Passengers and cargo?
Cost economies at airport level

Els Struyf

PhD thesis

Supervisors: prof. dr. Eddy Van de Voorde
prof. dr. Hilde Meersman

University of Antwerp
Faculty of Applied Economics
Department of Transport and Regional Economics

Members of the doctoral commission:

Prof. dr. Eddy Van de Voorde, supervisor (Faculty of Applied Economics, Department of Transport and Regional Economics, University of Antwerp)

Prof. dr. Hilde Meersman, supervisor (Faculty of Applied Economics, Department of Transport and Regional Economics, University of Antwerp)

Prof. dr. Ann Verhetsel, chairwoman (Faculty of Applied Economics, Department of Transport and Regional Economics, University of Antwerp)

Prof. dr. Anne Graham (University of Westminster, London)

Prof. dr. Rosário Macário (Instituto Superior Técnico, Lisbon Technical University/TransportNET)

Prof. dr. Juan Carlos Martín (Universidad de Las Palmas de Gran Canaria)

Dr. Evy Onghena (Faculty of Applied Economics, Department of Transport and Regional Economics, University of Antwerp)

It always seems impossible
until it’s done
- Nelson Mandela -

Table of Contents

List of Figures

List of Tables

Acknowledgements

During the last year of my PhD, I took on some projects, personal and professional. I combined the building of a new house and the creation of a new baby with a new job in a completely different sector, some necessary training and the final stages of my PhD… It sounds like a lot to take…and actually, it was heavy from time to time. Therefore, especially during that last year of my PhD-career, I sometimes fell back on some quotes for inspiration or motivation. Some of those quotes are by famous people, some of them by less famous people. My favorite however is a quote by Nelson Mandela, stating "*It always seems impossible until it's done*". Now, after many years of hard work, I can say "it's done! I did it", I have finished my PhD.

However, I could not have done it on my own, I was fortunate to be able to rely on many others, whom I would like to thank.

First of all, my sincere gratitude goes out to my supervisors, prof. dr. Eddy Van de Voorde and prof. dr. Hilde Meersman. Both stood by my side with their own expertise and knowledge, leading me to a finished product of good quality. Their door was always open for me, they listened to me with a lot of patience. Any PhD-student can relate to the nerves that precede a discussion of the progress of the dissertation, however, the last months, I rather looked forward to the meetings. The discussions brought new insights, new encouragement. So, thank you so much for being my guiding lights.

Secondly, I would like to thank the chairwoman of the department of Transport and Regional Economics, prof. dr. Ann Verhetsel. It was she who let me know that some positions were opening at the department. It was she who was the promotor of my master thesis and thus a familiar face at the department from day one. And I am very glad that now, it is she who is chair of my doctoral commission.

Furthermore, I would like also to thank the other members of my doctoral commission: prof. dr. Anne Graham (University of Westminster, London), prof. dr. Rosário Macário (Instituto Superior Técnico, Lisbon Technical University), prof. dr. Juan Carlos Martín (Universidad de Las Palmas de Gran Canaria) and dr. Evy Onghena (Universiteit Antwerpen). Their valuable comments and suggestions allowed me to further improve my dissertation.

Since writing a PhD is a hard and lonesome task, I am really glad that I could always count on my wonderful colleagues for vivid discussions, interesting thoughts and the opportunity to take my mind of the job from time to time. I especially want to thank Franziska Kupfer, Katrien De Langhe, Christa Sys and Frank Troch for always being there for me when I needed them and for providing me the chance to ventilate my frustrations every now and then.

As I already hinted, also in my personal life, it has been a busy year. Therefore, I would like to say “thank you”, especially to my husband Niek and my parents who were always there to support me, also when things got rough and I was maybe not the nicest company. I would not have been able to take on all the projects without your help! You are my rock!

I would also like to thank our daughter Nore and my brother Stefan for enabling me to take my mind of the PhD every once in a while and enlightening my day.

And, lastly, I would also like to apologize to my closest friends for having to reject another invitation for a pleasant get-together, especially during the last months. Although we might not see each other as often as we would like, I am very glad that you are all there, on call, when I need you!

Summary

The air transport sector is a dynamic market. During the last decades, the passenger market proved to be a growing market. During the interbellum, commercial (passenger) aviation required some governmental support in order to survive and – ironically – due to deregulation and liberalization passenger air transport rose even more. Technological progress and globalization, on the other hand, led to the rise of air cargo, evolving from by-product to a mature product.

This had an impact on the air transport actors. For airlines, the growing markets creates opportunities in the aim for profit maximization: using free capacity to take cargo on board, leads to a spread of the costs over a larger number of outputs, thus reducing the cost per unit flown. Literature review indeed reveals that airlines experience economies of scope, meaning that for them it is interesting (cost wise) to combine the transportation of passengers and cargo. Moreover, studies show that although airlines operate under constant returns to scale, they do experience returns to density. Thus, if they want to increase the scale of their operations, it is better to increase the traffic density on their existing network than to expand their network.

