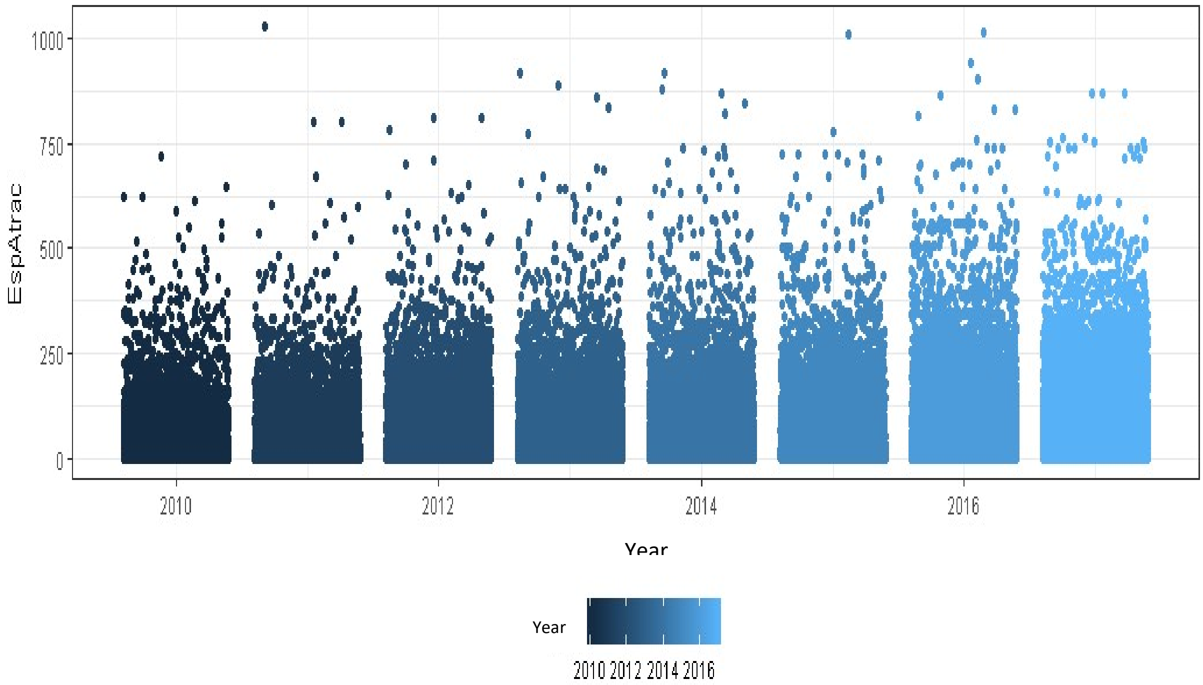


Chart 18 – Berth waiting time at the terminals that operate petroleum products in the port of Paranaguá - 2010 to 2017
Source: ANTAQ, 2018.

As mentioned above, the volume increase of diesel oil imports was absorbed in different proportions by the two terminals in Paranaguá. Cattalini terminal took the largest portion of this additional increase and this reflected in the waiting time difference for each terminal, as can be seen in Chart 19.

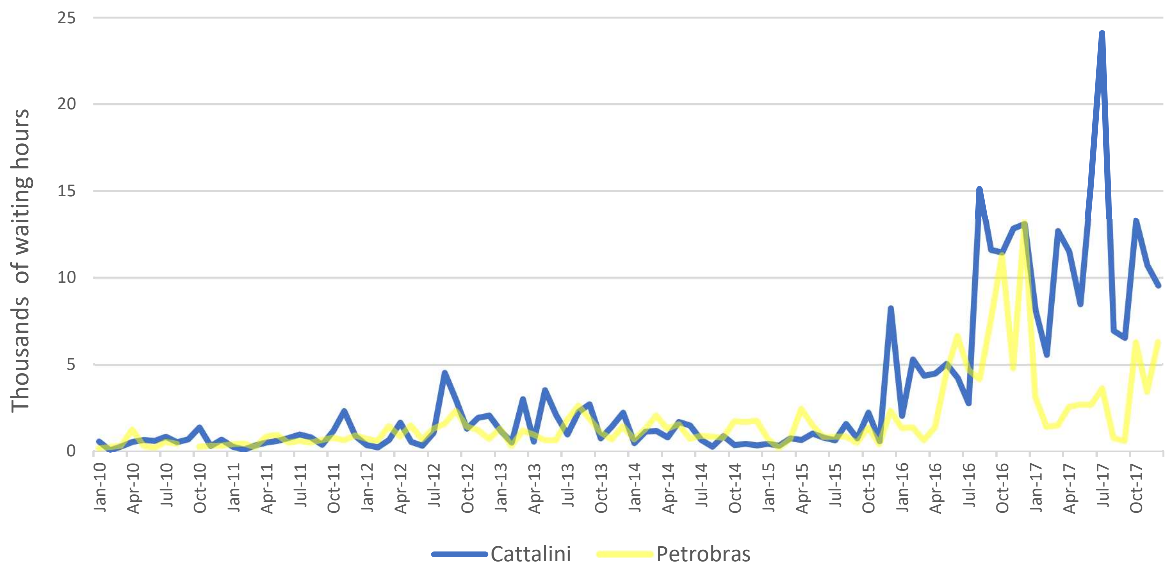


Chart 19 – The evolution of berth waiting hours at the terminals that operate petroleum products in the port of Paranaguá – 2010 to 2017
Source: ANTAQ, 2018.

From the beginning of 2017, it becomes evident that the increase in cargo volume has had an effect on the number of waiting hours for each terminal.

On analysis of Chart 20, it is seen that the monthly quantity moved by Petrobras terminal in this historical record of 96 months varied around 200 thousand tons. The historical movement of Cattalini terminal, otherwise, has had a completely different behavior between 2010 and 2015 and from then on. The monthly average movement of Petrobras terminal in the period from 2010 to 2017 was 203 thousand tons. In said historical average, Cattalini terminal moved 168 thousand tons per month. When separating the periods in two, from 2010 to 2014 and from 2015 to 2017, the average movement in Petrobras terminal was 213 thousand tons in the first period and 187 thousand tons in the second period, monthly. In Cattalini terminal, however, the average movement of 122 thousand tons in the period from 2010 to 2014, increased to 244 thousand tons, monthly, in the most recent period, from 2015 to 2017.

