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Repositioning of empty reefer containers: problems and strategies

By

Sun, Pei-Jen

Acknowledgements

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Abstract

In recent years, as people are getting wealthier, people are willing and able to afford a better life. Fresh products consumptions are increasing, some countries cannot meet this demand due to the natural environment limitation. The distances between each country are long and fresh products are easy to decay, therefore, there is a necessity to transport them under controlled temperature. It can guarantee the quality of fresh products.

Seeing the market of transport fresh products is rising, there is also trade imbalance of fresh products, which is called reefer cargoes. In this paper, we address on the reefer container because it has the advantage of door to door service. The imbalance trade of reefer cargoes will result in the imbalance trade of reefer containers. Our main research question is to find out how to reposition them.

In order to do the further research, we have determined types of cargo that are transported by reefer containers. Also we decided to limit our research area to Argentina, Australia, Brazil, New Zealand, and South Africa. These five countries lie in southern hemisphere and therefore the trade patterns are more affected by the season. The most important thing is that based on our assumptions, all the reefer cargoes are transported by reefer containers. We need to determine the number of reefer containers needed by the cycle.

To solve the empty container problem, lots of researches aiming at developing a mathematical model to see what the most cost-efficient way is to reposition them. We also developed a mathematical model and it has two major variables. One is the transportation cost, the other is the holding cost, and we use the Solver in Excel to determine the lowest cost and the number of reefer containers needed to be repositioned. Furthermore, we compared the results from different assumptions and try to analyze them.

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Chapter 1 Introduction

In Europe, most of the members show a positive growth rate of GDP, except for the downturn year in 2009. The positive growth rate of GDP implies that people are able to afford a better life. Moreover, due to the low birth rate and low death rate, the average age of EU members is increasing. In a highly aging society with high incomes such as in Europe, people are more concerned about their own health. At the same time, lots of groups and commercial advertisements are promoting healthy life by advising to eat more fruits and vegetables (The Greens). The concern will lead to the change of the consumer act especially in the daily life such as food consumption. People are willing and able to pay more for fresher and healthier products. The supermarket react to the phenomenon quickly, as we can see in the supermarket, they provide the fresh products from all over the world and also give the consumers more varieties to choose.

However, the weather in Europe is not suitable to plant all the products, that is because the weather changes too much in the four seasons. EU members have to import some products if those products (such as apples, citrus) are in off-season. And the southern hemisphere will become the major supplier during this period (UNCTAD). Moreover, people from other countries or continent are moving to EU, such immigrants are the other reason that makes the supermarket to provide diversified products to meet their demands. They will ask for more tropical fruit which is impossible to be grown in the Europe. Then, EU has the demand to import those products from the other countries, there's a need to transport those products to EU. Air and sea transportation are the only two solutions when it comes to the intercontinental transportation. Sea transportation has the advantages of lower cost per unit but it would take longer time in comparison with air transportation. For fresh products transportation, if the volume is large, then sea transportation is the better choice. Furthermore the products value is another issue to be considered, once the value of the cargo is low, sea transportation is more attractive. Air transportation is more suitable for the higher value products.

It is not easy to keep the fresh products in a good condition if they have to be transported for a long time and distances by sea transportation. To keep the temperature low will be one of the solutions to extend the time that the products to decay (Wagner, Dainello & Parsons, 2011). Before the wide use of container, the products that needed to be transported by sea would use bulk reefer vessel, which is like the traditional bulk vessel that equipped with cooling system. There's a disadvantage in this kind of vessel, as the products that need to be kept in low temperature may be exposed to the room temperature when they are loading to or discharging from the vessel, which may cause damage to the products. With the broad use of container may reduce this risk. Reefer container has the same advantage as the normal container, such as less transportation cost per unit. Moreover, it is easy for carriers to provide door to door service. The products that require temperature-controlled have less risk if they are transported by reefer containers. Some prediction about demand of reefer container will increase in the future; we think that one of the major reasons will be the increasing demand for fresh products (NEW HEAVY & OCEAN).

It seems like the demand of reefer containers will increase, liner companies should respond quickly. Since liner companies are the major service provider to transport containers globally, the reefer market is an increasing market which they have to pay more attention. Some of the news said the container vessel is getting bigger, which can provide more capacities than ever. In the other hand, reefer bulk vessels have fewer advantages on this market. According to the report from Drewry, the average age of some of the reefer bulk vessels reach 22 years. And there is no new booking on reefer bulk vessel recently. We can foresee that liners companies competing in the reefer market as well.

EU has a relatively strong market power than the trading partners which may result in trade imbalance. The component of the trade with each trade partner may vary a lot. If we focus on the trade between EU and the southern hemisphere country, such as Argentina, we found out that most of the cargoes that EU export is industrial products, which are transported by normal container. On the other hand, cargoes that EU imports are mainly food products, which are transported by reefer cargoes. This situation leads to the oversupply or shortage of both kinds of container boxes. They are relied on liner companies to send them to the destinations in need. As the freight rate for each slot is quite low, liner companies are concentrating on cost control more. The repositioning of container box should be carefully planned in order to meet the demand and lower the cost. Although there are plenty of researches on repositioning empty containers, not much are direct related to reefer market. So, me topic is mainly about the repositioning of reefer containers.

Therefore, our paper is aiming at answering the major research question:

How can empty reefer containers repositioning improved

In order to answer this question, we have several sub-questions as follows.

1. What are the strategies of repositioning empty containers nowadays? Which logistics concept exists in repositioning empty containers?

Besides from this, we have to focus on our major research question about reefer market.

2. What kinds of products are transported by reefer containers and what are the characteristics of reefer containers? What are the cargoes that are in the imbalance trade?
3. Analyze container vessels and bulk vessels in reefer market. How many numbers of reefer containers will be needed if only container vessels are in this market?
4. How do liners provide refrigerated containers that are ready to use to customers at the right place and right time in a cost-efficient way while at the same time that the demand of reefer container is seasonally? (Quick or slow response)

1.1 Method and Plan

In chapter 2, by reviewing some literatures, we can have the overview of what strategies for repositioning empty containers and to see if there's any logistic concepts exist. We can also get some information from literatures about how to set up models to calculate the cost of repositioning.

In Chapter 3, we will analyze the reefer market by introducing characteristics of reefer containers and reefer cargoes. Also we have some analysis about why reefer container will be used more than bulk reefer vessel.

In chapter 4, the trade partner of reefer cargoes are determined, they are Argentina, Australia, Brazil, New Zealand, and South Africa. With the trade statistic, we have the demand and supply pattern. Then, the tons of cargo are determined and the number of reefer containers needed is also calculated.

In Chapter 5, according to the demand and supply pattern between EU and these five countries, we build up a simple model and the Solver in Excel is used to determine the lowest cost. The result is analyzed and we also discuss what alternatives can improve the result.

1.2 Scope

In this paper, our aim is on the liners own reefer containers. There are three different strategies for owing containers. First, liners will buy their containers. The ownership of containers is the liner companies. Second, the long-term lease containers. Containers are owned by leasing companies and will be rented out for about 3 to 5 years according to the contract. During the leasing time, liners will have the right to use the boxes and if they are not in use, liners have to store them in the depot. Third, the short-term lease containers. The time period will be shorter and maybe just for one way cargoes. Leasing companies will charge liner companies some extra fee if the container cannot be returned to the right position. Although the long-term lease containers still belong to the leasing company, in practical, it will be seen as a company owned assets. So, in this paper, we assume that the total number of reefer containers needed is owned by liners companies or the long term leased.

Secondly, the imbalance trade is globally, but it would be difficult to collect and analyze data globally. It will be too wide and complex. I choose 3 trading regions 5 countries which are all in the southern hemisphere and they all play a major part in the reefer containers market with EU. They are the trade between, first, EU to Australia and New Zealand, second, EU with South Africa, third, EU to Argentina and Brazil. According to the EU bilateral trade statistic, these three regions are worth to make further research of reefer containers. Although Asia is one of the major trading partners of EU; we think there will are already many research about Asia. As a result, we take the other three regions as our targets. We believe that their distance and trading volumes are also significant enough to be the research target.

Third, the main research question is about repositioning empty refrigerated containers. Since the reefer market is the same as the dry cargoes market, bulk vessels also exist and play an important role. However, according to reports of Drewry and seeing the plan of the liner companies (such as Evergreen), the number of reefer containers are increasing and there are less bulk reefer vessels. Not only is the booking for new vessel less also the age of the vessel which is operating now is too old. It is impossible to exclude the effect of the bulk reefer vessel when I am writing this paper. However, in this paper, we assume that there is no bulk vessel when we are doing the calculation. That would make the result to be more consistent.

Chapter 2 Literature Review

Our major research question is about repositioning empty reefer containers. We use two key words (empty containers repositioning and policies) to search for papers which may be useful for our research. There are lots of papers about repositioning empty containers; however, we didn't find papers which are directly related to the reefer market. We chose some papers below to extract some information that would be important in our paper.

Liner companies are providing their service to transport container box all over the world. The trade imbalance is from country to country, or from region to region. Empty containers become a major problem, some regions may suffer from shortage, and others may face the oversupply. With lots of data and information are not clear, some of the researches are aiming at building mathematical model to search for the optimal results, which includes several containers types and scenarios. In this way, it can take more situations into consideration, which is more likely to reflect the real business situation (Crainic, Di Francesco & Zuddas).

Besides from that, container box is not only for sea transportation. One of the reasons that are broadly used is because it's convenient for intermodal transportation. To deal with the empty container problem, researchers need to think of the time and capacity of each modes of transportation. The paper aims at minimizing the total cost of empty container repositioning over a given time planning horizon (Choong, Cole & Kutanoglu, 2002).

Vessels in liner companies are sailing around from ports to ports according to the fixed time schedule. As we know that container vessels now sail in a lower speed which is called slow steaming to reduce the fuel cost and pollution. At the same time, container vessels are getting bigger than ever. Some say container vessels are becoming a moving warehouse. Under this concept, container vessels provide both transportation and storage service. Empty containers can be loaded on the vessel to sail around each port to see where is in shortage. A model was developed to illustrate such a situation, the result provides the decision maker about number of containers to load on to the vessel and lift off the vessel. Also it gives us a new idea for repositioning empty containers (Song & Dong, 2011).

And most of the time, there is not enough information to determine the demand or supply of empty containers. If we want to set up a model to deal with this problem, there are two ways. One is the deterministic formulations, the other is stochastic formulations. A paper compared the result of these two formulations in the Mediterranean region. Also it compared several different scenarios (Di Francesco, Crainic & Zuddas, 2009).

We can conclude from these literatures that there is not a best strategy to solve the empty container problem. We need to find out the important parameters about cost, and then set up a model of total cost to search for the minimum value. Because liner companies generating revenue by transporting loaded container, if the slot on the container vessel is occupied by empty containers, it lost the opportunity to carry a loaded container. Therefore, repositioning empty container is always being seen as a cost.

There are several definitions of logistics, because this term is widely used in many fields. In the transportation business, logistics can be referred to transport goods to the right place at the right time. For repositioning empty containers, it is part of the container logistics. However, container box cannot move by itself, vessels have to carry those boxes to move around destinations. Therefore, liner companies need to focus on container logistics and vessel logistics to provide efficient services. Because transportation business is integrated to the other part of the supply chains. Freight logistics is another issue to be discussed. We can say that for repositioning empty container problem, using logistics concept is standing on a higher point of view to make the decision (Fremont, 2009).

After reviewing these literatures, we have a comprehensive view of how to repositioning empty containers. Because our aim is at reefer market, we will find data to determine the demand and supply pattern. Based with the information from these literatures and the data that we have, we will build our own mathematical model and analyze the result. And we can determine what the best strategy for repositioning empty reefer containers is.

Chapter 3 Analysis of reefer market and reefer containers

In this chapter, we will introduce some characteristics about reefer containers and reefer cargoes. Then, there are some analysis about container vessel and bulk vessel in reefer market.

3.1 Types of reefer container and reefer cargoes

Reefer market is a highly specialize market, that is because of the cargoes which it transport. If we look at the shapes and exterior dimensions of reefer containers, they are all the same as dry cargo containers. Length is 20 feet or 40 feet, width is 8 feet, and height is 8.6 feet or 9.6feet in Hi-Cube containers. However, if we look at the capacity of reefer containers, we can tell that the capacity of reefer containers is less than normal containers. We have summarized the main capacity of different size of reefer container in Table 1.

Table 1 Characteristics of Reefer Container

	Interior			Weight		
	Length	Width	Height	MGW	TARE	Capacity(MGW-TARE)
20 feet M.G.S.S Refrigerated Container	5.5m	2.298m	2.276m	30,480kg	3,020kg	27460kg
20 feet Aluminum Refrigerated Container	5.480m	2.286m	2.235m	24,000kg	2,800kg	21200kg
40 feet M.G.S.S Hi-Cube Refrigerated Container	11.585m	2.29m	2.544m	34,000kg	4,760KG	29240kg
40 Feet Hi-Cube Aluminum Refrigerated Container	11.563m	2.286m	2.507m	30,480kg	4,300kg	26180kg

Source: (Evergreen Marine Corp., edited by the author)

M.G.S.S is a specific word in reefer container, we found the explanation as follows "The inner anti-collision plate is typically a plate member made of Muffler Grade Stainless Steel (MGSS) with a thickness of 0.7-1.6mm, and is spot-welded to the outer surface of the inner side plate so as to strengthen the inner side plate" (Peng, Sun & Sun, 2007). Reefer container need to have some special foam between the inner side plate and outer side plate to isolated heat from outside and keep the temperature under control inside. That is why the capacity is less than the normal container box.