The question remains whether this also applies to airports: it is interesting cost wise to combine passenger and cargo activities at an airport? Reality reveals that indeed, a lot of airports worldwide handle both passengers and cargo. However, some of them represent high numbers of passengers and have (almost) no cargo – or vice versa. Literature review can possibly shed some light on whether this is due to cost related factors, or because of the influence of non-cost related variables. However, contrary to the literature review concerning cost economies at airline level, the sources are not unanimous with respect to cost economies on airport level. Most sources state that airports operate under increasing returns to scale, but only up until a certain threshold. Where that threshold lies, is unclear. And only one source studying economies of scope at airport level can be found.

This dissertation provides an answer to this research gap and answers the question whether airports experience output-related cost economies.

The econometric analysis is preceded by an extensive analysis of the air transport sector, the main actors and the air transport cost structure in order to get a complete view of the airport activities and resources. This also allows the recognition of non-cost related influential variables.

The analysis of the air transport sector in the first chapter shows that the passenger market as well as the cargo market are characterized by a growth on long term. However, some evolutions have altered the air transport scene. The percentage of international traffic has risen, passenger air transport is performed more and more in scheduled services and, concerning cargo transport, in the long run, the combi market is losing ground to the all cargo market. Moreover, a shift from west to east (and on some extent to south) is noticeable as the emerging markets, such as Asia-Pacific and Middle East, are gaining market share.

Within this ever changing environment, the airport is only one player, surrounded by different stakeholders. Moreover, the airport is part of a two-sided market, where it is the platform on which airlines meet with their customers, being passengers and/or cargo. The airport can use the power of pricing to influence the two sides of the market, but obviously, the other stakeholders of this two-sided market also influence the airport.

Concerning passengers and cargo, the characteristics of the customers handled determine the price the airport is allowed to charge and the resources the airport needs – and thus, indirectly the cost structure. The airlines on the other hand, influence the airport's strategy concerning passenger and/or cargo activities directly. Depending on the type of airline by which the airport is served and its operational characteristics, the airport is possibly "forced" to handle both passengers and cargo.

The second chapter of this dissertation analyses the airport characteristics more in depth. The dissertation highlights that there are many types of airports, all with their own characteristics. The airport capacity of all of the different airports is influenced by either the airside infrastructure, the lay-out of the airport building and airport site, the airspace or the connection with the hinterland. However, depending on the type of airport, different activities are performed. All types of airport offer the activity of aviation, but some of them also offer consumer products and services (e.g. retail) or deal with real estate management. In this chapter, also the evolution concerning airport ownership is discussed: especially in Europe, more and more airports are evolving from public property to privately owned and operated companies. This entails that airports are focusing also more on the commercial side of operations, and not only on aviation.

This all impacts the resources the airports offer. Aeronautical infrastructure (runways, taxiways, apron, etc.) is indispensable, but also other landside infrastructure (buildings, check-in desks, gates, etc.) is a basic need. Next to these tangible assets, airports also rely on human resources and other resources such as electricity, water, gas or materials and equipment. These resources represent the costs the airport (potentially) bears: capital costs, labor costs and other costs (or “soft costs”).

Analysis of the cost structure in chapter 3 shows that the different cost are related to each other: providing the infrastructure entails capital costs, but the operation and maintenance of those resources entails labor and soft costs. In a setting where different stakeholders come together (such as an airport), different stakeholders can be responsible for different tasks, bearing different costs. The dissertation reveals that the airport is mainly responsible for the provision and maintenance of the resources, thus bearing the capital costs and labor and soft costs related to the maintenance. However, the operation of the resources is often done by third parties, who then bear the bulk of the labor costs. The large portion of costs borne by the airport entails a potential source of economies of scale. However, whether economies of scope are present depends on the fact whether the costs borne are joint costs for passenger and cargo activities.

Next to the analysis of the cost structure, this chapter also focuses on the airport revenues, more specifically on the regulation of airport pricing. It is shown that airports are not necessarily natural monopolies. Moreover, given the environment they act in, they have no incentive to abuse the potential power of pricing. Therefore, regulation should be seen rather as a monitoring tool than as control mechanism.

The empirical analysis in this dissertation is set on providing an answer to the question whether airport experience output-related cost economies (i.e. economies of scale or economies of scope). For this, the dissertation relies on the econometric estimation of a long-run multi-output translog cost function. However, given the limitations of the translog cost model for the calculation of product-specific economies of scale and economies of scope, the dissertation also makes use of a quadratic model as second best method.

Based on cross section data for 2012 of 157 airports worldwide (Europe, North America and Asia-Pacific), retrieved from the ATRS Database, this dissertation shows that for airports, most costs (43%) are incurred through soft costs such as energy, materials, etc. Labor represents the smallest cost which can be explained by the fact that a lot of the operational activities are indeed outsourced to third party providers. Capital accounts for 32% of the total costs.

Concerning output-related cost economies, the empirical analysis shows that airports indeed experience economies of scale. Based on the translog cost model, the level of economies of scale can be calculated for each of the airports in the sample, indicating that all of them operate under increasing economies of scale. This reinforces literature that the threshold for the economies of scale lies beyond the scope of the world's biggest airports. Based on the method of declining marginal costs, the translog model also shows that all airports in the sample experience passenger-specific and cargo-specific economies of scale, meaning that for airports it is interesting to increase the scale of both passenger and cargo activities. The quadratic model allows the calculation of the product-specific economies of scale for all airports in the sample, showing that mostly smaller airports are more inclined to increase the scale of their passenger and cargo activities.