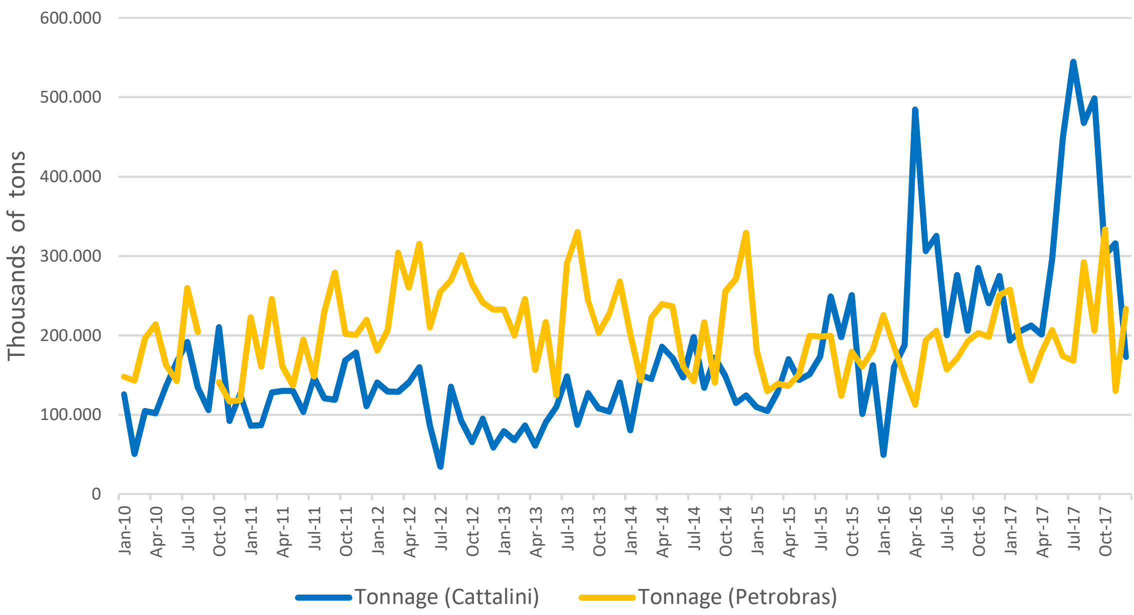


Chart 20 – The evolution of cargo quantity moved monthly at the terminals that operate petroleum products in the port of Paranaguá – 2010 to 2017
Source: ANTAQ, 2018.

The increase in the quantities moved affected negatively the terminal productivity, when measured in tons moved per hour. Both terminals had their cargo movement capacities reduced in tons per hour. Chart 21 demonstrates this reality.

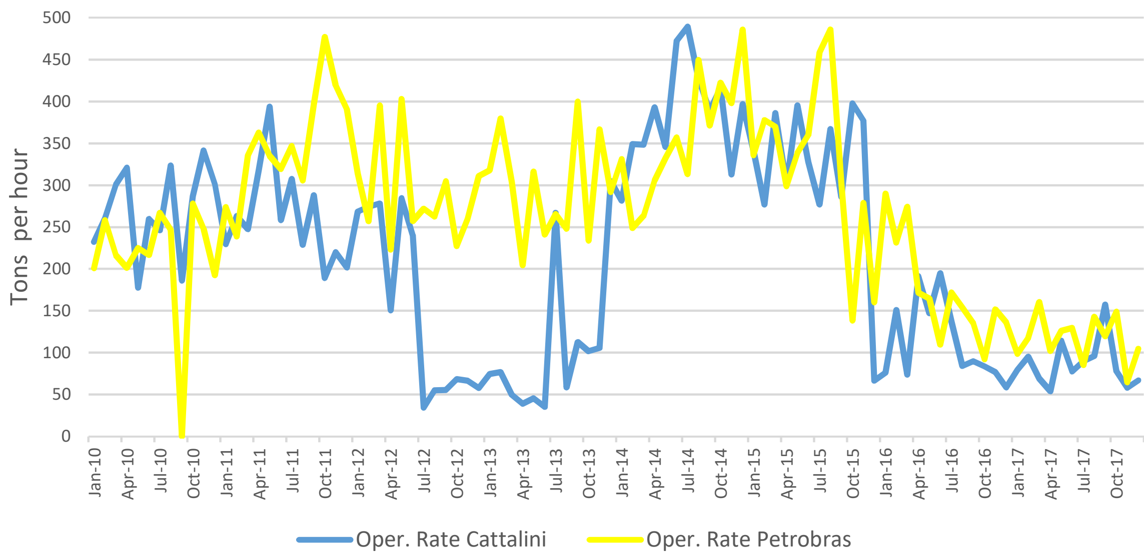


Chart 21 – The evolution of the operating rate, in tons per hour, at the terminals that operate petroleum products in the port of Paranaguá – 2010 to 2017
Source: ANTAQ, 2018.

The reduction in the terminal operating rate is more acute as from the second semester of 2015. This period coincides with the period when the port terminals started to face a growing demand for berths to discharge diesel oil.

When plotting together the evolution of operated quantities and the evolution of the discharge operating rates, the “scissors effect” is seen in Chart 22 and, likewise, in Chart 23. Said effect, which shows that two variables move in different directions, can be seen in the relation between operated quantity and operating rate in both terminals operating liquid cargos in Paranaguá. This drawing is suggestive of the depletion of the operational capacity of the terminals. The demanded quantities are driving the terminals to operate at a rate that is below the one that should be the optimal rate for each terminal.

The “scissors effect” can be seen in Chart 22 for the Cattalini terminal.