We have seen the characteristics of reefer containers; we also want to know what kinds of products are transported by reefer containers and what their characteristics are. Mainly those products can be divided by several categories as follows, fruit, vegetables, fishery products, meat products, and dairy products which will require to be transported in freeze or chill temperature. A refrigerated container is a container which is equipped special equipment or they are designed to keep the temperature under control. Cargoes that will be transported by reefer containers have different requirement of temperature, some of them need to be frozen, and some of them just need to be in chill temperature. So, there are two major cooling systems that are equipped in the reefer container to meet the requirements of different products.

One is called insulated container, which is to use the fan that will make the air ventilate the container together with the vent hole, and the shield of this kind of container is thermally insulated. The function is to keep the air circulate inside the container and isolated the heat from outside. Moreover, it is possible to use the cooling facilities on the vessel to control the temperature in the reefer container to make it able to carry the lower temperature requirement cargoes. Cargoes such as beans, gingers, potatoes, onions, yams, will be put in insulated containers. Characteristics of these cargoes are required to be transported in the chilled temperature but need to have air ventilation (about +5 to +15 Celsius, 10 to 50 cbm/h ventilation rates).

The other is called integral reefer container. It is equipped with the built –in cooling facilities in the container, which will enable them to carry cargoes required very low temperature (-35 Celsius or even lower). It is very convenient to use them for the door to door service which is largely promoted by liner companies. Because it can be used a moving refrigerator for customers and this kind of container only requires electricity to supply it cooling facilities. Cargoes such as fresh fish, ice cream will mainly be transported by this kind of container.

In Table 2 we can see that some products require ventilation, some require very low temperature. Since each kind of product has different temperature requirements, once the reefer cargoes cannot load full a container, it has certain limitation for products to be put in the same container. So, the stacking and combine products in the reefer container should be well planned.

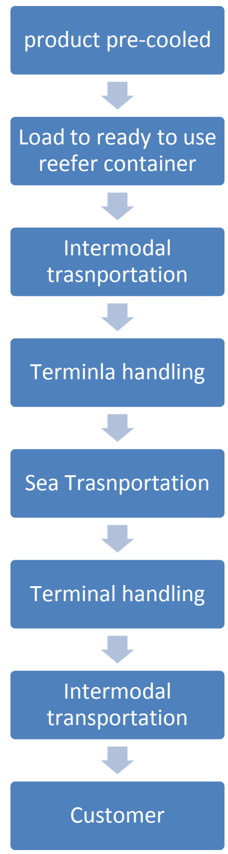
Table 2 Suitable transportation temperature for different products

Chilled products	Temperature (°C)	Ventilation (cbm/h)
Apples	-1 to +4	10 to 60
Apricots	-0.5 to 0	15 to 60
Avocados	+4 to +13	40 to 60
Bananas	+13 to +13.5	25 to 60
Cabbage	0	20 to 60
Carrots	0	10 to 20
Garlic	-3 to +1	0 to 15
Ginger	+12 to +14	10 to 15
Grapefruit	+10 to +15	15 to 50
Grapes	-1 to 0	10 to 15
Kiwifruit	0	20 to 60
Lemon	+10 to +14	15 to 25
Mangoes	+9 to +14	25 to 30
Melons	+2 to +12	25 to 30
Onions	0 to +2	10 to 15
Potatoes	+5 to +15	10 to 50
Frozen products	Temperature (°C)	
Butter (frozen)	-23	
Fish (frozen)	-18 or colder	
Ice cream	-26 or colder	
Meat (chilled)	-1.4	
Meat (frozen)	-18 or colder	
Poultry (frozen)	-18 or colder	
Shrimps (frozen)	-18 or colder	

Source: (Hamburg Süd, edited by author)

One thing to be noticed is that even though refrigerated container such as the integral reefer containers are equipped with facilities to cool down the temperature, they are not designed to use as a device to cool down the product or to be the role as a household refrigerator. We think that each device has its own function. A reefer container box is designed to load on cargoes and transported to its consignee. In order to take a look at how the reefer cargoes are being transported by reefer containers. We have checked several liner companies' website such as Maersk Line, NYK Line, Hamburg Süd and conclude the process as follows.

Figure 1 Process of reefer cargo handling and transportation



Source: (Hamburg Süd, edited by the author)

As we mentioned before, due to the vertical integration, liner companies are able to provide the door to door service. Which means only the pre-cooled process should be taken by the owner of the cargo. Liner companies take the rest of the process and deliver the reefer container to the customer. Many said that products pre-cooled are very important. Because we know that reefer container is mainly to maintain the temperature under control, once the cargoes are still in high temperature, it becomes difficult for reefer container to maintain the temperature. Furthermore, imagine the cargoes are not in the appropriate temperature, and the reefer container starts to cool down, hot and cold air will condense into ice. That will cause injury to the cargoes itself and to the package which is usually the cardboards. The reefer cargoes are perishable and more valuable in terms of weight/ price; it should be taken carefully to reduce the damage.

Besides from that, liner companies have to provide the ready to use reefer container. Because most of the reefer cargoes are edible, they should take it seriously about the hygiene problem. There is a strict rule about cleaning the reefer container and they will be carefully inspected before they are ready to use.

From the process of reefer cargo handling and reefer container transportation, we think it is better to transport fresh products in reefer container to insure the quality of products and reduce the damage risk.

3.2 Reefer container vessel and reefer bulk vessel

Container vessel and bulk vessel are competing in dry cargoes; reefer market is not an exception. As I mentioned before, the age of bulk reefer vessel is reaching the average year of 22years, which is too old to sail safely. Also bulk reefer vessel cannot meet the increasing demand of door to door service which can guarantee the quality of fresh products. Although bulk reefer vessel can transport large volume of fresh products at one time, we think it can be replaced by reefer container.

As the size of container vessels are increasing dramatically, liner companies have more capacities which mean there are more slots on vessels than ever. Not long time ago, Maersk has just decided to build the Tripe-E class container vessel which will have 18000 TEU capacities, and the other liner companies such as MSC, they also have decided to book several new container vessels that have the capacity about 14000 TEU. The vessel is getting bigger, but the cost of building such a huge vessel does not increase linearly. The economies of scale arise here. The transportation cost per TEU will become less if the vessel can be loaded full. There are many discussions about this topic, but I will not address much about this in this paper.

The issue that would be important here is that do liners want to build the pure reefer container vessel since the demand of reefer containers is increasing? I would say the answer will depend. The disadvantage is that if the vessel is designed to carry reefer containers, liners will face the problem to find enough cargoes to full-loaded the vessel. Because liner service means that the vessel will call at the port according to the scheduled time no matter the vessel is loaded full or not. If the vessel is specialized to carry reefer containers, liner companies lose the opportunities to carry the other dry containers that could utilize the vessel. If the vessel is not full-loaded, there is no benefit of economies of scale. On the other hand, the advantage is that the specialized reefer container vessel will tend to sail in a higher speed than the normal container vessels, because time is the most important issue to transport perishable cargoes. Moreover, there would be less port calls because the supply and demand pattern of reefer cargoes is fixed, and that will ensure the efficiency of the time schedule.

In our opinion, we think that in reefer market, bulk reefer vessel may not be as competitive as reefer container. As we mentioned in this chapter, reefer container can provide much more reliable service for fresh products. Moreover, the pure reefer container vessel is not a good option since liner companies now are aiming at reducing cost because they are competing on freight rate.

If the normal container vessel is the trend to transport reefer container, there should be some device on the vessel to provide the electricity for reefer container. The reefer plug is the capacity of the normal container vessel; we have summarized the capacity of each size of vessel in the table below.

Table 3 Reefer plugs of each size of vessel

Evergreen’s classification		
Series	Capacity	Reefer Plugs
S	7,024 TEU	839
NU	5,652 TEU	570
U	5,364 TEU	570
D	4,211 TEU	476
GX	3,753 TEU	130
G	2,922 TEU	130
A	1,164 TEU	200
Maersk classification		
Series	Capacity	Reefer Plugs
PS	14,770 TEU	1,000
S	6,600 TEU	700
K	6,000 TEU	700

Source: (Evergreen Marine Corp., Maersk Line, edited by the author)

The reefer plug represents the vessels’ capacities of carrying reefer containers. However, it is not the only place that needs to have such facilities. As the standard procedure of reefer container handling, cargoes should be pre-cooled, also reefer containers should be in the condition that is ready to use. Furthermore, after discharging reefer containers from the vessel, they will be placed in the terminal waiting for further distribution. Most of the terminals also provide reefer plug as well to ensure reefer containers to stay in the same temperature. This will be the major limitation for some terminals which is lack of facilities that cannot handle reefer containers. Besides from this, intermodal transportation is the main reason that make reefer containers can be broadly use. Because they can be more efficiency of handling and provide convenient door to door service. So far, I find out that the major intermodal transportation of reefer containers is still carried by trucks. The reason that trucks are still the major player in the reefer market would be because trucks can carry the extra facilities to generate enough power to sustain the operation of the gear on reefer containers. Both insulated reefer containers and integral reefer containers need to connect to the reefer plug to run the equipment, especially integral reefer containers need to keep in a relatively low temperature. Only some of the news in US said the reefer container can be transported by rail. Because this topic is far away from my research question, I would not address too much on it.

To conclude, reefer market is really a specialized market; we can see it from the characteristics of reefer cargoes and the complexity of reefer cargo handling. For the reefer container market, we are optimistic about the increasing demand, because reefer container can provide safer and higher quality of transportation. With the increasing imbalance trade of reefer cargoes leads us to make further research about how to reposition empty reefer containers.

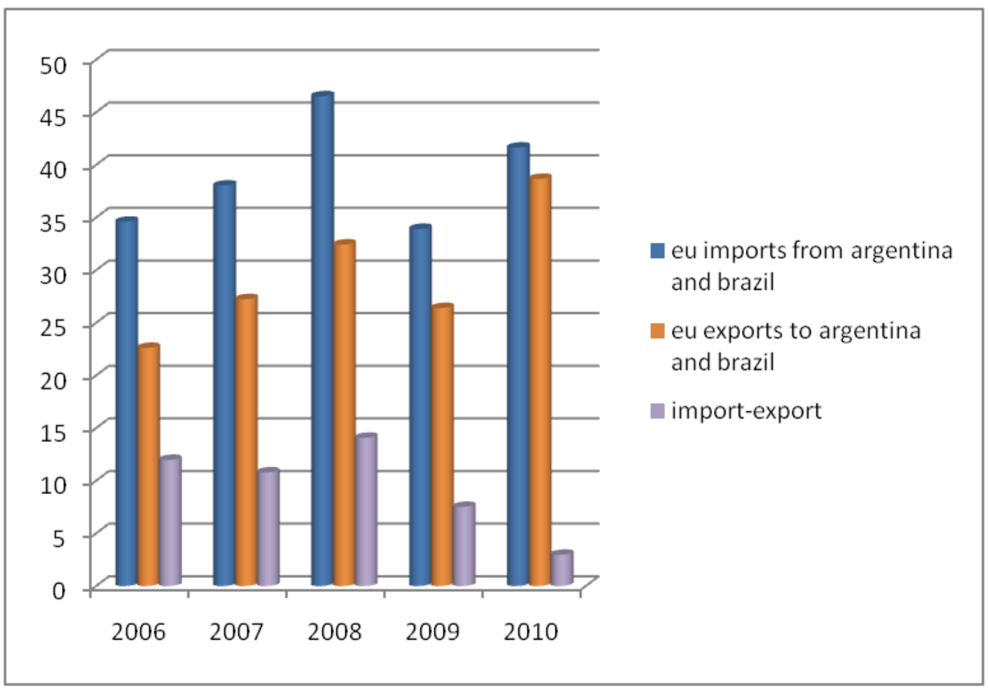
Chapter 4 Supply and Demand Pattern of reefer containers

As we mentioned in the scope of our research, we focus on the southern hemisphere trade partner which can provide EU seasonal agricultural products. They are Argentina, Australia, Brazil, New Zealand, and South Africa. Due to the imbalance trade is one of the major reasons that causes the empty container problem, we need to have an overview of these five trading route. Moreover, we are aiming on the empty reefer container, it would be better to investigate on the component of the trade of each trading route.

4.1 EU-Argentina, Brazil

In the figure below, it is obvious that there is a difference between imports and exports. We can say that is the trade imbalance of this trading route. In this figure, it shows the characteristic of trade deficit, which means that imports are more than exports for EU. Also we can see that from year 2006 to 2010 has the same trade pattern, but in year 2010, the gap between imports and exports had the smallest difference. Since EU import more than export to these two countries, we combine the overall trade statistic together. It provides us enough information about the imbalance trade.