Concerning economies of scope, the translog model shows, based on the cost complementarities, that there are no economies of scope. Calculations of the economies of scope, based on the quadratic model, show that cost wise, combining passenger and cargo activities is not interesting. Based on cost data, larger airports are less likely to combine passenger and cargo handling. However, the calculations also revealed that the difference in offering the activities separately or jointly is very small.

Based on these results, some sector recommendations can be made. Airport managers should take into account that combining passengers and cargo is crucial for airlines. This is something the airport – as a platform in the two-sided market – has to respond to. So, also for airports, it is necessary to combine passenger and cargo handling, although it is not interesting cost wise. Given the large costs the airport has to bear, it is interesting to increase the scale of their activities and making use of the free capacity. Moreover, since airports experience product-specific economies of scale on both passengers and cargo, it is interesting to increase the scale of both type of activities. By doing so, airports can enlarge their market share, be more competitive and thus respond to the changing environment, seizing the opportunities of the growing and emerging markets.

Other institutions, such as governments, should be aware of the evolution towards more privatization and commercialization. Due to this, the risk of potential (pricing) power abuse is lowered, meaning that regulation can be seen as a monitoring tool rather than a controlling mechanism.

Samenvatting

De luchtvaartsector is een dynamische sector. De laatste decennia bewees de passagiersmarkt dat het een groeiende markt is. Gedurende het interbellum, was er overheidssteun nodig om de commerciële luchtvaart (van passagiers) te doen overleven. En, ironisch genoeg, groeide de passagiersluchtvaart nog verder door deregulering en liberalisering. Technologische vooruitgang en globalisering maakten dan weer dat ook luchtvracht groei kende, met een evolutie van bijproduct tot een op zich staand product als gevolg.

Dit heeft uiteraard een impact op de luchtvaartactoren. Voor luchtvaartmaatschappijen creëren de groeiende markten opportuniteiten in hun streven naar winst: vrije capaciteit kan aangewend worden om cargo te vervoeren, wat leidt tot het spreiden van de kosten en dus tot een daling van de kost per gevlogen eenheid. Literatuuronderzoek toont inderdaad aan dat luchtvaartmaatschappijen scopevoordelen kennen, waardoor het voor hen (kostengewijs) interessant is om het vervoer van passagiers en cargo te combineren. Bovendien blijkt uit studies dat, hoewel luchtvaartmaatschappijen opereren onder constante schaalvoordelen, ze wel densiteitsvoordelen hebben. Als ze dus de schaal van hun operaties willen vergroten, kunnen ze beter de densiteit op hun bestaande netwerk verhogen in plaats van hun netwerk te vergroten.

De vraag blijft of dit ook geldt voor luchthavens: is het kostengewijs interessant om passagiers- en cargo-activiteiten te combineren op een luchthaven? In de praktijk blijken inderdaad heel wat luchthavens wereldwijd zowel passagiers als cargo af te handelen. Nochtans hebben sommige luchthavens hoge passagierscijfers en (bijna) geen cargo, of omgekeerd. Mogelijk kan literatuuronderzoek verhelderen of dit kosten-gerelateerd is of dat er andere factoren spelen. Echter, in tegenstelling tot het literatuuronderzoek omtrent luchtvaartmaatschappijen zijn de verschillende bronnen het nu niet unaniem eens over het bestaan van kostenvoordelen. De meeste bronnen halen aan dat luchthavens opereren onder schaalvoordelen, maar slechts tot aan een bepaalde niveau. Waar deze grens ligt, is onduidelijk. Bovendien is er slechts één bron die het bestaan van scopevoordelen op luchthavenniveau behandeld.

Dit proefschrift gaat hierop in door een antwoord te formuleren op de vraag of luchthavens output gerelateerde kostenvoordelen ondervinden.

De econometrische analyse die hiervoor wordt uitgevoerd, wordt voorafgegaan door een uitgebreide analyse van de luchtvaartsector, de belangrijkste actoren en de kostenstructuur om een compleet beeld te vormen van de luchthavenactiviteiten en benodigde middelen. Dit laat ook toe om zicht te krijgen op potentiële niet-kosten-gerelateerde beïnvloedende variabelen.

De analyse van de luchtvaartsector in het eerste hoofdstuk toont aan dat zowel de passagiersmarkt als de cargomarkt gekenmerkt worden door groei op lange termijn. Toch zijn er belangrijke evoluties waar te nemen. Het percentage internationale trafiek is gegroeid, passagiers worden meer en meer vervoerd in lijndienst en, met betrekking tot cargo, is de "combi"-markt op lange termijn terrein aan het verliezen in het voordeel van de "all cargo"-markt. Bovendien is een verschuiving van oost naar west (en tot op zekere hoogte naar zuid) merkbaar nu het marktaandeel van de groeimarkten, zoals Azië-Pacific en het Midden Oosten, vergroot.