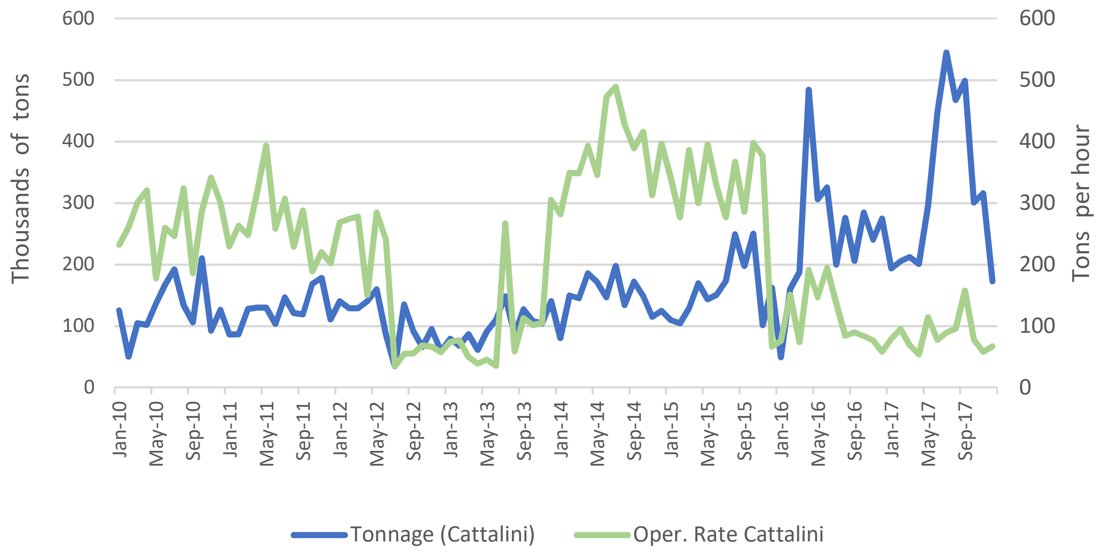


Chart 22 – The evolution of operated quantity x operating rate, in tons per hour, at Cattalini terminal, in Paranaguá – 2010 to 2017
Source: ANTAQ, 2018.

And similar reading can be made from Chart 23, which joined up the same data, with regard to Petrobras Terminal.

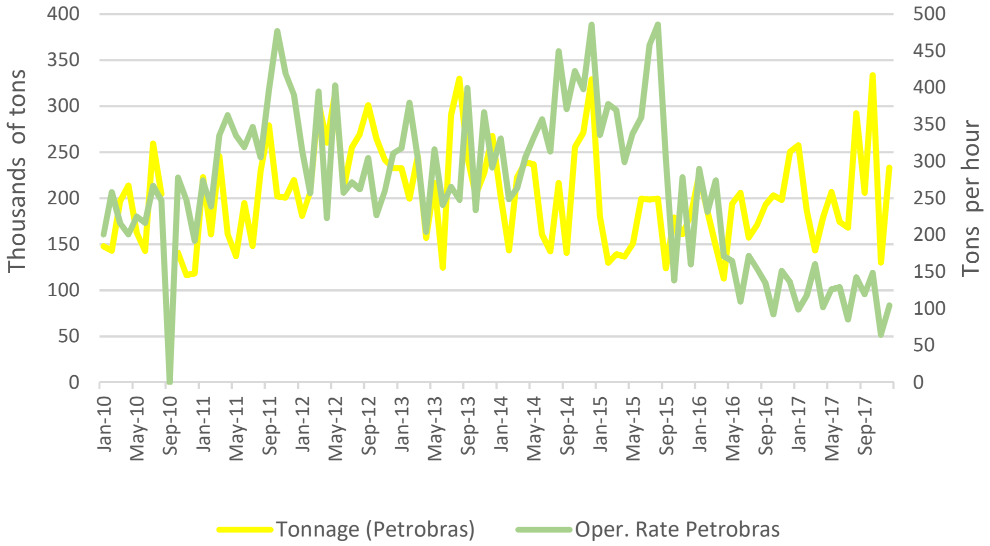


Chart 23 – The evolution of operated quantity x operating rate, in tons per hour, at Petrobras terminal, in Paranaguá – 2010 to 2017
Source: ANTAQ, 2018

Each one of these two terminals specialized in the discharge of liquid cargoes in Paranaguá has two berths for mooring and operating vessels.

Considering the unattainable average number of 24 operational hours a day, the maximum operating hours in a month should be 720 hours. This number is the product of the multiplication of the 24 hours of a day by the 30 days of a month. This operating hour number is unattainable due to the unavoidable interruptions occurring between the end of a vessel's operation, its preparation to sail and unberthing. Only after a vessel sails, the next to operate can then berth, prepare to start operations and, finally, start operating. Such time gap between the completion of an operation and the beginning of the other varies from port to port and from terminal to terminal. Nevertheless, said interval is never less than three hours in the terminals for liquid cargo discharge in the port of Paranaguá.

Even considering 720 hours monthly of operation for the four mooring berths in Paranaguá, taking into account the average operating rate in the two last years when the terminal capacity was challenged by the demand volume, the monthly movement capacity of Paranaguá terminals should be 350,000 tons a month.

From these numbers, it can be concluded that the port of Paranaguá operated above its capacity from 2016 to 2017. In case of an increase in the demand for diesel oil, the port of Paranaguá cannot be deemed an option to absorb a greater volume of this cargo. This affirmation is made on the assumption that the existing superstructures would be maintained and the volumes of other cargoes competing for these facilities would remain constant.

It remains to be ascertained the potential increase capacity for discharge volumes of diesel oil in the other five Brazilian ports, which, jointly with the port of Paranaguá, were responsible for 90% of the capacity utilized in the discharge of diesel oil in 2017.

4.4.3. Other main ports of discharge for diesel oil

Same methodology applied in the previous section was maintained to estimate the capacity of response of the other ports. The results of the analyses will be provided in a brief manner.

Because of its location, the port of Manaus is not included among the ports of interest to this study. Due to its eccentricity and the need to employ the waterway mode of transportation to have any diesel oil that might be discharged there arrive at the other regions of the country, the port of Manaus did not reach the status of a viable alternative to help the country face a possible crisis of diesel oil shortage.

In the port of Santos, the diesel oil is discharged at the terminal of Alamoa or at Barnabé Island terminal. Until 2016, these terminals have had a monthly operation volume close to the line of 200 thousand tons. The vessels totaled around 5,000 hours of wait a month, with the Santos terminals operating at that level. In the period from 2010 to 2017, there were waiting peaks in several months, in some of which the vessels accumulated already more than twice the average waiting time in the period. Such behavior of the number of hours waiting in the terminals in question is better demonstrated from the analysis of Chart 24.