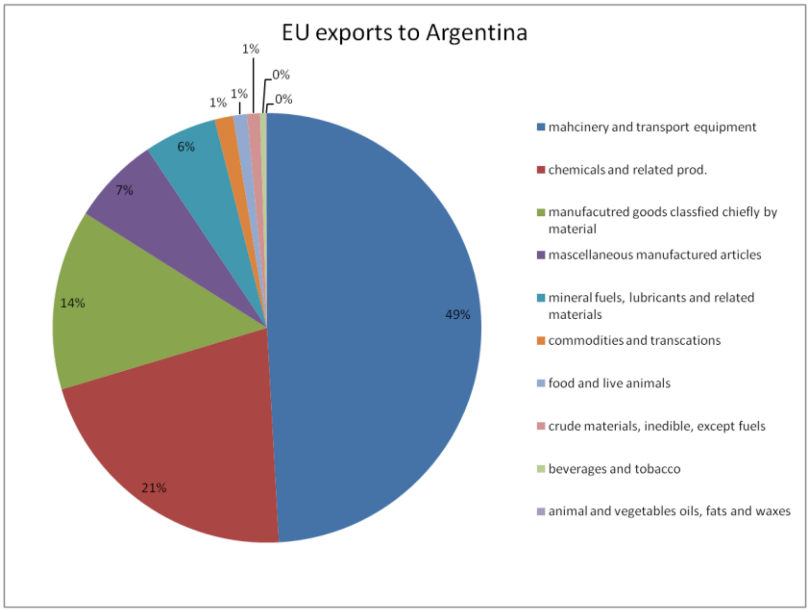
Figure 2 Total import and export of EU-(Argentina, Brazil)



Source: (eurostat, edited by the author)

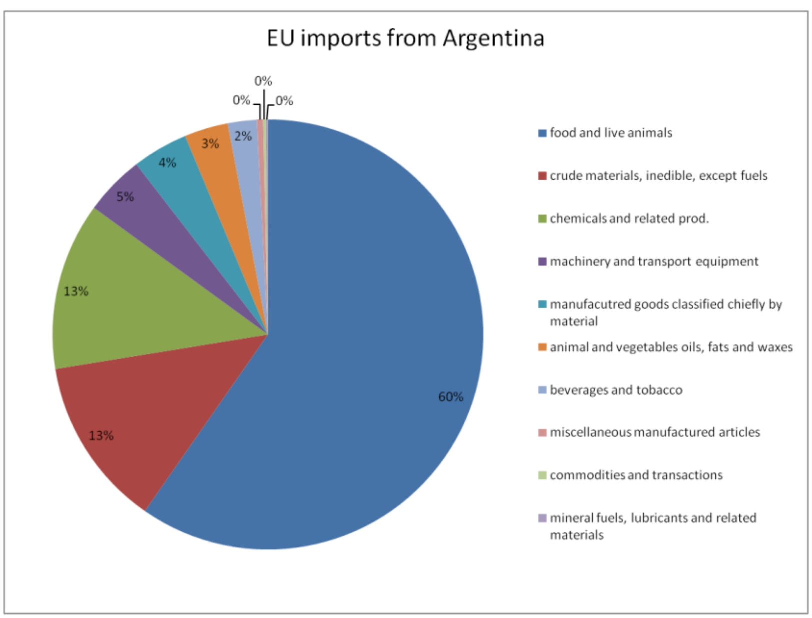
Knowing that the trade in this route is imbalance is not enough. Our aim is about repositioning empty reefer containers. The next step is to see what the component of the trade is. By doing so, we can have the broad view of what the trade is like. Furthermore, we can determine if there is any trade imbalance of reefer cargoes.

Figure 3 EU export to Argentina by categories



Source: (eurostat, edited by the author)

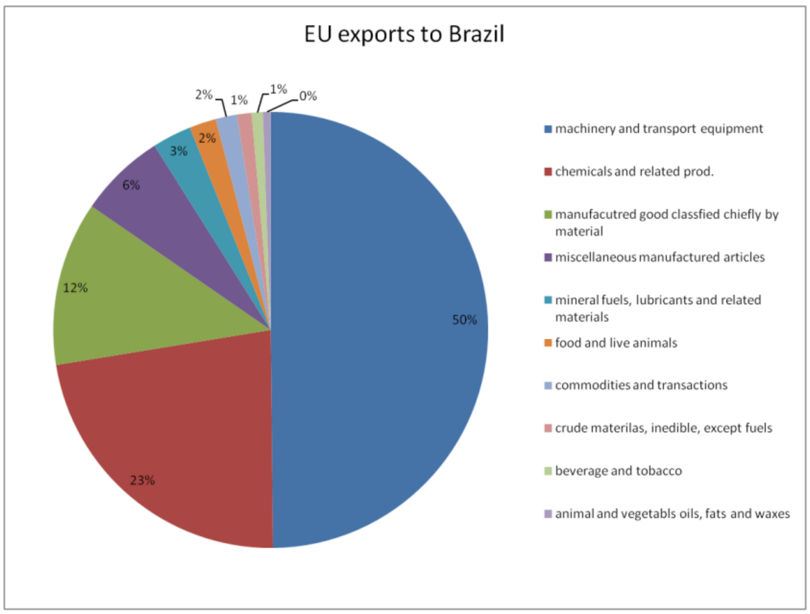
Figure 4 EU import from Argentina by categories



Source: (eurostat, edited by the author)

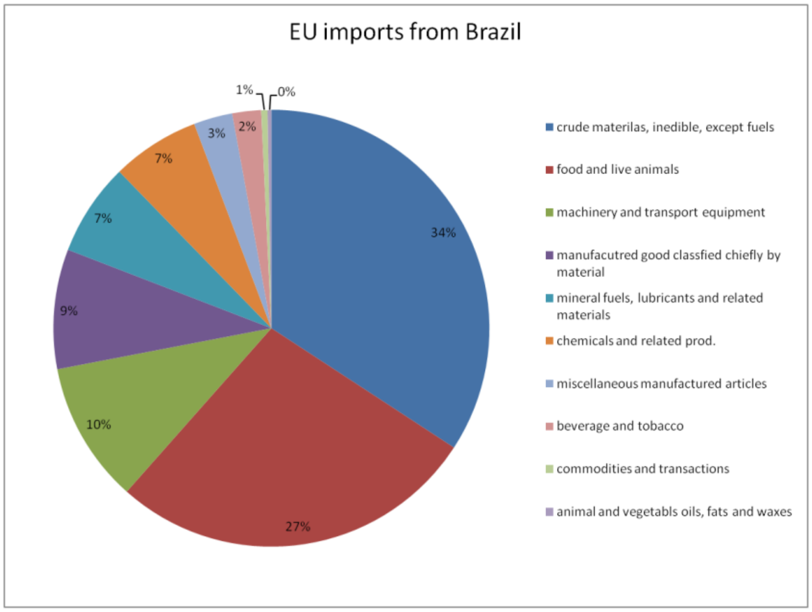
In the figure 3 and figure 4 above show the detail of the trade between EU and Argentina. The pie chart separates cargoes into several categories. The majority that EU imported is the food and live animals categories (60%). And EU exported mainly cargoes in machinery and transport equipment (49%). However, in food and live animals categories, EU only exported some minor percentage. Although we cannot say that all the cargoes in the food and live animals categories are needed to be transported by reefer containers, we are sure that industrial products are not the primary cargoes that would be put into reefer containers. From this point of view, we can say that there is an imbalance trade of reefer cargoes between EU and Argentina. Then we move on to see the component of trade between EU and Brazil.

Figure 5 EU export to Brazil by categories



Source: (eurostat, edited by the author)

Figure 6 EU import from Brazil by categories



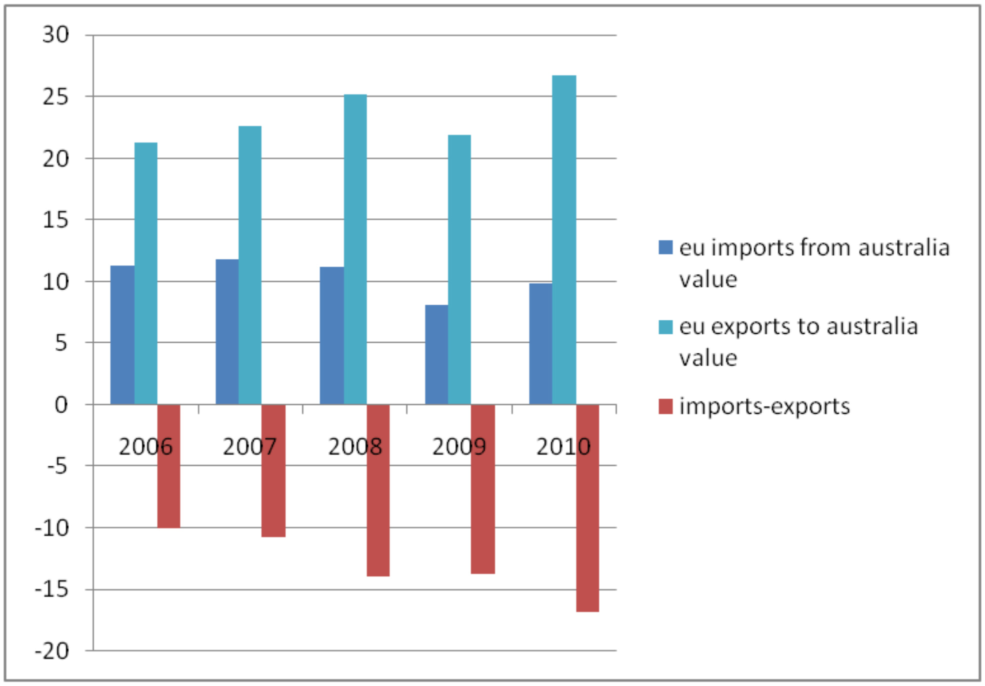
Source: (eurostat, edited by the author)

Then in the figure 5 and figure 6 above is the component of trade between EU and Brazil. EU exports lots of machinery and transport equipment products to Brazil (50%), food and live animals only consists of a minor percent (2%). On the other hand, EU imports lots of crude materials except fuels from Brazil(34%), and food and live animals products is the second largest import cargoes(27%). Again, we assume that reefer cargoes will be mainly in the food and live animals, trade of reefer cargoes are different is obvious. From previous chapter, we always address that reefer containers are mainly used to transport cargoes that need to be under temperature control. The trade pattern between EU-(Argentina, Brazil) has a gap of reefer cargoes which will result in the imbalance of reefer containers. According to the trade component about these two countries, it tells us that there are more chance that empty reefer containers will stay in Europe more than in Argentina and Brazil.

4.2 EU-Australia, New Zealand

Because Australia and New Zealand have different characteristics of trade with EU, we made them into two figures. First we look at the figure of EU-Australia. EU exports were far more than imports. And the difference of the trade imbalance of these five years are getting more and more, which reached the most in 2010. EU had a significant trade surplus with Australia, for the rest of the other 4 countries; most of the time, EU had a trade deficit. If there is a trade imbalance, the gap of the imbalance need to be further investigated, and we made the pie chart to show the component of the trade. Before that, we will show the overall trade statistic in the figure 7 below.

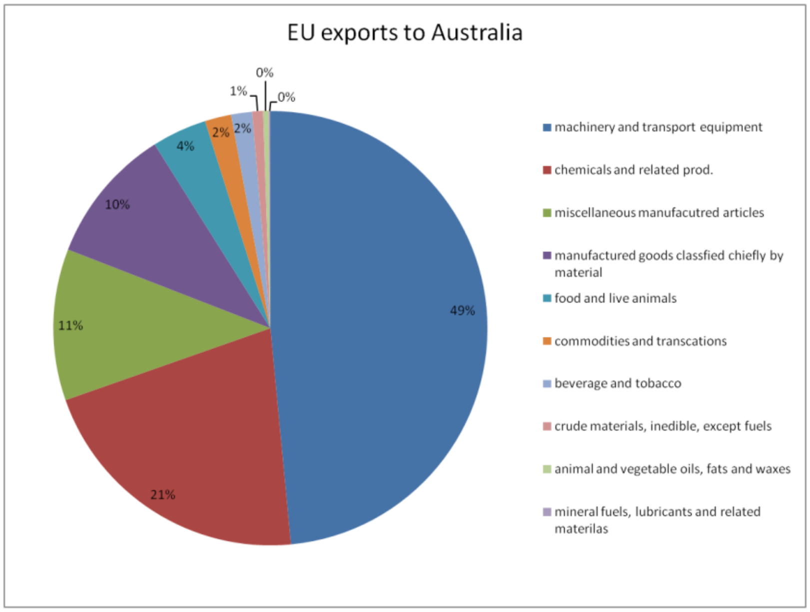
Figure 7 Total import and export of EU-Australia



Source: (eurostat, edited by the author)

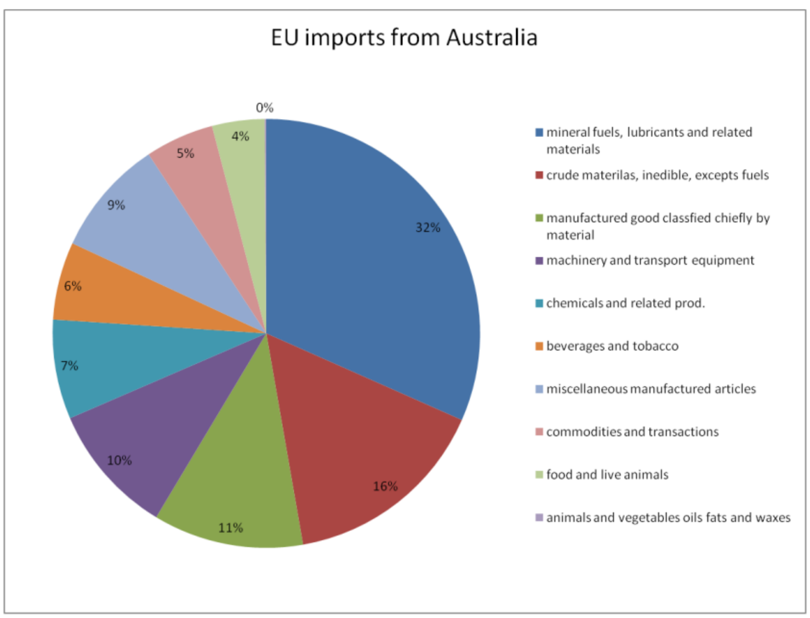
In the figure 8 and figure 9, we use the pie chart to show that the major cargoes that EU export is industrial products in machinery and chemical sectors, which consisted of 70% of the overall export. Looking at what EU imports from Australia, mineral fuels and crude materials are the largest group of cargoes, which is 48% of overall import. To our surprise, food and live animals are not in the top category of trade. The percentage of food and live animals that EU imported from Australia is almost the same as EU exported to Australia (4%). It doesn't mean that reefer cargoes reached the balance trade here. Due to the products in the food and live animals category are too wide. More detail data in this category will be examined to determine if the reefer containers flow will equal in this trading route.