Binnen deze veranderende omgeving is de luchthaven slechts één speler, dewelke wordt omringd door vele andere actoren. Bovendien is de luchthaven deel van een tweeledige markt, waar het een platform is waarop luchtvaartmaatschappijen in contact komen met hun klanten, zijnde passagiers en/of cargo. De luchthaven kan dan zijn prijszetting gebruiken om beide zijden te beïnvloeden, maar uiteraard is ook de invloed van de andere actoren van deze tweeledige markt op de luchthaven voelbaar.

Wat betreft passagiers en cargo, zijn het vooral de karakteristieken van deze klanten die bepalen welke prijs de luchthaven kan vragen en over welke middelen de luchthaven moet beschikken – wat dus indirect de kostenstructuur beïnvloedt. De luchtvaartmaatschappijen hebben een directe invloed op de strategie die de luchthaven hanteert met betrekking tot passagiers en cargo. Of de luchthaven gedwongen wordt om zowel passagiers als cargo te behandelen, is afhankelijk het type luchtvaartmaatschappij(en) dat de luchthaven aandoet en haar operationele karakteristieken.

In het tweede hoofdstuk van dit proefschrift worden de luchthavenkarakteristieken meer diepgaand geanalyseerd. Het proefschrift geeft aan dat er verschillende typen luchthavens zijn, allemaal met hun eigen karakteristieken. De capaciteit van al deze luchthavens wordt bepaald door de infrastructuur aan luchtzijde, de indeling van de luchthavengebouwen en luchthavensite, het luchtruim of de verbinding met het hinterland. Echter, afhankelijk van het type luchthaven, vinden er andere activiteiten plaats. Alle luchthavens faciliteren het aanbieden van luchttransportdiensten, maar sommigen vullen dit aan met een aanbod aan consumentenproducten en –diensten (zoals retail) of doen aan real estate management. In dit hoofdstuk wordt ook ingegaan op de evoluties wat betreft luchthaveneigendom: vooral in Europa is een trend merkbaar waarbij luchthavens die publieke eigendom zijn meer en meer in privéhanden terechtkomen en ook door private partners worden uitgebaat. Dit houdt in dat luchthavens zich ook meer en meer gaan focussen op de commerciële aspecten en niet langer enkel op de luchtvaartactiviteiten.

Uiteraard heeft dit invloed op de middelen die luchthavens aanbieden. Zowel luchtvaartinfrastructuur (landingsbanen, tarmac, etc.) als infrastructuur aan landzijde (gebouwen, check-in balies, gates, etc.) zijn onmisbaar. Daarnaast moet een luchthaven ook beroep doen op personeel en andere middelen zoals elektriciteit, water, gas of materiaal. Deze middelen vertegenwoordigen de kosten die een luchthaven (mogelijk) moet dragen: kapitaalkosten, personeelskosten en andere kosten.

Een analyse van de kostenstructuur in hoofdstuk 3 toont aan dat de verschillende typen kosten aan elkaar gerelateerd zijn: voorzien van infrastructuur brengt kapitaalkosten met zich mee, maar de uitbating en het onderhoud van deze middelen vertegenwoordigt dan weer personeelskosten en andere kosten. In een setting waar verschillende actoren samenkomen (zoals op een luchthaven), kunnen ook verschillende actoren verantwoordelijk zijn voor verschillende taken en dus de bijbehorende kosten dragen. Het proefschrift toont aan dat de luchthaven verantwoordelijk is voor het aanbieden en onderhouden van de infrastructuur en dus de kapitaalkost, personeelskost en andere kosten die ermee gepaard gaan zal moeten dragen. Echter, de exploitatie is vaak in handen van een derde partij, die daarmee het gros van de personeelskosten draagt. Het feit dat een groot deel van de kosten toch door de luchthaven gedragen worden, is mogelijk een bron van schaalvoordelen. Of de luchthaven ook scopevoordelen ondervindt, hangt af van het feit of er genoeg gedeelde kosten zijn tussen passagiers- en cargoactiviteiten.

Naast een analyse van de kostenstructuur, wordt er in dit hoofdstuk ook gefocust op de luchthaveninkomsten, en dan meer specifiek op de prijszettingsregulering. Er wordt aangetoond dat luchthavens niet noodzakelijk een natuurlijk monopolie zijn. Bovendien hebben zij, in de omgeving waarin ze opereren, geen prikkel om hun potentiële prijszettingsmacht te misbruiken. Daarom moet regulering eerder gezien worden als instrument tot monitoring in plaats van als controlemechanisme.

De empirische analyse van dit proefschrift heeft als doel om een antwoord te bieden op de vraag of luchthavens output gerelateerde kostenvoordelen (schaal- en scopevoordelen) ondervinden. Hiervoor wordt beroep gedaan op een econometrische schatting van een lange termijn multi-output translog kostenfunctie. Dit model wordt aangevuld met een kwadratisch model, gezien de beperkingen van het translog kostenmodel met betrekking tot de berekening van product-specifieke schaalvoordelen en scopevoordelen.