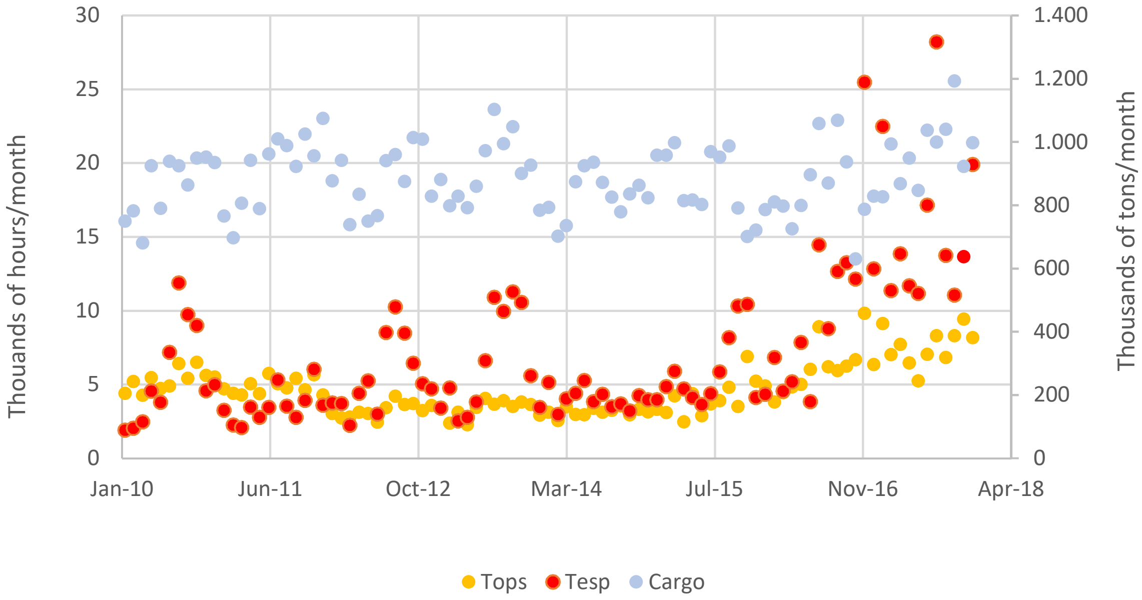


Chart 24 - The evolution of operated quantity x operating rate, in tons per hour, at the terminals that operate 2710 cargoes in the port of Santos – 2010 to 2017
Source: ANTAQ, 2018.

Already from the end of 2016, an increase in cargo quantity is seen in these terminals. The number of operating hours also expands; however, waiting hours soared to 25 thousand hours in certain months.

It is important to note that the total number of waiting hours suffers the influence of port capacity. A port presenting more possibilities of spaces to moor vessels tends to have higher absolute demand, while more vessels waiting for a larger berth will be said indicator. A port with one sole berth and where one vessel waits for 48 hours to moor to said berth will have a total waiting time indicator lower than a port with four mooring berths and four vessels waiting 20 hours each.

However, the average waiting time per vessel is in fact augmenting in the port of Santos. At the beginning of the studied series, in 2010, the average time that each vessel stayed in the port was shorter. To discharge a typical cargo of 15,000 tons, in 2010, the total turn-round time was 93 hours. In 2017, the average turn-round time for a vessel to move this same cargo is 163 hours. The total turn-round time in the port to operate the same quantity of cargo increased 74% in seven years.

The third more contributing port for the entry of the imported diesel oil volume in the year 2017 was the port of Itaqui, in São Luís do Maranhão.

This port is situated in an area where the economic growth is expected to be above the country's growth average. Luz (2015) states as an example that, between 2004 and 2014, while the demand for diesel oil in the state of Tocantins grew by 95%, in the state of Rio Grande do Sul such growth was only 21%.

The port of Itaqui, as the other ports previously studied, has also had an increment in the waiting time. The waiting hours computed for the vessels discharging diesel oil in Itaqui reached record levels in the years 2016 and 2017.

Interestingly, in this port, the tonnages of liquid petroleum products in the years with the maximum waiting time are not the largest ones compared to the preceding years in the study sample. The port of Itaqui already operated a greater volume of liquid cargoes at lower cost of time waiting for berth, as shown in Chart 25[2]:

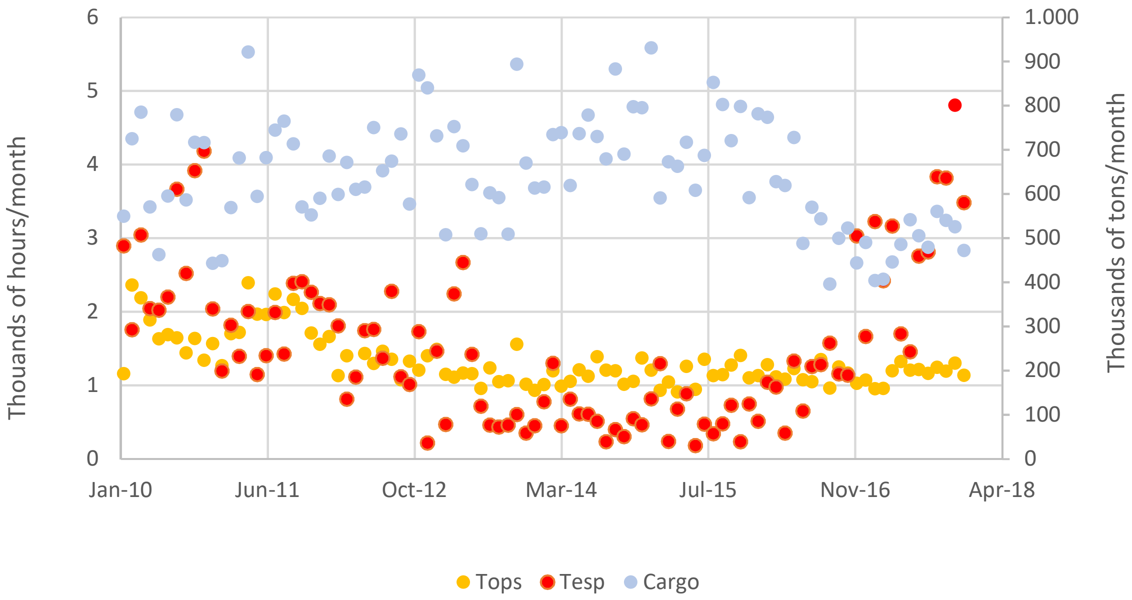


Chart 25 – The evolution of operated quantity, operating time and waiting time at Itaqui
Source: ANTAQ, 2018.