Figure 8 EU export to Australia by categories



Source: (eurostat, edited by the author)

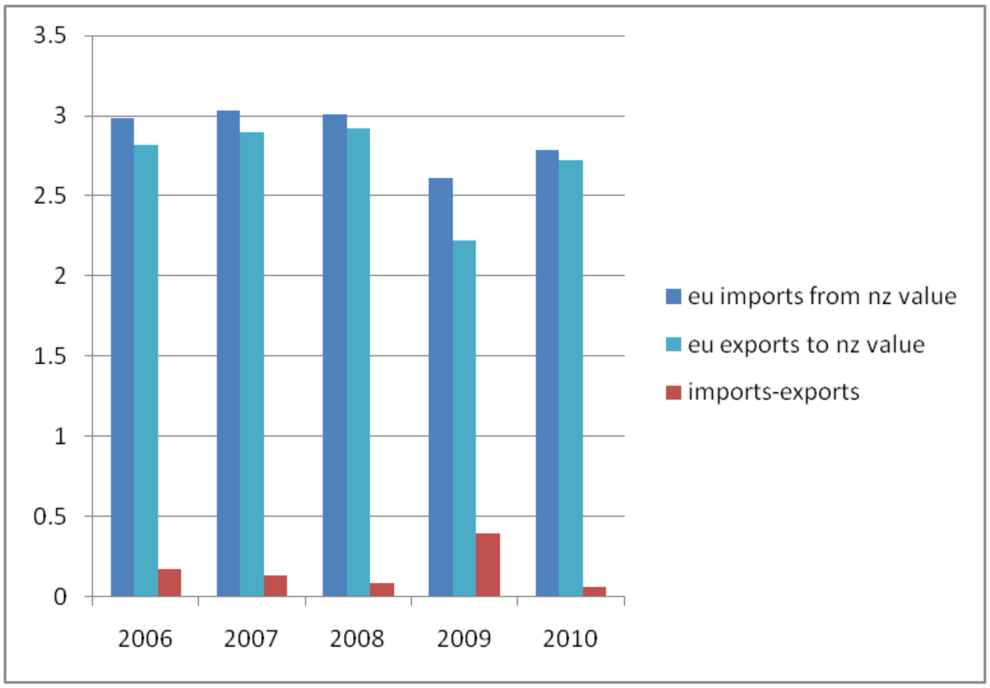
Figure 9 EU import from Australia by categories



Source: (eurostat, edited by the author)

In the figure 10 shows that the total trade value between EU-New Zealand is not a lot(both import and export individually didn't exceed 3 million), and the difference between import and export is small (less than 0.5 millions). However, EU still imported more than exported to New Zealand.

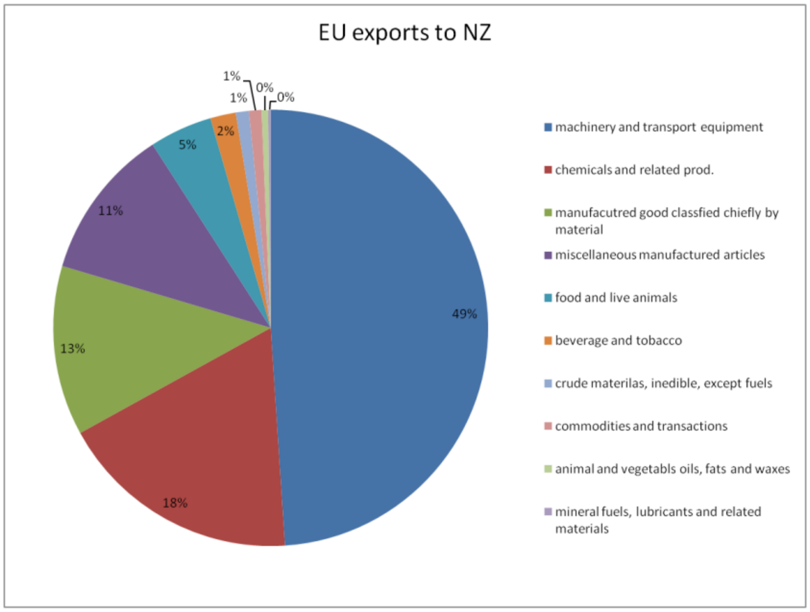
Figure 10 Total import and export of EU-New Zealand



Source: (eurostat, edited by the author)

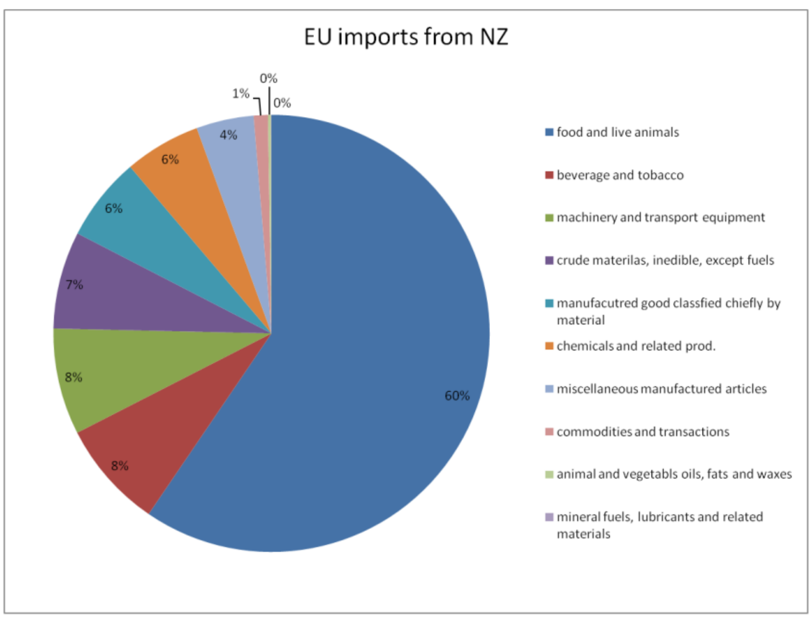
From figure 11 and figure 12, it is obvious to tell that cargoes EU imported from New Zealand are mainly food and relative products (68%), which is mainly about agriculture. When looking at cargoes that EU exported to New Zealand, industrial products were the majority which consisted of 67%. In other terms, EU exported only few reefer cargoes (5%). Also because of the low value in the total trade, we don't expect there are lots of volumes of all the products.

Figure 11 EU export to New Zealand by categories



Source: (eurostat, edited by the author)

Figure 12 EU import from New Zealand by categories

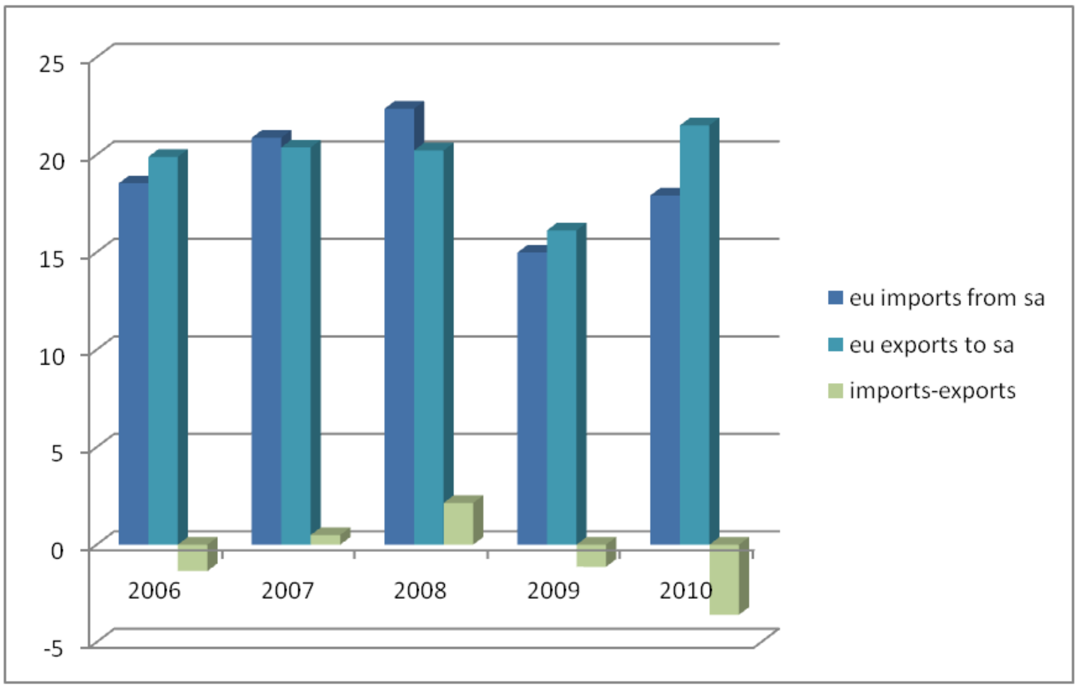


Source: (eurostat, edited by the author)

4.3 EU-South Africa

Comparing to South American and Oceania (Australia, New Zealand), South Africa is the nearest places for EU to import fruit from during winter. From EU's aspect, year 2006, 2009, and 2010 had a trade surplus, EU exported more. However, in year 2007, 2008, there was a trade deficit. We are not aiming to find out why the trade will be like this. Our goal is to find out if the reefer cargoes' trade is imbalance. Since the gap between import and export existed, there is a need to make further research of component of the trade.

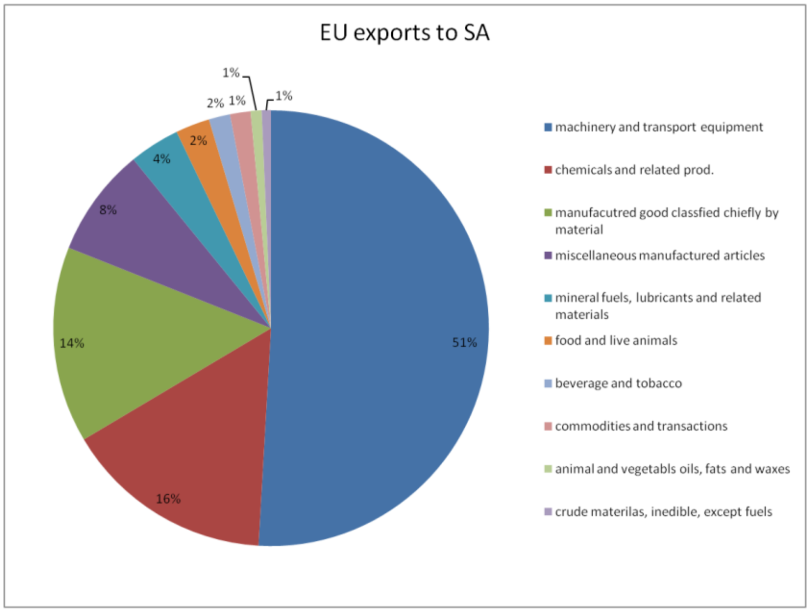
Figure 13 Total import and export of EU-South Africa



Source: (eurostat, edited by the author)

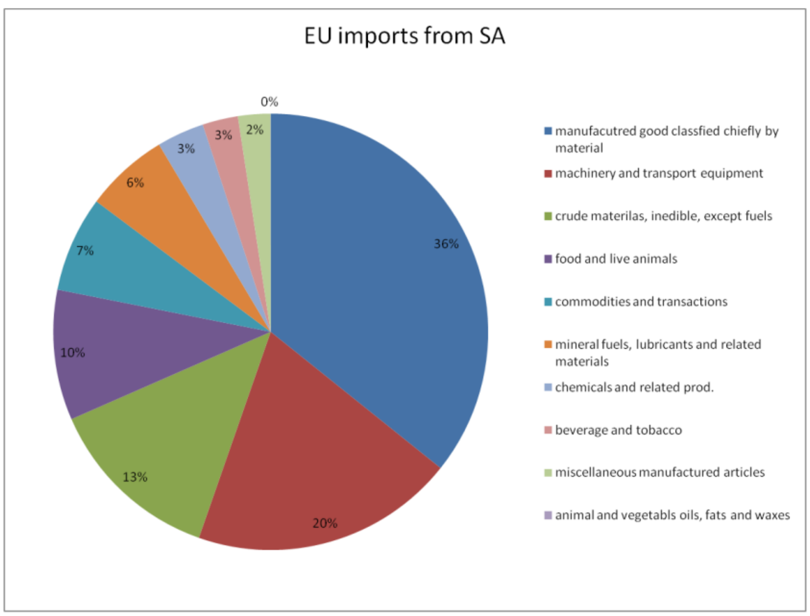
We can see that in figure 14 and figure 15, the cargo that EU export is more than half of the trading (51%) is in the category of machinery and transport equipment. On the other hand, cargoes that EU import is mainly manufactured good classified chiefly by material and machinery and transport equipment (together 56%). Then if we look at the category that we are aiming for is the food and live animals. EU imports from South Africa are 1.689 millions, and it consists of 10% of the overall trading. EU exports to South Africa are 0.534 millions, which consists of only 2% of the overall trading. As a result, the empty reefer container problem is highly possible happen in this trade route.