Op basis van cross section data voor 2012 voor 157 luchthavens wereldwijd (Europa, Noord-Amerika en Azië-Pacific), uit de ATRS Database, toont dit proefschrift aan dat op een luchthaven de meeste kosten (43%) veroorzaakt worden door andere kosten als energie, materiaal etc. Personeelskosten vertegenwoordigen het kleinste kostenaandeel, wat verklaard kan worden doordat vele activiteiten uitbesteed worden. Kapitaalkosten, tot slot, vertegenwoordigen 32% van de totale kosten.

Wat betreft output gerelateerde kostenvoordelen, kan, op basis van het translogmodel het niveau van schaalvoordelen voor de verschillende luchthavens berekend worden. Hieruit blijkt dat ze allemaal schaalvoordelen ervaren. Dit versterkt wat gevonden werd in de bestaande literatuur: de grens voor het bestaan van schaalvoordelen ligt hoger dan wat de grootste luchthavens wereldwijd verwerken. Op basis van de methode van dalende marginale kosten toont het translog model ook aan dat alle luchthavens in de steekproef passagiers- en cargo-specifieke schaalvoordelen ondervinden en het dus interessant is om zowel de schaal van hun passagiers- als cargoactiviteiten te vergroten. Aan de hand van het kwadratische model kunnen deze product-specifieke schaalvoordelen dan uitgerekend worden en blijkt dat vooral grotere luchthavens geneigd zijn hun schaal van passagiers- en cargo-activiteiten te vergroten.

Op basis van cost complementarities toont het translog model aan dat er geen scopevoordelen zijn. Ook op basis van berekeningen met het kwadratisch model blijkt dat het combineren van passagiers- en cargoactiviteiten geen kostenvoordelen met zich meebrengt. Op basis van kosten-gerelateerde factoren, zouden grotere luchthavens de minste prikkels ondervinden om beide activiteiten samen aan te bieden. Echter, de berekeningen laten wel zien dat het verschil tussen het aanbieden van de activiteiten apart of samen zeer gering is.

Aan de hand van deze resultaten kunnen er aanbevelingen voor de sector geformuleerd worden. Luchthavenmanagers moeten in het achterhoofd houden dat het voor luchtvaartmaatschappijen cruciaal is om passagiers en cargo te combineren. Daarop moet de luchthaven, als platform in de tweeledige markt, inspelen. Dus ook voor luchthavens is het aanbieden van een combinatie van passagiers- en cargo activiteiten noodzakelijk, hoewel het kostengewijs niet interessant is. Gezien de vele kosten die een luchthaven moet dragen is het wel interessant om de schaal van hun activiteiten zo groot mogelijk te zetten en zo alle vrije capaciteit te benutten. Bovendien, aangezien luchthavens zowel passagiers- als cargo-specifieke schaalvoordelen ondervinden, is het interessant om de schaal van beide te vergroten. Zo kunnen luchthavens ook hun marktaandeel vergroten, competitiever handelen en ook hoofd bieden aan de veranderende omgeving waarmee ze geconfronteerd worden en de opportuniteiten van de groeiende en groeimarkten benutten.

Andere instituten, zoals overheden, moeten rekening houden met de evolutie naar meer privatisering en commercialisering. Hierdoor wordt het risico op potentieel misbruik van prijszettingsmacht verkleind waardoor regulering gezien mag worden als instrument tot monitoring, eerder dan als controlemechanisme.

Introduction and research framework

The air transport sector is a dynamic sector. Also during the last decades, it experienced some defining developments. The passenger market is a growing market: during the interbellum, commercial (passenger) aviation required some governmental support in order to survive and – ironically – due to deregulation and liberalization passenger air transport rose even more. On the other hand, technological progress and globalization also led to the rise of air cargo, from by-product to a mature product.

This had an impact on the air transport actors. For airlines the growing markets obviously create opportunities in the aim for profit maximization (Van de Voorde & de Wit, 2013): using free capacity to take cargo on board, leads to a spread of the costs over a larger number of outputs and thus a reduced cost per unit flown. The question remains whether this also applies to airports. Is it interesting cost wise to combine passenger and cargo activities at an airport?

This dissertation answers this question by analyzing the existence of cost economies related to output (economies of scale and economies of scope) at an airport. Furthermore, explanatory variables for the existence or absence of cost economies are highlighted.

In order to develop hypotheses, it is interesting to analyze what reality and the existing literature reveals.

Passengers and cargo at airports worldwide

In practice, indeed it becomes clear that a lot of airports opt for a combination of cargo and passenger handling.

Table 1 contains the 10 biggest airports of Europe in terms of passengers and shows that big airports handling passengers also handle cargo. However, when looking at Table 2, where European airports are sorted by tons of cargo, the big passenger airports are not necessarily also big cargo airports. The airports London Heathrow, Paris Charles de Gaulle, Frankfurt am Main, Amsterdam Schiphol and Istanbul Atatürk appear in both tables, but Cologne Bonn Airport, Luxembourg Findel Airport, Brussels Airport, Zürich Airport and Milan Malpensa Airport handle more cargo than the remaining 5 big passenger airports.