It is noted that the total time of operation remained at the level of thousand hours per month, that there was a reduction in the quantity of cargo moved and, even though, there was a significant increase in the levels of time waiting for a berth. Between December 2014 and May 2016, the monthly cargo movement remained around the

[2] The Y-axis of this graph is in 5:1 scale compared to similar graphs shown for the previous ports.

700.000 ton axis, and waiting time increased to the quadrant from 3 thousand to 4 thousand hours monthly.

A possible explanation for this phenomenon can be the change in the quantitative profile of the cargoes. From a search in ANTAQ (2018) database, the study extracts that the average consignation, that is, the average quantity of cargo operated per vessel, diminished as illustrated in Chart 26.

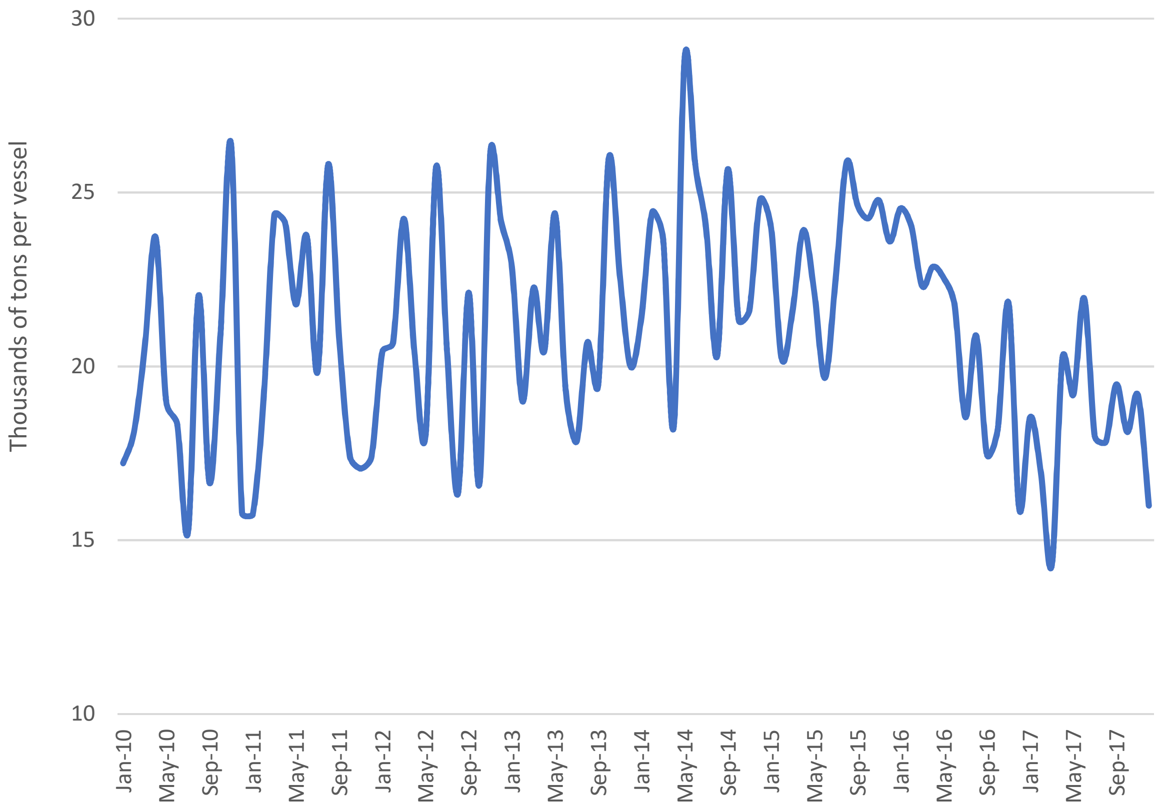


Chart 26 – The evolution of the average quantity of liquid bulk per vessel in the port of Itaqui
Source: ANTAQ, 2018.

From the analysis of the chart it is possible to see a negative relation between average consignation and waiting time at the end of the studied series. Although it is not the purpose of this study to understand the reason for such atypical behavior of the port-of-Itaqui indicators, the study of this case is useful. A better planning of the average consignation per vessel can have a positive impact on the increase in the diesel oil import capacity.

With 11% contribution to the total volume of diesel oil imported by Brazil in 2017, Suape is a port that has managed to increase its operating hours in response to the

increase of the demand. Nevertheless, as all other ports studied, the increase was not sufficient to prevent the growing of hours lost by vessels waiting for a mooring berth.

There was a continuous growing of the three indicators studied in the port of Suape during all the sample period, according to what is plotted in 27[3]:

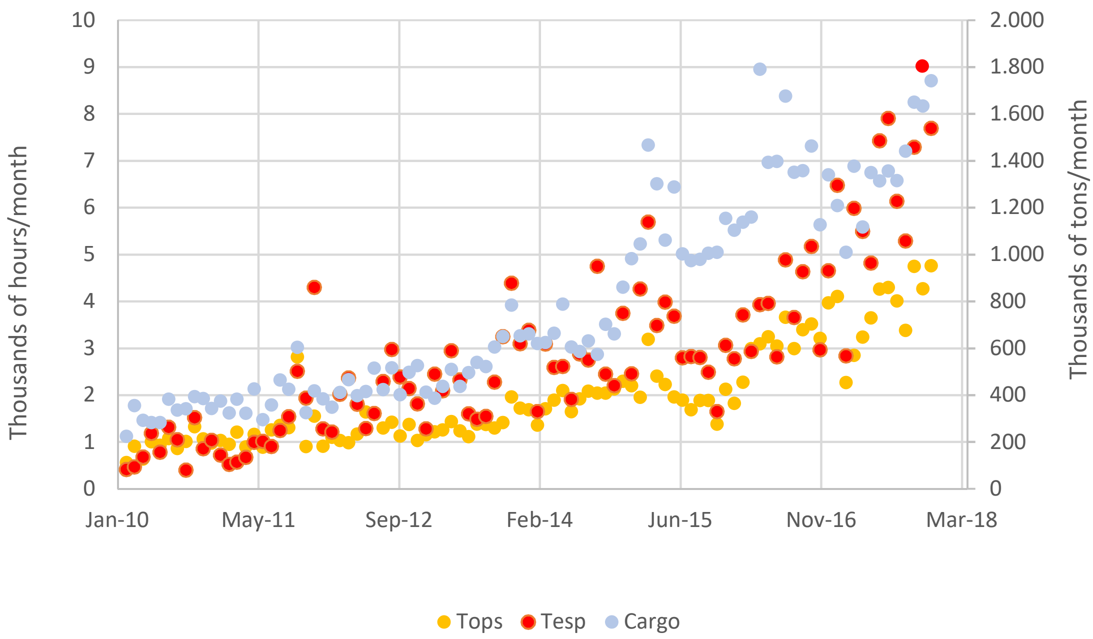


Chart 27 – The evolution of operating time, time waiting for berth and operated quantity
Source: ANTAQ, 2018.