Figure 14 EU export to South Africa by categories



Source: (eurostat, edited by the author)

Figure 15 EU import from South Africa by categories



Source: (eurostat, edited by the author)

It is clear from previous paragraphs and figures that these five trading countries had not only an imbalance trade in total value but also the reefer cargoes' value are not the same in import and export. According to this, there would be the problem of empty reefer containers. To make further research and be more specific, cargoes in the food and live animals' categories that will be transported by reefer containers will be defined in the later paragraph. Moreover, the quantity of those cargoes will also be determined.

4.4 Types of cargoes and tons of cargoes

We decided to assume five sectors that are in the food and live animals category to be the representative reefer cargoes. They are meat, fishery products, dairy products, vegetables, and fruits. Because we think it is the main sector of cargoes that need to be transported under temperature control and our research trading route has some special conditions of demand and supply of those cargoes.

In order to know how many tons of reefer cargoes are trading between these three regions (EU-Argentina, Brazil, EU – Australia, New Zealand, EU-South Africa), we used the data from International trade centre (ITC) which provided statistic database of trading value of each country. And in the following paragraph will show the converting process from value of cargoes into weight of cargoes including assumptions.

4.4.1 Meat

In this category, the list of the name of meat contains many types of products; they are meat of swine, bovine, sheep, horses and so on. It is difficult to get each products price because most of the price data is not easy to access. In order to converting value of cargoes into weight of cargoes, a price index is needed. We found out that the price index of IMF (Actual Market Price for Non-Fuel and Fuel Commodities, 2008-2011) is a way of solution. Because IMF is a globally well know organization, the price index which is provided by it may not be totally accurate to converting the value into tons, however, it provided the globally view of price of several meat(beef, lamb, swine, and poultry). The price will be the base to transforming value into weight. The steps will be as follows: first the unit of value which is provided by IMF is cts/lb, to make it into the unit that is easier to use is to become dollar$/ton. For example, the list said the beef price is 152.5 cts/lb, which is equal to 3362.6 $/ton (1 kg=2.205 lb, 1 ton=1000 kg). Following the same method we can have the price of each products, beef is 3362.6 $/ton, lamb is 3212.7 $/ton, swine is 1640.5 $/ton, and poultry is 1891.9 $/ton. However we cannot access to some of the other meat's price. We decided to use the average price as the base price to transforming the value into weights. The average price of those four meat is 2526.9 $/ton. The process of converting will be the total value of the year divided by the average price, the answer that we get is the weight of cargoes. The converting process may be not accurate as the reality, but due to some of the limitation, we think this is one of the methods to solve this problem and the result will not make too many differences. According to the steps that mentioned above, it is easy to determine tons of cargoes that EU import and export in the 3 trading regions. Because we use year 2010 as the base year to determine the quantity of cargoes, the table below summarizes the total quantity of meat products traded in the 3 regions 5 countries.

Table 4 Demand and supply of meat (in tons)

		Argentina	Brazil	Australia	New Zealand	South Africa
EU	Import from	298,449	575,911	90,598	588,387	23,542
	Export to	4,587	2,704	69,948	10,622	29,068

Source: (ITC, IMF, calculated by the author)

4.4.2 Fishery products

In this category, the same price index will be used as the meat category, which is from IMF. The price index provided 2 prices of fishery products, fish (6.1 $/kg) and shrimp (7.5 $/kg). The same converting method is applied here, the unit of price becomes $ per ton. Then we get the base value of fish (6100 $/ton) and shrimp (7500 $/ton). The average price of fish and shrimp is 6800 $/ton. In the converting process of value into weights, we also make the assumptions that the average price of fish and shrimp is the base price of all the fishery products. There are different products in this category, such mollusks, furthermore, some of the fish are live, others are frozen, the price will vary in each products. The price information of each product is difficult to get, although making the assumption would cause some changes during the converting process, we think the different weight is acceptable, because the value is so large and the price difference of each products may not big enough to influence the total volume. So we summarize the total trade volumes in the table below.

Table 5 Demand and supply of fishery products (in tons)

		Argentina	Brazil	Australia	New Zealand	South Africa
EU	Import from	122,504	7,833	3,452	17,485	37,066
	Export to	494	119,999	3,320	56	1,667

Source: (ITC, IMF, calculated by the author)

4.4.3 Dairy products

In this category, the price index from IMF is no longer used. We need to find another database to continue our work. From the website of Food and Agriculture Organization of the United Nations, we found out there is some data that provided enough commodity price about dairy products. They are the price of butter (4042.72 $/ton), cheddar cheese (4009.5 $/ton), skim milk powder (3126.75 $/ton), and whole milk powder (3464.25 $/ton). The average price of these four products is 3660.813 $/ton. There are several different kinds of products in this category in the list; they include something that is not mentioned in the price index of FAO, such as natural honey, eggs. To assume the average price as the base price to converting value into weights is reasonable for us. The total trade value is large enough that if we use the assumption of base product price, the effect is minor to affect the total weights too much.

Table 6 Demand and supply of diary product (in tons)

		Argentina	Brazil	Australia	New Zealand	South Africa
EU	Import from	28,455	6,954	8,152	70,963	11
	Export to	744	7,978	34,913	2,906	13,153

Source: (ITC, FAO, calculated by the author)

4.4.4 Vegetables

In the vegetables category, it is the same as the other categories, almost impossible to find out the accurate price index to set up the base price to convert value to weight. We still need to find some alternatives to continue our research. As a result, commodity price which is provided by United States Department of Agriculture will be used as the base price. Because the unit price provided here is in $/pound. The standard unit we use in this paper is $/ton. For example, the potato is $0.48 per pound. One kilogram equals 2.205 pounds. Each ton of potato will cost $1058.4. Following the same logic and step, we can have the price of lettuce (4299.75 $/ton), cabbage (1367.1 $/ton), carrots (2205 $/ton), onions (1477.35 $/ton), and tomatoes (4410 $/ton). The average price of these 6 commodities price will be the base price for converting value into weight (2469.6 $/ton). The price of each commodity seems like a lot of difference, using the average to be the base price may be not precise enough. But it makes sense that we only aim to find out the difference of export and import in weight.

Table 7 Demand and supply of vegetables (in tons)

		Argentina	Brazil	Australia	New Zealand	South Africa
EU	Import from	81,086	3,591	20,248	29,201	9,007
	Export to	579	10,191	6,911	509	2,551

Source: (ITC, USDA, calculated by the author)

4.4.5 Fruits

To convert the value into weight in the fruit category is complex. In the list of this category, there are lots of different kinds of products and the price of each product is difficult to be found as the others. Then there is no specific website or company that I can get the price information. So, we decided to use the website of United States Department of Agriculture as the inquiry together with the price list from IMF. Then the major products' value can be found here. The main products' price after converting from pound to ton in fruit category includes peaches (4057.2 $/ton), apples (2359.4 $/ton), kiwi (3969 $/ton), cherries (7739.6 $/ton), banana (881.4 $/mt), and citrus (1028.4 $/mt). Here mt represents metric ton equals exactly one ton.

Table 8 Demand and supply of fruits (in tons)

		Argentina	Brazil	Australia	New Zealand	South Africa
EU	Import from	240,952	284,322	25,346	157,363	592,118
	Export to	1,248	28,499	6,198	830	5,086

Source: (ITC, IMF, USDA, calculated by the author)

4.5 Supply and Demand pattern

In previous paragraph, we gathered the historical trade data in value and converting them into weight of cargoes. So the total yearly trade volume is determined. But the volume in a yearly base is too large and it is too slow for responding empty reefer containers problem in a yearly base. Monthly trade quantity is more appropriate. In order to determine the monthly trade volume in year 2010, the data is the same as above but there are some differences.

Then the issue here is to set up how to separate the yearly volume into each month of each category of cargoes. For meat, fishery products, and dairy products categories, we assume the trade pattern is not influenced by weather changes. The total volume in export and import will spread evenly to each month. In other words, EU has the same demand and supply pattern in each month. However, the situation in vegetables and fruits categories is not the same. Products in these 2 categories have a characteristic that is easy to be influenced by the weather. Moreover, the trading route that we chose to make the further research such as Argentina, Brazil, Australia, and New Zealand, all have the opposite season than EU because they all locate in southern hemisphere. EU will import more winter fruit from those 4 countries to meet the demand in summer in northern hemisphere. When winter time comes, EU will do the vice versa. However, not all the fruit are influenced by season. According to the fruit calendar some of the fruits and vegetables are available whole year.(*www.cuesa.org*) The reason that perishable products are available whole year is due to some of the products are harvest in very early age and the improving techniques of storing facilities help those products to be matured later on. This method makes some of the products are available in the market whole year. Despite for this reason, we assume only 1/3 of the total volume fruits and vegetables are influenced by the weather. Because EU member is in such a wide range, some of the Mediterranean countries are still able supply some fresh products. However, we still set up the trade pattern to show some changes in summer and winter seasons in order to meet the demand of some EU countries. As a result, we assume that winter is from November to February, summer is from May to August. In this way, we try to reflect the real situation of the trade. According to our assumption, export and import will be more in this 2 specific season. To put this assumption into excel sheet, we use 2/3 of the total trade volume spread evenly to each month. The rest of the 1/3 cargoes distribute evenly to summer and winter season. Then we can get the monthly volume of export and import of each category. Here we use EU import from each country in vegetable category as example. The monthly demand of volume is determined. Because there are too many data sets, they will be list in the Annex.

Table 9 Demand of vegetables in month

EU import vegetables from each country (in tons)					
Month	Argentina	Brazil	Australia	New Zealand	South Africa
January	7,883	349	1,969	2,839	876
February	7,883	349	1,969	2,839	876
March	4,505	200	1,125	1,622	500
April	4,505	200	1,125	1,622	500
May	7,883	349	1,969	2,839	876
June	7,883	349	1,969	2,839	876
July	7,883	349	1,969	2,839	876
August	7,883	349	1,969	2,839	876
September	4,505	200	1,125	1,622	500
October	4,505	200	1,125	1,622	500
November	7,883	349	1,969	2,839	876
December	7,883	349	1,969	2,839	876

Source: (Table 7, calculated by the author)

Our next step is to transform the volume of cargoes into numbers of containers. As we mentioned in previous chapter, the trend in nowadays of reefer containers are 40 feet high cube reefer containers, the capacity will vary from 26 tons (40 Feet Hi-Cube Aluminum Refrigerated Container) to 29 tons (40 feet M.G.S.S Hi-Cube Refrigerated Container). Taking into consideration of practical operation and different size of cargoes, the stacking of cargoes inside container may not be fully used due to some of the ventilation limitation. Therefore, we assume each 40 feet high cube reefer container can carry 25 tons of cargoes. The number of reefer containers of each category in each month is then to be determined.

In order to see clearly about what the quantity flow of reefer containers, first we need to define the demand and supply of reefer containers. EU is the destination that imports more cargoes than export in comparison of these five countries (Argentina, Brazil, Australia, New Zealand, and South Africa). When looking at the demand and supple in cargoes, EU is the demand side, and the five countries are in the supply side. However, our aim is at empty reefer containers. The situation is just the opposite. From our point of view, when EU exports cargoes to those five countries, EU has the demand of reefer containers to load cargoes and export them. And when EU imports cargoes from those five countries, they will supply reefer containers to EU.

According to the description above, the demand and supple pattern of reefer containers is settled. Moreover, we used the assumption mentioned in pervious paragraph which said that each forty feet reefer container can carry 25 tons of reefer cargoes, and then we calculated the demand and supply quantities of reefer containers in the five countries. The process of calculation of converting tons of cargoes into number of reefer containers, we take Table 9 as example, each cell is divided by 25, and then we summarize the monthly demand and supply pattern of reefer containers in the table below.

Table 10 Monthly demand of reefer containers

		Demand(export)			
month	Argentina	Brazil	Australia	New Zealand	South Africa
January	27	586	412	50	176
February	27	586	412	50	176
March	23	522	390	48	163
April	23	522	390	48	163
May	27	586	412	50	176
June	27	586	412	50	176
July	27	586	412	50	176
August	27	586	412	50	176
September	23	522	390	48	163
October	23	522	390	48	163
November	27	586	412	50	176
December	27	586	412	50	176
Total	306	6,775	4,852	597	2,061

Source: (Table 4 to Table 8, calculated by the author)

Table 11 Monthly supply of reefer containers

		Supply(import)			
month	Argentina	Brazil	Australia	New Zealand	South Africa
January	2,750	3,089	518	2,982	2,540
February	2,750	3,089	518	2,982	2,540
March	2,214	2,609	442	2,671	1,538
April	2,214	2,609	442	2,671	1,538
May	2,750	3,089	518	2,982	2,540
June	2,750	3,089	518	2,982	2,540
July	2,750	3,089	518	2,982	2,540
August	2,750	3,089	518	2,982	2,540
September	2,214	2,609	442	2,671	1,538
October	2,214	2,609	442	2,671	1,538
November	2,750	3,089	518	2,982	2,540
December	2,750	3,089	518	2,982	2,540
total	30,858	35,144	5,912	34,536	26,470

Source: (Table 4 to Table 8, calculated by the author)

The table above is the sum of five categories of reefer cargoes (meat, fishery products, dairy products, vegetables, and fruits) in numbers of reefer containers, which is according to our assumption in previous paragraph and following the same logics to transform cargoes weight into number of reefer containers. However, this is a table only shows each month demand and supply pattern. We haven't taken into consideration of the cycle usage of reefer containers. If reefer containers is disposable, which is only for one time use, the table above shows the total number of reefer containers needed in the market. The real story of a container is that it is going to be used several years according to the condition. No matter how many years, a container is not onetime use goods. That is why empty containers' problem exists. Back to the table, we know that the supply is far more than demand. In other words, more reefer containers are transported to EU than from EU to other destinations. From EU's point of view, it has the situation of supply surplus. To make further investigation of how empty reefer containers are repositioned. We need to know what the container box flow is. The cycle of container box or the life of a container box is as follows. It starts at a point where it loads cargoes, and then the transportation company carries the container box to its destination to the consignee. To this level, we can use the table above to show the quantities of reefer containers. However, this is not the end. The container box may wait in the depot or go to another customer's place to load cargoes. Then it will be transported to the next destination. The container box is going to be used repeatedly. Taking EU-Argentina for example, EU needs 27 forty feet reefer containers in January, at the same time, those three trading regions transport total 2750 to EU. Then February comes, the number of reefer containers stay in EU and try to find customers to load cargoes is 2750-27=2723. The situation will keep going on and on. More and more container boxes will come to EU and that is why empty container repositioning should be considered.