Table 1[1]: Top 10 European airports in terms of passengers

2012	Passengers		Cargo (in tons) Freight & mail	
London Heathrow (LHR)	**1**	69 984 868	(4)	1 464 550
Paris Charles de Gaulle (CDG)	**2**	61 611 934	(1)	2 150 951
Frankfurt am Main (FRA)	**3**	52 520 001	(2)	2 066 431
Amsterdam Schiphol (AMS)	**4**	51 035 590	(3)	1 511 851
Madrid Barajas (MAD)	**5**	45 195 014	(11)	359 362
Istanbul Atatürk (IST)	**6**	44 998 508	(5)	1 231 504
München Franz Joseph Strauss (MUC)	**7**	38 217 181	(13)	290 301
Rome Leonardo Da Vinci (Fiumicino) (FCO)	**8**	37 063 000	(19)	135 847
Barcelona El Prat (BCN)	**9**	35 145 176	(28)	96 520
London Gatwick (LGW)	**10**	34 241 200	(26)	99 736

Source: own composition based on ATRS (2015).

Table 2:Top 10 European airports in terms of cargo

2012	Cargo (in tons) Freight & mail		Passengers	
Paris Charles de Gaulle (CDG)	**1**	2 150 951	(2)	61 611 934
Frankfurt am Main (FRA)	**2**	2 066 431	(3)	52 520 001
Amsterdam Schiphol (AMS)	**3**	1 511 851	(4)	51 035 590
London Heathrow (LHR)	**4**	1 464 550	(1)	69 984 868
Istanbul Atatürk (IST)	**5**	1 231 504	(6)	44 998 508
Cologne Bonn (CGN)	**6**	751 266	(40)	9 281 703
Luxembourg Findel (LUX)	**7**	614 906	(66)	1 919 694
Brussels (BRU)	**8**	459 265	(21)	18 971 332
Zürich (ZRH)	**9**	451 687	(12)	24 802 400
Milan Malpensa (MXP)	**10**	414 317	(24)	17 230 649

Source: own composition based on ATRS (2015).

Analogously, these tables and comparison can be drawn up for North America and Asia-Pacific (see Table 3 and Table 4 for North America and Table 5 and Table 6 for Asia-Pacific).

In North America, four of the big passenger airports also appear in the top 10 with respect to cargo. However, the ranking is completely changed: the biggest passenger airport (Atlanta Hartsfield Jackson Airport) is only the 10th biggest cargo airport. And the four biggest cargo airports (Memphis Airport, Ted Stevens Anchorage Airport, Louisville Standiford Field Airport and Miami Airport) did not even appear in the top 10 with respect to passengers.

[1] Tables 1 to 6 give the top 10 airports in terms two types of airport output, being passengers and cargo, for Europe, North America and Asia-Pacific. The place in ranking is indicated in bold. The indicated ranking between brackets specifies the ranking in terms of the other type of output.

Table 3: Top 10 North American airports in terms of passengers

2012	Passengers		Cargo (in tons) Freight & mail	
Atlanta Hartsfield Jackson (ATL)	**1**	90 476 742	(10)	658 234
Chicago O'Hare (ORD)	**2**	64 222 204	(6)	1 443 281
Los Angeles (LAX)	**3**	62 273 218	(5)	1 658 705
Dallas Fort Worth (DFW)	**4**	55 629 321	(11)	605 219
Denver (DEN)	**5**	51 570 726	(24)	221 528
New York John F. Kennedy (JFK)	**6**	49 009 778	(7)	1 196 426
San Francisco (SFO)	**7**	41 664 866	(18)	385 113
Las Vegas McCarran (LAS)	**8**	39 752 130	(37)	96 173
Phoenix Sky Harbor (PHX)	**9**	39 359 155	(21)	271 109
Charlotte Douglas (CLT)	**10**	38 998 303	(31)	127 230

Source: own composition based on ATRS (2015).

Table 4: Top 10 North American airports in terms of cargo

2012	Cargo (in tons) Freight & mail		Passengers	
Memphis (MEM)	**1**	3 978 315	(48)	7 812 249
Ted Stevens Anchorage (ANC)	**2**	2 486 056	(61)	5 044 689
Louisville Standiford Field (SDF)	**3**	2 172 242	(71)	3 232 610
Miami (MIA)	**4**	1 906 504	(12)	37 071 794
Los Angeles (LAX)	**5**	1 658 705	(3)	62 273 218
Chicago O'Hare (ORD)	**6**	1 443 281	(2)	64 222 204
New York John F. Kennedy (JFK)	**7**	1 196 426	(6)	49 009 778
Indianapolis (IND)	**8**	1 016 974	(53)	7 093 753
Newark Liberty (EWR)	**9**	672 475	(15)	33 952 143
Atlanta Hartsfield Jackson (ATL)	**10**	658 234	(1)	90 476 742

Source: own composition based on ATRS (2015).

For Asia-Pacific, seven airports appear in both the ranking according to passengers and the ranking according to cargo. Tokyo Haneda Airport, Soekarno Hatta Airport and Kuala Lumpur Airport are big in number of passengers, but small(er) in terms of cargo. Incheon Airport, Narita Airport and Taiwan Taoyuan Airport on the other hand handle a lot of cargo while their number of passengers is small(er).