Notwithstanding the increase in waiting, the port of Suape has succeeded in increasing its operating hours and expanding a lot the volumes of operated cargoes.

The port complex of Aratu – Salvador was the fifth in importance in the supply of the diesel oil required to complement the nationally originated supply. Aratu was responsible for 7% of the imported volumes of the product. The port historical indicators of liquid cargoes for the terminals where petroleum products are discharged are as shown in Chart 28.

[3] This chart is in a scale different from the one of similar charts shown at the beginning of the section.

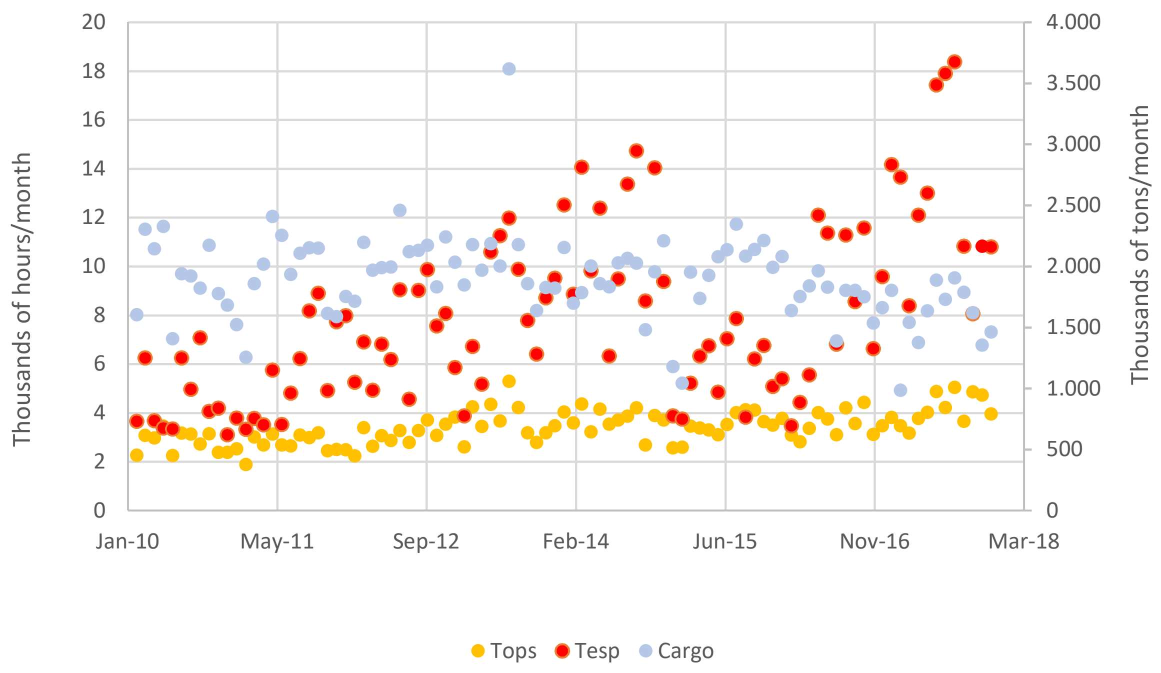


Chart 28 – The evolution of operating time, time waiting for berth and operated quantity
Source: ANTAQ, 2018.

In the Aratu chart, the right axis is also important to be noted. The volumes are larger than the volumes of the previous ports, mainly due to the fact that the terminals receiving the diesel oil are also used for operations with oil. Aratu terminals are mature, and demonstrate regularity in relation to the number of operating hours practically all over the 7-year period examined. Even though, the number of waiting hours has grown sharply as from the end of 2016.

Chart 29[4] indicates a reduction in the operating rate in the terminals where diesel oil is discharged in the port of Aratu:

[4] The chart points out a cargo peak computed in the month of May 2013. It is in agrement with the database, but inspires more investigation.