In chapter 4, we determined there is trade imbalance of reefer cargoes in these 5 trading route. It is obvious to tell from those pie charts, as EU is most of the time the importer of reefer cargoes. Then, we determined there are 5 major categories of reefer cargoes (meat, fishery products, dairy products, vegetables, and fruits). According to the data that we got is the values of cargoes, we make several assumptions to convert them into tons of cargoes. With the information of tons of cargoes, we can make up the basic demand and supply pattern of reefer containers. In chapter 5, we will calculate the number of reefer containers needed per cycle according to the data that we have in chapter 4.

Chapter 5 How many reefer containers are needed?

In previous chapter, we determined the monthly supply and demand pattern of reefer containers for each country. In this chapter, the cycle of reefer container is taken into consideration. We will aim at looking for the number of reefer containers needed, moreover, the number of empty reefer containers may be calculated, and the most important is that we hope to find out what is the most cost-efficient way to reposition empty reefer containers.

5.1 The number of reefer containers needed in cycle

In order to determine the number of reefer containers needed in the cycle, first we need to address on the characteristics of container box. It is not a onetime use good, and liner companies will provide the service to transport the container box from one destination to another. In terms of liner companies, they need to provide the service in a routine no matter their vessels is fully loaded or not. The time schedule of the vessel to call the port is fixed. The vessel will depart to the other port according to the time schedule. According to this kind of service, the each month demand of reefer containers are not the exact number of reefer containers that are needed as the number in table 10.

To identify the time that from EU to those five countries, the distance between each ports should be determined. Because Rotterdam is the largest port according to the total TEU throughput in EU, we assume it to be the port that trade with those five countries. For the destination port of five countries, we assume them to be Buenos Aires of Argentina, Santos of Brazil, Melbourne of Australia, Auckland of New Zealand, and Cape Town of South Africa. These five ports are also the major port in each country. There may be some terminal or port which is mainly for reefer containers handling. But we think that will not influence our main goal here which is only to determine the distance from Rotterdam to these five countries. We have summarized the distance in the table 12.

Next assumption is the speed of the container vessel. Some say the container vessel now are in slow-steaming, which means they sail in a relatively slow speed than before to save fuel cost, but we are not sure if every vessel are taking this strategy. Therefore, we assume 20 knots is the speed for our calculation. It is because 20 knots does not exceed the maximum speed of container vessel (22 to 26 knots) but not as slow as the speed of slow-steaming which is about 16 knots. With the distances and the speed of vessel, we can determine the time of sea transportation. However, this is not the total time of the cycle of reefer containers.

In order to calculate the cycle time of the reefer container box, here we use the trade between Rotterdam and Buenos Aires as example. Once the container box reaches the terminal in Rotterdam, the time that unloads the reefer container box in the terminal needs to be calculated. Moreover, the procedure of custom clearance may take lots of time especially for cargoes about food, because some of them need special inspection, the time varies a lot. Here we assume the time that the reefer container box stays in the terminal would reach 3 days to finish all the process. Then the reefer container box is ready to leave the terminal and to be transported to the end user. Because Rotterdam is in a central location of Western Europe which is well connected to the other cities, we assume it takes about 2 days to deliver reefer containers to the consignee. After that, the reefer container box will be loaded with new cargoes and head back to the terminal in Rotterdam. We assume the time it would take is also 2 days. This is an optimistic assumption that the liner companies can always find cargo owners to full the reefer container box in such a short time. When the reefer container box reaches the terminal in Rotterdam, there is a great possibility that the container box should wait for few days because the vessel that sails long distances will not call the port every day. We assume the container box need to stay in the terminal for 3 days to be loaded on vessel to be transported to Buenos Aires. After the sea transportation, the container box reaches the terminal of Buenos Aires; it needs to be inspected and waits for all the process done. We assume the efficiency in the terminal of Buenos Aires is the same as in Rotterdam, which will take 3 days. The container box is transported by intermodal to the end user and loaded full with new cargoes back to the terminal and gets ready to be loaded on vessel again, the total time here we assume the same as in Europe, which in total is 4 days.

If we sum up all the days as we described above then the total time in a cycle with the assumption of direct return and direct re-use of a container box in Rotterdam- Buenos Aires route. We add the numbers together, and then we get 43 days as a cycle. This means that it takes 43 days for a fully loaded container box to depart from Buenos Aires to Rotterdam, unload those cargo and load with new one, then back to Buenos Aires and load again. In a year there may be about 9 cycles.

Then we can look at the demand of EU, it needs 306 reefer containers in a year to export all the cargoes to Argentina. If each reefer container can have 9 cycles per year, in other terms, each container can be used 9 times in a year, we can derive from that 34(306/9) reefer containers will be needed to support the demand of EU, which means each cycle carries 34 reefer containers and there is 9 cycles per year. It seems like 34 reefer containers are able to meet the demand of each month in the table above. However, it is not the right way to say that. The demand in the table is in a monthly standard, 34 reefer containers can meet the demand of total year but only in 9 cycles. To make them to be able to compare, we need to evaluate them in the same standard. First we need to transform the 12 months demand into 9 cycles to determine the number of reefer containers needed in each cycle. Then each cycle consists of 1+1/3 month's demand. Then, the maximum demand is 36 (total demand of January+ one third of February). It is more than the original calculation, but we can determine that 36 reefer containers are able to meet the total demand and the peak demand of EU.

The total cycle time is the time of sea transportation of outbound and inbound plus the land time. The land time is fixed, 17days. This is according to our assumption in previous paragraph. Applying this calculation can determine cycles per year in each country. Then we can calculate the number of reefer containers needed in each cycle. However, in order to make the monthly demand can be comparable with the cycle demand, we need to transfer month into cycle. Then we can see if the number of reefer containers can meet the maximum demand of each cycle. The number of reefer container needed can be determined after this calculation. We have summarized the result in the table below.

Table 12 Cycle times and number of reefer container needed

From Rotterdam To	Argentina (Buenos Aires)	Brazil (port of Santos)	Australia (Melbourne)	New Zealand (Auckland)	South Africa (Cape Town)
Distance (nautical miles)	6,327	5,423	11,086	11,379	6,142
20 knots/days	13	11	23	23	13
Days per cycle	43	39	63	63	43
Cycles per year	9	10	6	6	9
Total reefer containers demand	306	6,775	4,852	597	2,061
Total number of reefer containers needed according to cycle	34	678	809	100	229
Max demand per cycle(peak demand)	36	704	824	100	235
Number of container vessel needed(10000 teu vessel)	1	7	8	1	2

Source: (SeaRates.com, calculated by the author)

In table 16 above, we calculated the container cycle per year in each trading country. Then we can determine the number of total reefer containers needed to meet the demand of each country. However, we still need to look at the demand in per cycle instead of per month. In order to make them comparable, we need to transform the monthly demand into the cycle in the table, then we can determine the number of total reefer containers needed is enough to support the demand or not. As we can see from the table, most of the countries when they convert their monthly demand into cycle, they have greater number of reefer containers needed, which is because cycle is less than a month; there is an accumulating demand affect. In order to meet the max demand per cycle, the number of total reefer containers needed should follow the rule that if the max demand per cycle is larger than the demand per cycle, then the total number of reefer containers needed is the max demand per cycle.

Now we have the total number of reefer containers needed, we can also know how many container vessels would need to provide the service. In the table 3 has shown that reefer plugs consist of about 10% total capacity. Taking into consideration that these five countries are not the major trade partner with EU, the extra large vessel may only used in the Asia-Europe line. We assume the container vessels serve for these five countries are between 8000 to 10000 teu vessels. So the reefer plugs are about 100 in each vessel. Therefore, we can determine the number of container vessels needed for each country to provide enough capacity for each cycle.

5.2 Find the cost-efficient way of repositioning empty reefer containers

In the previous paragraph, we concluded the total number of reefer containers needed according to the distance to different destination and we have calculated the total time. Furthermore, we also know that how many rotations or cycle a reefer container box have in a year. With this information, we have determined the number of total reefer containers needed.

We have known the total number of reefer containers, and then we can move on to search for the optimistic result of repositioning empty reefer containers. We need to illustrate the empty reefer containers problem first. Using the monthly demand and supply pattern between EU and Argentina, also we assume that only one vessel provides service in this route. That implies that if the vessel departs from EU in the beginning of the month, it takes about half month to reach Argentina. Then the vessel will be loaded with new cargo and sail back to EU. In the table 13 is the basic flow of reefer container. EU export 27 reefer containers and receive 2750 reefer container in period 1. If this is the fixed trade pattern, we can see that reefer containers are staying more in EU. With the time gets longer, the situation is getting worse. Therefore the repositioning empty container problem needs to be solved.

Table 13 Example of accumulative reefer containers in EU

	EU-Argentina		
Period	Out-flow	In-flow	Reefer containers in EU
1	27	2,750	2,723
2	27	2,750	5,446
3	27	2,750	8,169
4	27	2,750	10,892
5	27	2,750	13,615

Source: (Table 10, Table 11, edited by the author)

As we illustrated the empty container problem in the table 13, our aim is to find the cost-efficient way to reposition those empty reefer containers. In order to do this, we decided to develop a mathematical model and use the Solver in Excel to find the lowest cost.

There are several cost can occur when it comes to reposition empty container problem. Due to some of the cost information is difficult to get, we assume there's only two costs in this model. One is the transportation cost, which means that when repositioning empty containers, it must be transported to the country that is in shortage. Liner companies generate revenue by providing slots to carry loaded containers. Once the slot is occupied to reposition empty containers, it is a lost for liner companies. Therefore, the total transportation cost is the sum up of total empties outflow times the transportation cost.

The second cost is the holding cost. As we know that once there's imbalance trade, empty containers may stay in one destination for a long time. The container box needs to be stored in the terminal or in a container depot. It incurs some cost. Moreover, each move of the container box incurs more cost, such as lifting off. Besides from this, liners companies need to rent a container box in the shortage country to meet the demand or they endure the risk of losing customers. In this paper, we assume the holding cost include all these cost as we discussed.

To introduce our model, first we introduce the notation in the formula

X_i --- Outflow of empty reefer containers in period i

Y_i^t--- Y_i is the end inventory of reefer container in period t, but this end inventory doesn't include the inventory from previous period

T --- Transportation cost in dollars per FEU

H --- Holding cost in dollars per FEU per period

N --- Number of period

TC --- Total cost in dollars of repositioning empty reefer containers

Therefore, our mathematical model of repositioning empty reefer containers is determined as follows, and our aim is to find the lowest total cost

$$TC = T \times \sum_{i=1}^{n} X_i + H \times \sum_{t=1}^{n} \sum_{i=1}^{n} Y_i^t$$

Explanation

$$\sum_{t=1}^{n} \sum_{i=1}^{n} Y_i^t$$

We use the matrix in the table below to illustrate the situation to explain this formula.

Table 14 Number example of explanation

Period	Starting Inventory	End Inventory	Y_i^t
1	25	50	50
2	50	110	50+60
3	110	180	50+60+70
4	180	260	50+60+70+80

Source: (edited by the author)

When we are using this model, we have the assumption that each period's end inventory becomes the next period's starting inventory. Basically, the inventory in period 2 consists of the inventory from period 1. We have to take the time duration into consideration, because the holding cost is calculated by the time. Therefore we set the formula like this.

Besides from the formula above, in order to use the Solver in Excel to find the lowest cost, we need to set up the matrix to fill in the data and can set up the formula in Excel. Therefore, the cell contains the information as below.

Table 15 Matrix form

period	Starting Inventory	End Inventory	Flow-in	Flow-out	Empties outflow

Source: (edited by the author)

The column of flow-in and flow-out are filled in the data according to the demand and supply pattern of reefer containers. The values of these two columns are determined. And each period has columns of starting inventory, end inventory, and empties outflow, the value is still unknown. Therefore, we set up the cell in Excel according to the rule as follows.

End Inventory = Starting Inventory + (Flow-in) – (Flow-out) – (Empties outflow)

Because there are two variables in our mathematical model, they are calculated by the Solver in Excel. Values in the column of the starting inventory, end inventory and empties outflow are determined by the Solver. It helps us to find the lowest cost at the end.

Constraints of the matrix

First, the number of outflow of reefer containers in each period should be smaller or equal to the number of previous period end inventory. This is logical because there should be enough reefer containers in inventory then they can be repositioned.

Second, in the period 1, the outflow of empties of reefer container is 0. Here we assume that period 1 is the starting point; there is no need to reposition any of them.

Third, the outflow of number of reefer containers should be greater than 0. Because we use the Solver in Excel to look for the minimum cost according to our formula mentioned above, without this constraint, it is possible to have a negative value. We cannot interpret a negative value in this formula.