Table 5: Top 10 Asia-Pacific airports in terms of passengers

2012	Passengers		Cargo (in tons) Freight & mail	
Beijing Capital (PEK)	**1**	81 929 359	(7)	1 799 864
Tokyo Haneda (HND)	**2**	66 795 178	(12)	846 764
Soekarno Hatta (CGK)	**3**	57 772 864	(16)	629 706
Dubai (DXB)	**4**	57 700 000	(4)	2 279 624
Hong Kong (HKG)	**5**	57 200 000	(1)	4 040 000
Bangkok Suvarnabhumi (BKK)	**6**	52 368 712	(9)	1 360 879
Singapore Changi (SIN)	**7**	51 940 972	(6)	1 806 225
Guangzhou Baiyun (CAN)	**8**	48 309 410	(10)	1 248 764
Shanghai Pudong (PVG)	**9**	44 880 164	(3)	2 938 157
Kuala Lumpur (KUL)	**10**	39 887 866	(14)	673 170

Source: own composition based on ATRS (2015).

Table 6: Top 10 Asia-Pacific airports in terms of cargo

2012	**Cargo (in tons)** Freight & mail		Passengers	
Hong Kong (HKG)	**1**	4 040 000	(5)	57 200 000
Incheon (ICN)	**2**	3 059 333	(11)	38 970 684
Shanghai Pudong (PVG)	**3**	2 938 157	(9)	44 880 164
Dubai (DXB)	**4**	2 279 624	(4)	57 700 000
Narita (NRT)	**5**	1 952 207	(15)	32 793 596
Singapore Changi (SIN)	**6**	1 806 225	(7)	51 940 972
Beijing Capital (PEK)	**7**	1 799 864	(1)	81 929 359
Taiwan Taoyuan (TPE)	**8**	1 577 730	(20)	27 836 550
Bangkok Suvarnabhumi (BKK)	**9**	1 360 879	(6)	52 368 712
Guangzhou Baiyun (CAN)	**10**	1 248 764	(8)	48 309 410

Source: own composition based on ATRS (2015).

It becomes clear that there are a lot of airports which handle both passengers and cargo. However, some of them are high in numbers of passengers and have (almost) no cargo – or vice versa.

For example, Barcelona El Prat Airport is on the 9th place regarding number of passengers, but only on the 28th place with respect to cargo. In Las Vegas McCarran Airport, the difference is even larger, being ranked on the 8th place in terms of passengers, but on the 37th place regarding cargo. Luxembourg Findel Airport on the other hand is a cargo airport: with respect to cargo, it is on the 7th place, but only on the 66th in terms of passengers. Memphis Airport, Ted Stevens Anchorage Airport, Louisville Standiford Field Airport and Indianapolis are also examples of cargo airports.

The question remains whether output related cost economies lie at the base of this. Also non-cost related factors can be of influence. The combination of passenger and cargo activities at an airport might also be market driven. For example, market power and pressure from airlines can lead airports to combine passengers and cargo, even though this is not interesting for airport cost wise. Existing literature can reveal whether combining passengers and cargo is opportune for airlines or airports.

Literature review

To find a possible explanation for or proof on why airlines and airports combine passenger and cargo activities, existing literature is reviewed. As stated before, for airlines the combination of passenger and cargo activities creates opportunities in the aim of profit maximization; using free capacity on board allows a reduction of cost per unit flown. The existence of output related cost economies is thus more evident and therefore, airlines are first under review. In a second section, this literature review lists papers which analyzed the existence of output related cost economies for airports to examine whether an explanation can be found on why most airports combine passenger and cargo handling, but not all activities are equally as big in all airports.

Output related cost economies for airlines

Literature shows that airlines can experience different kinds of cost economies. Zuidberg (2014) revealed that the (operating) cost of an airline can be influenced in many different ways. Fleet characteristics can influence the operating costs. For example, aircraft size or aircraft age affect the costs which airlines have to bear. Also market-related variables have an impact. Different studies (such as Baltagi, Griffin, & Rich, 1995) have shown that hubbing leads to significant cost savings. Also route dominance or alliance membership might have some effect. Furthermore, also output-related variables can lead to (a combination of) cost economies such as economies of scale, economies of scope or economies of density. If the output increases or the output mix changes, the costs might increase too, but maybe not at the same rate. Also Kirby (1986) did some research on different cost economies. He analyzed how load factor, aircraft size and stage length influence costs.

Regarding cost economies related to output, a lot of studies have been conducted. Those studies differ in the method or data used and in the scope of research. With respect to the method used, there are differences in functional form or type of function. A lot of early studies estimated cost functions using the Cobb Douglas functional form, but since 1984 mostly the transcendental logarithmic (or "translog") functional form is used (e.g. Caves, Christensen, & Tretheway, 1984; Formby, Thistle, & Keeler, 1990; Kumbhakar, 1990; Sickles, Good, & Johnsons, 1986). Furthermore, studies vary in whether total cost functions or variable cost functions or whether single-output functions or multiple-output functions are estimated. Regarding data, almost every study uses different inputs, outputs or other explanatory variables. Also the use of information dating from before or after the deregulation might influence the results. The scope of research moreover varies from study to study. Some studies analyze airlines worldwide or only in one continent or country. Others take into account large airlines, rather small airlines or all different types.