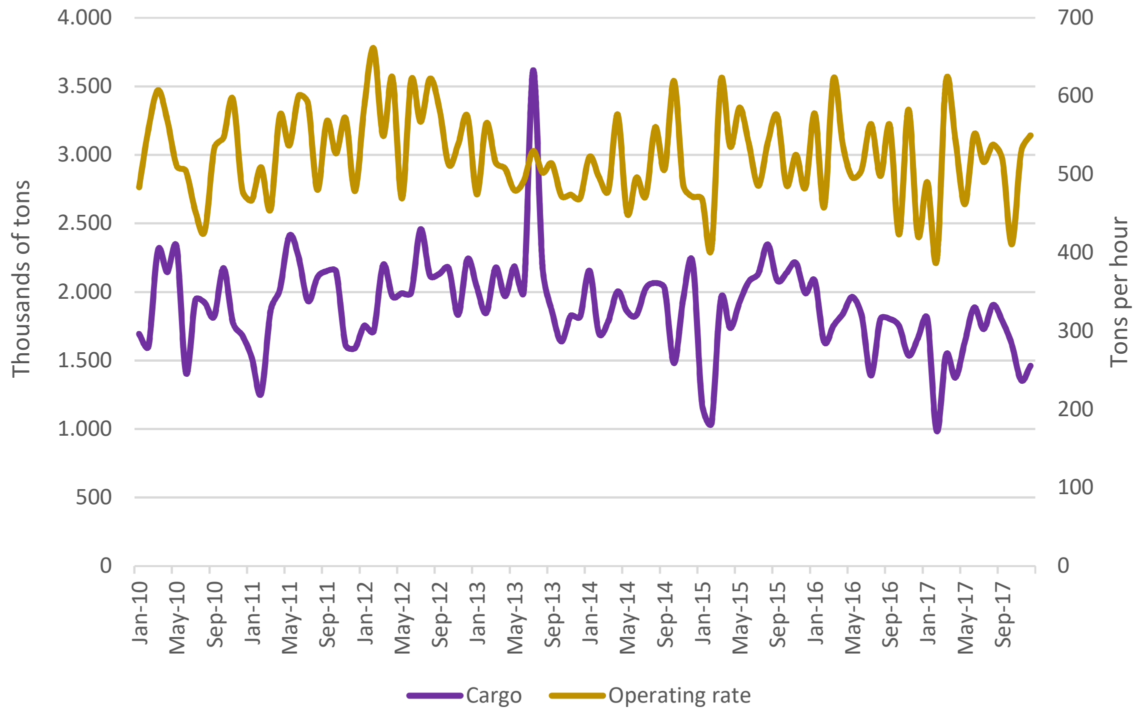


Chart 29 – The evolution of cargo quantity and operating rate
Source: ANTAQ, 2018.

The 7-year historical data indicates the complex Aratu – Salvador as saturated too. The operating rate, the cargo volume operated per hour, is dropping while the queue of vessels waiting for a berth is augmenting.

4.5. Analysis of the results

Based on the results found and on the expected GDP growth, the study projected a continuous expansion of the demand for diesel oil in the coming years.

The analysis of the port data for the selected sample revealed that the system reached the depletion level at the mark of 11 million tons of imports in 2017. Considering the numbers of waiting hours and the decreasing productivity, revealed through the reduction in the operating rates, it can be considered that the maximum capacity was reached – if not, exceeded. It is not sustainable to keep during several periods such port indicators as seen in 2017 for diesel oil discharges.

Nevertheless, the port shares its structures with the most different types of liquid bulk cargoes. It is not possible to stipulate the maximum operating capacity for the

diesel oil or even for the petroleum products separately. In case of an increase in the demand for port services by the other cargoes, the availability of services for the cargo under analysis decreases. And, if the port demand for competing cargoes is reduced, the availability for the concerned cargo increases.

The survey on the national refining capacity revealed that the total increase in the refining capacity was less than 10%, between 2006 and 2016. In spite of the discreet expansion of the refining capacity, the recession of the last years took off the pressure on the refineries, which are operating at a historically high level of idleness as from 2016.

Considering the maximum and minimum points of the GDP growth rate projected for the coming years; considering that the maximum capacity of the refineries for the production of diesel oil is maintained at the quantity they were able to deliver in 2014; and considering, still, that the port is able to enter a volume of 10 million tons of diesel oil, every year, in an environment of economic growth, the results found are briefly shown in Table 12.

Table 12 – Estimated capacities of supply and demand as projected

Year	Refining	Import	Supply	Demand -	Demand +	Scenario-	Scenario +
2018	42	11	53	46.9	47.8	6.1	5.2
2019	42	10	52	47.8	49.4	4.2	2.6
2020	42	10	52	48.5	51.1	3.5	0.9
2021	42	10	52	49.3	52.8	2.7	**-0.8**
2022	42	10	52	50.0	54.5	2	-2.5
2023	42	10	52	50.8	56.3	1.2	-4.3
2024	42	10	52	51.6	58.1	0.4	-6.1
2025	42	10	52	52.3	60.0	**-0.3**	-8
2026	42	10	52	53.1	62.0	-1.1	-10
2027	42	10	52	53.8	64.0	-1.8	-12
2028	42	10	52	54.7	66.1	-2.7	-14.1

Source: Prepared by the author

In Table 12, refining is the maximum refining capacity considered. “Import” is the estimated port capacity to discharge imported diesel oil. The sum of those two columns forms the supply column. Demand and scenario, “ - “ and “ + “, are the projections of demand and the excess of theoretical supply capacity, computed on the basis of the projections of GDP maximum and minimum growth, respectively.

In 2014, when the refineries delivered almost 42 million tons of diesel oil, the declared utilization capacity was around 95%. Petrobras financial and administrative situation and the mere utilization along the years can have affected the capacity of the refineries.

Even at a great logistics cost, it was possible to discharge 11 million tons of diesel oil in the Brazilian ports in 2017. This was so in a period of low economic growth, and a low economic growth over a very narrow base too. Upon a rise in the product level and a consistent growth at rates exceeding 2.5%, as have been indicated in the projections, the port will be more demanded. On a growing economy, the level of port occupancy increases because of the expansion in the movement of all types of cargo. Such cargoes compete for the port capacity estimated for the diesel oil.

Considering the numbers in Table 12 and disregarding the comments that followed it, the study outlined Chart 30.

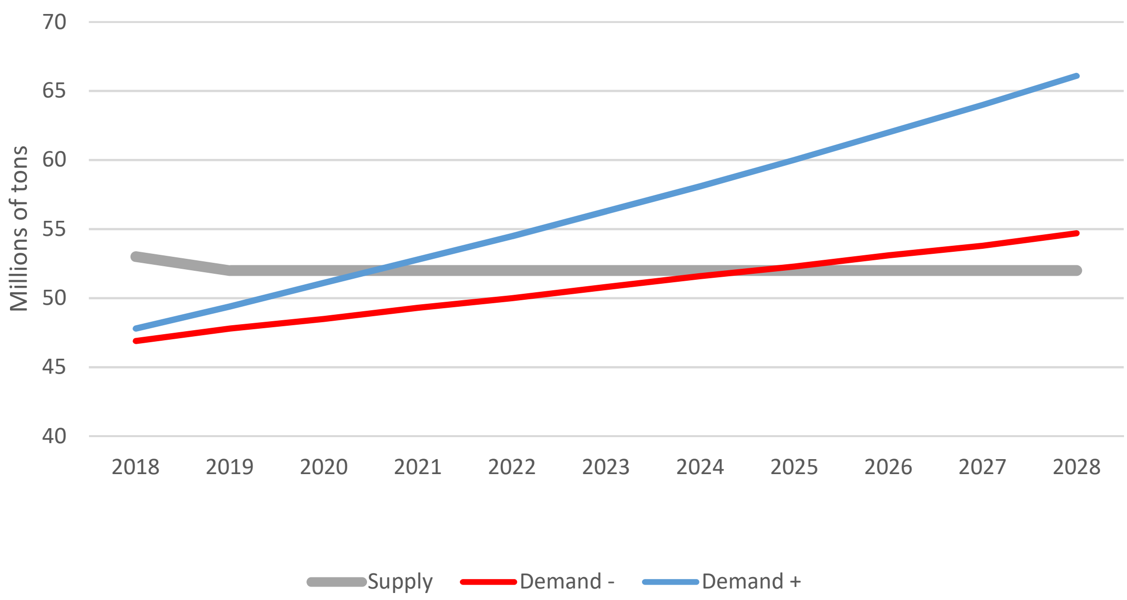


Chart 30 – Production, imports and sales of diesel oil
Source: Prepared by the author

Based on the projected values, on a more moderate economic growth scenario, the diesel oil supply capacity should be exceeded within 7 years, in 2025.