In previous paragraph, we have explained the model and the constraints. Now we will apply it to the data that we have to see what the result will be.

5.3 Application

With the formula and constraint that we described, we can start to illustrate how to determine the lowest cost. Here we use the example between EU and Argentina to show how to use the Solver in Excel to search for the minimum cost of our formula according to the data that we put into the formula. First we need to determine the time that how many periods will be. Referring to the previous paragraph; we have determined that per reefer container box has 9 cycles in this route, each cycle takes about 43 days include the time on the sea and land. In order to address on the issue of empty reefer containers, we extend the demand pattern in 20 days, which is about half days of the cycle. Then we can get 18 periods in a year.

Then, we have to assume the cost of transportation. However, the actual freight rate of transporting a container box is confidential and difficult to get. To make the assumption, we found that in Lloyd's list, it mentioned that the average freight rate of Hapag-Lloyd is $1546 per teu. We would like to base on this news to make our assumption. As we mentioned in previous chapter, we set up the condition that the most used size of reefer containers are 40 feet. If it is fully loaded, the freight rate must be higher than $1546. But according to the real business situation, there's always a discount freight rate for repositioning a container box. Therefore we assume the transportation cost of a 40 feet reefer container is $1500.

It is also difficult to have the information about the holding cost that we use here. We still need to continue on our research, therefore, we have to make some assumption. The cost of container depot and the cost of lifting a container box could vary from country to country. We found a paper mentioned the inventory and lifting cost are about 33 pounds in Rotterdam in 2004, we assume it is about $60 nowadays.(Song, 2011) Then imagine the situation that happens between EU and Argentina. Because Argentina is the supply country of reefer containers, if all the reefer containers are staying in EU, there will be a shortage. For Argentina, it has the option whether is to rent a reefer container or it has to endure the risk of losing a customer. Both of the situations incur cost. Since we are lack of information of the cost, we need to make assumption about here also. We only know that to buy a new forty feet reefer container is about $27000, and in average, a reefer container can last for 10 years. If it can be used 10 times in each year, then each time it cost about $270. We would say this is the cost of renting a reefer container. For the cost of losing customers, we really don't have any clue about this. Also it is difficult to determine the value of each customer or the goodwill of each company. Therefore, we add up only these two costs together, and the holding cost we use here is 330.

After assuming the transportation cost and holding cost, we can move on to put the data into the excel sheet. The data that we put in is fixed only in the reefer containers flow in and flow out, which is derived from table of demand and supply pattern. We set up that in period 1, the starting inventory is the total number of reefer containers EU needs. Then, sum up starting inventory and flow in minus flow out and empties outflow, we can get the end inventory. The table below follows this rule and it contains the result from the Solver in Excel.

Table 16 Results from the Solver in Excel

period	Starting Inventory	End Inventory	Flow-in	Flow-out	Empties outflow
1	36	1,852	1,834	18	0
2	1,852	1,816	1,834	18	1,852
3	1,816	1,816	1,834	18	1,816
4	1,816	1,460	1,476	16	1,816
5	1,460	1,460	1,476	16	1,460
6	1,460	1,460	1,476	16	1,460
7	1,460	1,816	1,834	18	1,460
8	1,816	1,816	1,834	18	1,816
9	1,816	1,816	1,834	18	1,816
10	1,816	1,816	1,834	18	1,816
11	1,816	1,816	1,834	18	1,816
12	1,816	1,816	1,834	18	1,816
13	1,816	1,460	1,476	16	1,816
14	1,460	1,460	1,476	16	1,460
15	1,460	2,920	1,476	16	0
16	2,920	4,736	1,834	18	0
17	4,736	6,552	1,834	18	0
18	6,552	8,368	1,834	18	0
	holding cost		transportation cost		total cost
	330		1,500		48,594,480
	15,264,480		33,330,000		

Source: (excel sheet, calculated by the author)

From the table, the empties outflow column is determined by the Solver in Excel. It follows the constraint that we set up in previous paragraph. According to the data that we put in and set up, the total cost is 48,594,480, which is the minimum cost determined by the Solver in Excel. In order to compare the total cost here with the situation that if no reefer containers are repositioned to Argentina, in other terms, all these reefer containers are staying in EU, then there is only holding cost, we also calculated it. It is 95,994,360 in total. We can say that with repositioning them to Argentina, the total cost is far more less.

Besides from that, it shows the number of reefer containers should be repositioned to Argentina from period 2 to period 14. In order to reach the minimum cost, all those reefer containers in inventory are repositioned immediately in this time period. There is no reefer container left from previous period. We think the reason is because there is an aggregate effect in holding cost, once the time is getting longer, the total cost increase dramatically. So we can say that if the real business situation is following our assumption, then the best strategy to reposition empty reefer containers is the quick response way to avoid the accumulating holding cost.

After seeing the example between EU and Argentina, we applied the same method (with T = 1,500 and H = 330) and calculated all the cost and summarize them in cost without repositioning and the cost with repositioning in the table below.

Table 17 Total costs in $ of transporting and holding costs of empties

From Rotterdam to	Argentina	Brazil	Australia	New Zealand	South Afirca
Without repositioning	95,994,360	102,947,064	5,537,255	73,195,241	77,917,363
With repositioning	48,594,480	47,027,756	3,074,368	50,397,344	38,934,507

Source: (Annex 1, calculated by the author)

In each country, the cost with repositioning is much more less than that without repositioning. The cost without repositioning is direct related with the total number of reefer containers in demand and supply of each country and the time period. Brazil has the longest period and the second largest number of reefer containers needed. So the total cost without repositioning is the highest. Furthermore, the strategy for these five countries of repositioning empty reefer containers is the same. They repositioned those empty reefer containers right in the period 2, and they all stop transporting them to the supply country in the last five period. In other words, those empty reefer containers in the last four periods stay in EU. We can say that the quick response strategy is mainly based on the high cost of the holding cost. Once the holding cost is lower, we can foresee that more reefer containers are stacking in EU.

In order to determine the most cost-efficient way of repositioning empty reefer containers, we set up the formula and some constraints. According to our assumptions, we have calculated the results and found out that the most cost-efficient way or the lowest cost way is to response the empty reefer containers quickly. The pattern shows once there are aggregate inventory in EU, they should be transported out right in the next period. By doing this, liner companies can avoid to pay a large amount of money for holding the empty reefer containers. And it is quite reasonable in the real business situation. Because we know that the price of land in EU is relatively high in the world, with the scarcity of land, holding empty reefer containers in EU is not the best decision according to our calculation.

5.4 Different demand scenario

Trade imbalance is the major reason of empty reefer containers. So far, some literatures and our model are aiming at looking for the minimum cost of repositioning them. We think this is a passive action for liner companies. As we mentioned before, they generate profit by providing reefer containers to cargo owner to load it full and transport them. Only by loading the container full are profitable. If we want to utilize the reefer container to make more profit, we need to search for cargoes which can be put into reefer containers. However, when we look at the characteristics of reefer container, there are several limitations for those cargoes. For example, cargoes should be non-toxic, odorless, which is better for the future use. We think that to find cargoes to be loaded on reefer containers to compensate the gap of trade imbalance of reefer cargoes is a new way of solving this problem. Here we want to take this into consideration and to see what the result is.

As we know that the gap of the imbalance trade between EU and those five countries are very large. We can see this from the number of reefer containers flow-in and flow-out. Therefore, here we assume the demand of using reefer containers is increasing due to there are other cargoes can be loaded to reefer containers. It means the demand in EU of reefer containers is increasing. And the increasing demand is filled by those over-supply reefer containers.

All the assumptions and formulas is the same as above, the matrix is also the same. However, the data that filled in the cell of flow-out is changed. Because EU is going to export more reefer containers to those five countries, we assume those reefer containers are from previous period over-supply. The new trade pattern is as follows.

Flow-out = X% of previous period's flow-in

X=10, 20, 30

With this assumption, we can get the new trade pattern. We only make the assumption that maximum 30% of reefer containers can be loaded and exported again, because we still are not sure about what kinds of products are harmless to reefer containers. And we only want to see what the effect of this kind of increasing demand to the total cost or the repaginating cost according to our mathematical model.

Here we use the trade between EU and Argentina as example. The data in the flow-in column is the same as before, but the flow-out has the new pattern, we summarized them in below.

Table 18 New pattern of flow-out

Period	X = 10%	X = 20%	X = 30%
1	18	18	18
2	201	385	568
3	201	385	568
4	199	383	566
5	164	311	459
6	164	311	459
7	166	313	461
8	201	385	568
9	201	385	568
10	201	385	568
11	201	385	568
12	201	385	568

13	199	383	566
14	164	311	459
15	164	311	459
16	166	313	461
17	201	385	568
18	201	385	568

Source: (Table 16, edited by the author)

Only the first period flow-out pattern is the same as previous one, the other periods increase due to we assume that we find products other than reefer cargoes can be transported in reefer containers. Then we put these data to our model, we can have the result as below.

Table 19 Cost comparison

	Original	10%	20%	30%
Without repositioning	95,994,360	87,337,008	78,679,656	70,022,304
With repositioning	48,594,480	43,997,496	39,400,512	34,803,528

Source: (calculated by the author)

From the result of this table, we can see that with the increasing flow-out of reefer containers can significantly reduce the cost of empty containers. With the 10% of the demand increase, there's 9% cost reduction. With the 20% increasing demand, the cost reduces about 18%, 19% respectively of without repositioning and with repositioning. And with the 30% increasing demand, the cost reduces 27% in without repositioning, 28% in with repositioning. It is worth to notice that more percentage reducing in cost with repositioning. Besides from that, the strategy of repositioning empty reefer containers is still quick response, and those empty reefer containers in the last four periods are still staying at EU.

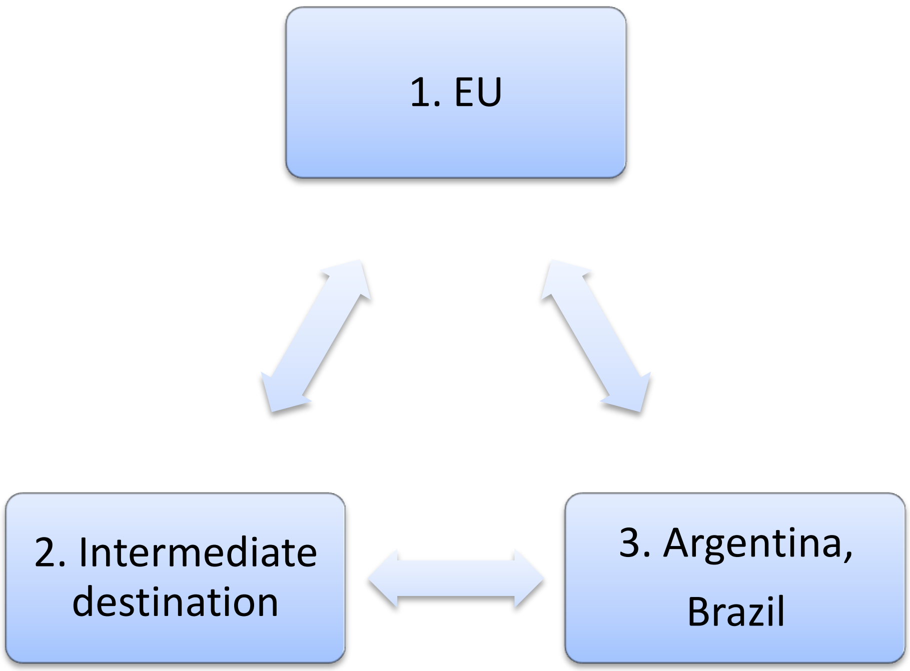
Therefore, we can summarize from this comparison that if more products can be loaded in reefer containers to increase the demand of reefer containers in EU, the cost will reduce according to the percentage of increasing demand. Also it shows that more percentage reducing in the cost with repositioning. We can say that with carefully planning repositioning strategy can really reduce more cost than doing nothing.

5.5 Discussions about loop

From the previous paragraph, we know that we can increase the demand of reefer containers by searching new cargoes to be put into them. Once the demand of reefer containers in EU increases, the cost of repositioning empty reefer containers are becoming less. In our previous research, we assume that reefer containers are traveling between EU and those five countries only. We also assume those reefer containers are directly returned to their supply country or direct re-used in EU. In order to compare different solutions about repositioning empty reefer containers, here we want to see what the effect is if there is an intermediate destination between those five countries.

In this section, first we address on the trade route between EU and Argentina, Brazil. The flow of reefer containers becomes like this.

Figure 16 Loop of reefer containers



Source: (edited by the author)

In our previous paragraph, EU has the demand of reefer containers, and Argentina, Brazil are the supplying countries. The flow of reefer containers is 1→ 3 → 1. They are traveling only in these two areas. Because of the imbalance trade of reefer cargoes, liner companies make profit in the flow from 3 →1, and the repositioning cost occurs in 1 → 3. In the previous paragraph we determined that the quick response strategy can have the lowest cost of repositioning.

If there is one more port calls in the trading route, the reefer container flow becomes 1 → 2 → 3 →1. We hope that by adding this port calls can make the repositioning cost be reduced. We can examine this method is applicable or not by the following discussion.