In a more optimistic scenario in relation to the GDP growth rate, there should be lack of capacity to meet the demand for diesel oil in the country within a little over two years, in 2021.

5. CONCLUSIONS

The stated aim of this study was to investigate the capacity of the country to satisfy an increase in the demand for diesel oil. The study demonstrated through collection, analysis, synthesis and evaluation of a large amount of sparse data that there is indeed a depletion of port capacity to take delivery of the discharge of liquid petroleum products in bulk. Among them, the diesel oil.

Through the rereading of conjunctural facts about the sector of commodities, including and specially the petroleum, the author could become acquainted with the probable causes for the lack of sufficient basic operational structures for the support and running of said industry formerly – and not long ago – so strong.

Through literary review, use of coefficients estimated through econometric tools and supported on economic grounds, it was possible for the author to define demand scenarios for diesel oil and, consequently, for refining, and specialized port logistic structure.

The behavior of the three key variables lies at the core of the research question. Said variables will determine whether a supply crisis will take place, namely: the demanded quantity; the refining capacity; and the port capacity to take delivery of the diesel oil imports.

Together, the economic growth prospects, the analysis of the ports and the evaluation of the national refining capacity pointed out to a worrying scenario in relation to the diesel oil supply. The projection of the installed capacity for the processing of biodiesel, which could be an alternative to the fossil diesel oil, showed it to be insufficient to meet even the mandatory consumption as from the year 2024.

Also during the recession period, it was not possible to organize a diesel oil logistics solution to prevent the high demurrage costs on vessels, which remained hostage to non-availability of sufficient port structures to operate their cargoes within a reasonable timeframe.

Such lack of capacity to take delivery of the diesel oil imports was passed on to the fuel costs, and this cost has a significant multiplying effect on the entire productive chain. During the preparation of this study, in the year 2017, the fuel blackout did happen. At this first moment, it reached only the vessels that required fuels to proceed on international voyage. They were not served for lack of product availability. The fuel used by the ships is the same used to feed the thermal power plants in situations of

hydric stress. Therefore, the plants were supplied firstly in detriment of the vessels. Nevertheless, the fact of going so far as to denying supply to vessels that need to sail on voyage is a strong sign that, in the domestic market, the risk of failure in the diesel oil supply chain is real.

To sustain the average growth level of 2.76% a year as projected by the Focus report, the country would have to increase its diesel oil supply capacity by 2.5 million tons already in 2019. Such volume can be met by the idle capacity of refineries. However, in the years following the strong devaluation of its shares, Petrobras has repeatedly declared that it would behave as a market oriented company and maximize its profits. The additional demand volume predicted for 2019 represents an additional 25% on the volume imported in 2017. The impact of such volume on the port structure was detailed in this study. In the case that GDP percent change tends to the upper band of the confidence interval of this prediction, the additional demand for port operation jumps to 3.3 million tons. A profit maximizing company, market oriented, should calculate if the maximum point of profit will be reached by increasing the use of the installed capacity or by increasing the supply. When not expanding the supply, it will allow the price of its products to rise in the market. In a scenario where the refineries do not expand the diesel oil production, the stress on the port logistics structure ought to continue and generate more and more additional costs to the imported diesel oil. The costs of diesel oil produced in the Brazilian refineries should not bear such increase in costs. As a consequence, the Brazilian refineries should benefit from the price increase triggered by the increase of a cost they do not have.

In four years, according to the Focus report projections, the additional volume of demanded diesel should reach 4.8 million tons to sustain a 2.40% product growth. After the average growth level projected by the Focus research is reached and if maintained the current port structures, this study does not reject the hypothesis that there will be a diesel oil supply crisis in Brazil within the next 4 years.

Considering the shown ports' decreasing level of productivity as cargo quantities increase, and if the refineries fail to expand the diesel oil production, the perception is that there is imminent risk in our horizon of a fuel blackout.

If the government remains firm in its policy of non-interference in the fuel market prices, the cost of this logistics bottleneck should be passed on to the consumer. This situation can represent a break in the premises of the model, which estimated the

elasticity used in this study. Depending on the level of price variation, the elasticity of the demand price for diesel oil might be displaced.

Based on the compiled information, it is strongly recommended that public policies be adopted to give priority to the country's energy security with particular attention to the imminent risk of diesel oil shortage. It is necessary that the federal government acquire perception of the serious short-term risk and take efficient measures toward the product allocation problem. In the short term, it is recommended that incentives be created for investments in port discharge infrastructure, storage and forwarding of imported diesel oil. To mitigate the problem in the middle term, greater incentives should be granted toward the processing of larger quantities of biodiesel. An increase in the biodiesel participation in the transportation matrix should expand the country's energy security and reduce the external dependency. Additionally, it should represent a decline in carbon emissions and contribute to the conservation of the environment.

It is still recommended that projects for the expansion of the oil refining capacity in the country be supported. The status of importer of liquid petroleum products strongly contrasts with the condition of large producer and exporter of crude oil that the country has been consolidating. To guarantee the domestic supply of oil derivatives in a more independent manner and aggregate more value to the exports, it is essential that the domestic refining capacity increase.

However, this study lacks an in-depth complementary investigation on possible new port facilities for discharge of liquid bulk. Even works to increase the operational capacity of the already existing facilities can change the conclusions. The existence of said investments, if any, tends to mitigate the problem.

Another important improvement opportunity to be studied is through an investigation per region. The diesel oil supply chain has regional asymmetries both on the side of the supply and the demand. An analysis based on a geographically segmented perspective will certainly result more efficacious.

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