First, we need to determine the number of reefer containers needed. If the travel distance is the same, with one more port calls, the cycle time will increase. The time spent on the process of reefer container handling and waiting for the vessel to call the port can vary a lot. We assume there are 7 days more in one cycle. The result is that more reefer containers will be needed to meet the demand. Take EU-Argentina for example, the original cycle time is 43 days, and 9 cycles per year. If we add 7 days as the one more port call in the intermediate destination, the cycle time becomes 50 days, and 7 cycles per year. Then we can determine the number of reefer containers needed, which is about 44 (306/7). The number of reefer containers needed to meet the demand is different than before, at least 8 (44-36) more reefer containers need to be bought. Therefore, the increasing cost of buying extra reefer containers is 8 * $27,000 = 216,000. At this stage, we can conclude that the increasing cycle time leads to the increasing number of reefer containers needed, and there is extra cost for those new equipments.

Second, the reason to have one more port call is that we want to increase the usage of reefer containers. In the previous chapter, we know that by finding new cargoes to full loaded reefer containers is one of the solutions of empty reefer container problem. To have one intermediate destination is the other solution. We hope that in this additional port calls, EU can export some reefer containers to this area or this area can export some reefer containers to Australia. It means we want to utilize reefer containers in the route of 1 → 2 → 3.

Based on our mathematical model, once the reefer container cannot find cargoes to be loaded, it occur two costs. One is the holding cost ($330), the other is transportation cost ($1500). This is the direct return cost. With the intermediate destination, the holding cost is still the same in EU, but the transportation cost will be lower because the distance is shorter. We can illustrate the situation with an intermediate destination as follows.

EU now has several options for the oversupplying reefer containers. If there is no demand of reefer containers in the intermediate destination, then it is only a time consuming process to transport reefer containers through this port. We can say the total cost of repositioning empty reefer containers will increase. It includes the cost of buying new reefer containers and the cost of holding and transporting.

However, if the intermediate destination has the demand for reefer containers, the cost of repositioning may be reduced. As we mentioned before, liner companies generate revenue by transporting reefer containers with cargoes. Only half of the trip in 1 → 2 → 3 the reefer container is empty. Because we are lack of the data and information to determine the demand and supply pattern in the case that there's an intermediate destination. We cannot really calculate the revenue and cost in this situation. But when we look at the cost of repositioning calculated by our mathematical model, the result is $48,594,480. Our aim is to find out if the reducing cost can compensate the new cost of buying reefer containers $216,000. As a result, once the original repositioning cost can reduce about 0.045%, it can recover the new cost due to the longer cycle time. As we mentioned in the previous paragraph, the repositioning cost reduces with the increasing demand of reefer containers. We think it is not too difficult to increase the demand of reefer containers by 0.045%.

We can conclude here that there is a new cost of buying more reefer containers to meet the demand due to the longer cycle time. And if there is a demand of reefer container in the intermediate destination, it is not very difficult to lower the repositioning cost to recover the new cost of buying reefer containers. Although this is an approximately estimation, we think it is applicable in the real business.

Chapter 6 Conclusion and suggestions

6.1 Conclusion

The imbalance trade is the main reason of empty container problem. We addressed at the reefer market between EU and five countries (Argentina, Australia, Brazil, New Zealand, and South Africa).

First, we determined cargoes that are transported by reefer containers. Base on the distances between each destination and we assume the time on the process of reefer container handling, we determined the cycle time of each trading route. With this information, we calculated the number of reefer containers needed according to the cycle.

Second, we built a mathematical model to see how to deal with the empty reefer container problem. This model has two variables which is the transportation cost and the holding cost. Base on our result, we can say that the quick response way of repositioning empty reefer containers can have the lowest cost. Besides from this, in order to lower the cost of repositioning empty reefer containers, improving the usage of reefer containers is the active way. We also create different demand scenario and know that the repositioning cost reduces with the increasing demand of reefer containers.

Third, we try to add one more intermediate destination between each trading route to become a loop. This is different from our previous assumptions that the reefer container is directly return and direct reuse. With this new intermediate destination, it increased the possibilities of the usage of the reefer container. Although the cycle time is getting longer and more reefer containers are needed. We find out there's a great possibilities that the revenue gained from transporting more loaded reefer containers can recover the cost of buying more reefer containers.

6.2 Suggestions

First, our conclusion of the quick response way of repositioning empty reefer containers is based on several assumptions. To be more accurate to reflect the real business situation, we think it is better to include more variables in the mathematical model. There would be more alternatives for repositioning empty reefer containers.

Second, we made several assumptions to create the demand and supply pattern in this paper. In order to be more precisely reflects the trading pattern for future research, people can use the statistical method, such as different probability distribution to create different scenarios of demand and supply pattern to show the seasonal effect or high-low season for certain cargoes.

Third, the port call is another thing can be improved. In this paper we address on the distance of the major ports only. In the real situation, the vessel calls at several ports in a trading route, the number of reefer containers needed which will vary from our calculation due to the time difference.

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Annex

Annex 1. Demand and supply pattern of each cargoes in monthly base

Demand and supply of meat in each month

EU import meat from each country (in tons)					
Month	Argentina	Brazil	Australia	New Zealand	South Africa
January	24,871	47,993	7,550	49,032	1,962
February	24,871	47,993	7,550	49,032	1,962
March	24,871	47,993	7,550	49,032	1,962
April	24,871	47,993	7,550	49,032	1,962
May	24,871	47,993	7,550	49,032	1,962
June	24,871	47,993	7,550	49,032	1,962
July	24,871	47,993	7,550	49,032	1,962
August	24,871	47,993	7,550	49,032	1,962
September	24,871	47,993	7,550	49,032	1,962
October	24,871	47,993	7,550	49,032	1,962
November	24,871	47,993	7,550	49,032	1,962
December	24,871	47,993	7,550	49,032	1,962

EU export meat to each country (in tons)					
Month	Argentina	Brazil	Australia	New Zealand	South Africa
January	382	225	5,829	885	2,422
February	382	225	5,829	885	2,422
March	382	225	5,829	885	2,422
April	382	225	5,829	885	2,422
May	382	225	5,829	885	2,422
June	382	225	5,829	885	2,422
July	382	225	5,829	885	2,422
August	382	225	5,829	885	2,422
September	382	225	5,829	885	2,422
October	382	225	5,829	885	2,422
November	382	225	5,829	885	2,422
December	382	225	5,829	885	2,422

Demand and supply of fishery products in each month

EU import fishery products from to each country (in tons)					
Month	Argentina	Brazil	Australia	New Zealand	South Africa
January	10,209	653	288	1,457	3,089
February	10,209	653	288	1,457	3,089
March	10,209	653	288	1,457	3,089
April	10,209	653	288	1,457	3,089
May	10,209	653	288	1,457	3,089
June	10,209	653	288	1,457	3,089
July	10,209	653	288	1,457	3,089
August	10,209	653	288	1,457	3,089
September	10,209	653	288	1,457	3,089
October	10,209	653	288	1,457	3,089
November	10,209	653	288	1,457	3,089
December	10,209	653	288	1,457	3,089

EU export fishery products to each country (in tons)					
Month	Argentina	Brazil	Australia	New Zealand	South Africa
January	41	10,000	277	5	139
February	41	10,000	277	5	139
March	41	10,000	277	5	139
April	41	10,000	277	5	139
May	41	10,000	277	5	139
June	41	10,000	277	5	139
July	41	10,000	277	5	139
August	41	10,000	277	5	139
September	41	10,000	277	5	139
October	41	10,000	277	5	139
November	41	10,000	277	5	139
December	41	10,000	277	5	139

Demand and supply of dairy products in each month

EU import dairy products from each country (in tons)					
Month	Argentina	Brazil	Australia	New Zealand	South Africa
January	2,371	580	679	5,914	1
February	2,371	580	679	5,914	1
March	2,371	580	679	5,914	1
April	2,371	580	679	5,914	1
May	2,371	580	679	5,914	1
June	2,371	580	679	5,914	1
July	2,371	580	679	5,914	1
August	2,371	580	679	5,914	1
September	2,371	580	679	5,914	1
October	2,371	580	679	5,914	1
November	2,371	580	679	5,914	1
December	2,371	580	679	5,914	1

EU export dairy products to each country (in tons)					
Month	Argentina	Brazil	Australia	New Zealand	South Africa
January	62	665	2,909	242	1,096
February	62	665	2,909	242	1,096
March	62	665	2,909	242	1,096
April	62	665	2,909	242	1,096
May	62	665	2,909	242	1,096
June	62	665	2,909	242	1,096
July	62	665	2,909	242	1,096
August	62	665	2,909	242	1,096
September	62	665	2,909	242	1,096
October	62	665	2,909	242	1,096
November	62	665	2,909	242	1,096
December	62	665	2,909	242	1,096

Demand and supply of fruits in each month

EU import fruits to each country (in tons)					
Month	Argentina	Brazil	Australia	New Zealand	South Africa
January	23,426	27,642	2,464	15,299	57,567
February	23,426	27,642	2,464	15,299	57,567
March	13,386	15,796	1,408	8,742	32,895
April	13,386	15,796	1,408	8,742	32,895
May	23,426	27,642	2,464	15,299	57,567
June	23,426	27,642	2,464	15,299	57,567
July	23,426	27,642	2,464	15,299	57,567
August	23,426	27,642	2,464	15,299	57,567
September	13,386	15,796	1,408	8,742	32,895
October	13,386	15,796	1,408	8,742	32,895
November	23,426	27,642	2,464	15,299	57,567
December	23,426	27,642	2,464	15,299	57,567

EU export fruits to each country (in tons)					
Month	Argentina	Brazil	Australia	New Zealand	South Africa
January	121	2,771	603	81	494
February	121	2,771	603	81	494
March	69	1,583	344	46	283
April	69	1,583	344	46	283
May	121	2,771	603	81	494
June	121	2,771	603	81	494
July	121	2,771	603	81	494
August	121	2,771	603	81	494
September	69	1,583	344	46	283
October	69	1,583	344	46	283
November	121	2,771	603	81	494
December	121	2,771	603	81	494

Supply of vegetables in each month

EU export vegetables to each country (in tons)					
Month	Argentina	Brazil	Australia	New Zealand	South Africa
January	56	991	672	49	248
February	56	991	672	49	248
March	32	566	384	28	142
April	32	566	384	28	142
May	56	991	672	49	248
June	56	991	672	49	248
July	56	991	672	49	248
August	56	991	672	49	248
September	32	566	384	28	142
October	32	566	384	28	142
November	56	991	672	49	248
December	56	991	672	49	248

Annex 2. Results from the Solver in Excel

Brazil

period	Starting Inventory	End Inventory	Flow-in	Flow-out	Empties outflow
1	704	2,206	1,853	352	0
2	2,206	1,502	1,853	352	2,206
3	1,502	1,502	1,853	352	1,502
4	1,502	1,335	1,661	326	1,502
5	1,335	1,252	1,565	313	1,335
6	1,252	1,252	1,565	313	1,252
7	1,252	1,335	1,661	326	1,252
8	1,335	1,502	1,853	352	1,335
9	1,502	1,502	1,853	352	1,502
10	1,502	1,502	1,853	352	1,502
11	1,502	1,502	1,853	352	1,502
12	1,502	1,502	1,853	352	1,502
13	1,502	1,502	1,853	352	1,502
14	1,502	1,335	1,661	326	1,502
15	1,335	1,252	1,565	313	1,335
16	1,252	1,252	1,565	313	1,252
17	1,252	2,588	1,661	326	0
18	2,588	4,089	1,853	352	0
19	4,089	5,591	1,853	352	0
20	5,591	7,092	1,853	352	0
	holding cost		transportation cost		total cost
	330		1,500		47,027,756
	14,055,956		32,971,800		

Australia

period	Starting Inventory	End Inventory	Flow-in	Flow-out	Empties outflow
1	824	930	518	412	0
2	930	106	518	412	930
3	106	52	442	390	106
4	52	52	442	390	52
5	52	106	518	412	52
6	106	106	518	412	106
7	106	106	518	412	106
8	106	106	518	412	106
9	106	159	442	390	0
10	159	211	442	390	0
11	211	317	518	412	0
12	317	424	518	412	0
	holding cost		transportation cost		total cost
	330		1,500		3,074,368
	883,587		2,190,781		

New Zealand

period	Starting Inventory	End Inventory	Flow-in	Flow-out	Empties outflow
1	100	3,031	2,982	50	0
2	3,031	2,931	2,982	50	3,031
3	2,931	2,622	2,671	48	2,931
4	2,622	2,622	2,671	48	2,622
5	2,622	2,931	2,982	50	2,622
6	2,931	2,931	2,982	50	2,931
7	2,931	2,931	2,982	50	2,931
8	2,931	2,931	2,982	50	2,931
9	2,931	5,554	2,671	48	0
10	5,554	8,176	2,671	48	0
11	8,176	11,107	2,982	50	0
12	11,107	14,038	2,982	50	0
	holding cost		transportation cost		total cost
	330		1,500		50,397,344
	20,396,330		30,001,014		

South Africa

period	Starting Inventory	End Inventory	Flow-in	Flow-out	Empties outflow
1	235	1,811	1,693	117	0
2	1,811	1,576	1,693	117	1,811
3	1,576	1,576	1,693	117	1,576
4	1,576	916	1,025	109	1,576
5	916	916	1,025	109	916
6	916	916	1,025	109	916
7	916	1,576	1,693	117	916
8	1,576	1,576	1,693	117	1,576
9	1,576	1,576	1,693	117	1,576
10	1,576	1,576	1,693	117	1,576
11	1,576	1,576	1,693	117	1,576
12	1,576	1,576	1,693	117	1,576
13	1,576	916	1,025	109	1,576
14	916	916	1,025	109	916
15	916	1,833	1,025	109	0
16	1,833	3,409	1,693	117	0
17	3,409	4,985	1,693	117	0
18	4,985	6,560	1,693	117	0
	holding cost		transportation cost		total cost
	330		1,500		38,934,507
	11,809,468		27,125,039		