All these differences might lead to different results. Nevertheless, the results of most studies analyzing cost economies related to output for airlines seem to be rather similar.

Regarding economies of scale, the majority of papers (Antoniou, 1991; Braeutigam, 1999; D. W. Caves et al., 1984; R. E. Caves, 1962; Douglas & Miller, 1974; D. Gillen & Morrison, 2005; J. P. Keeler & Formby, 1994; White, 1978) find that airlines operate under constant returns to scale. For example Keeler (1978) showed that this is especially true for large(r) airlines. Most papers analyzing the existence of economies of scale also take into account extra variables (such as numbers of points served, average stage length) explaining the economies of density. Also here, there is consensus (Bailey & Friedlaender, 1982; Baltagi et al., 1995; Braeutigam, 1999; Brueckner & Spiller, 1994; D. W. Caves et al., 1984; D. Gillen & Morrison, 2005; J. P. Keeler & Formby, 1994): airlines experience increasing economies of density. Therefore, if airlines want to decrease their costs by increasing their scale, it is better for them to increase the traffic density of their network, rather than expanding their network (Basso & Jara-Díaz, 2005). Also regarding the presence of economies of scope, most sources (D. W. Gillen, Oum, & Tretheway, 1990; Gimeno & Woo, 1999; J. P. Keeler & Formby, 1994; Leggette & Killingsworth, 1983; Roy & Cofsky, 1985; Zhang, Van Hui, & Leung, 2004) are unanimous: the economies of scope are strong for airlines.

Output related cost economies for airports

Similar analyses were carried out for airports. And also in this area of research, differences in method, data or scope can lead to different results. The translog functional form is often used and difference between single or multiple-output specifications are highlighted in some papers.

The amount of papers that studies the cost structure of airports or cost economies at airport level, is scarcer than that of airlines. A possible explanation for this is that, for airports, it is more difficult to find data. For example, a lot of airports are clustered within an airport group which then reports in a consolidated way. Nevertheless, some authors attempted to get a view on the output related cost economies for airports.

Walters (1978) pointed out that there is a difference in cost economies for runway operations or operations of terminals. Regarding runways, the lumpiness of investment for even a minimal use, causes economies of scale. While, at terminal operations, there are diseconomies of scale. The study of Starkie & Thompson (1985) argues that the high costs to link airside with terminal facilities cause diseconomies of scale. Especially large airports need additional infrastructure and thus do not enjoy economies of scale. Graham (2001) on the contrary does believe that economies of scale for airports exist, based on the ICAO Working Paper (2000)[2] that concluded that unit costs per Work Load Unit[3] (WLU) decrease as size increases. Airports with less than 300 000 WLU deals with 15 USD unit costs per WLU, while airports with WLU between 300 000 and 2.5 million WLU are confronted with only 9.4 USD unit costs per WLU. For larger airports (between 2.5 million and 25 million WLU) the unit costs per WLU decrease to 8 USD.

Studies that actually calculate the economies of scale at airport level also have different findings. Keeler (1970) is the pioneer in analyzing airport cost data. Based on pooled data from 13 US airports between 1965 and 1966, he found evidence for constant returns to scale.

[2] In 2003 ICAO reported similar findings: airports with less annual traffic than 300 traffic units (where 1 traffic unit corresponds to 1000 passengers or 100 tons of freight or mail), expenses per traffic unit averaged US$ 40 600. For airports with traffic between 300 and 2 500 traffic units, the average was about US$ 14 400 and for airports with traffic between 2 500 and 25 000 traffic units, the average was about US$ 10 600.

[3] A Work Load Unit (WLU) is measurement by which the output of an airport can be expressed: 1 WLU = 1 passenger or 100kg of cargo.

However, since he separated the capital and operating costs and used Cobb Douglas functions, which come with restrictions, his findings are criticized.

Doganis & Thompson (1973, 1974) calculated average cost functions based on total, capital, maintenance, labor, administrative and operations costs of 18 British airports for 1969 and used WLU as output. They found significant economies of scale at 1 million WLU which dissipated at 3 million WLU and where finally exhausted. Also this study has the same limitations as the one from Keeler (1970).

Tolofari et al. (1990) had similar findings: they found economies of scale which disappeared at some point. However, the threshold they found is at a much higher level, being 20.3 million WLU. They based their research on 7 BAA airports between 1979 and 1987 using a translog function with WLU as output and labor, equipment and residual factors as input. Capital stock, passengers per air movement, percentage of international passengers and terminal capacity utilization were the other explanatory variables. Their findings can however not be generalized, because their dataset only holds one airport with more than 20 million WLU, i.e. London Heathrow.

Main et al. (2003) used two datasets, one from the Centre for the study of Regulated Industries (CRI) holding 27 UK airports for 1988, and one from the Transport Research Laboratory (TRL) comprising 44 airports around the world between 1998 and 2000. Based on four Cobb Douglas functions (i.e. two outputs, being WLU and passengers, and taking into account depreciation or not) they found economies of scale until a threshold of 5 million WLU or 4 million passengers for the CRI data. The TRL data led to the same conclusions, but the cost curve was not as steep at lower output scales. This study had the same errors and modelling restrictions as those from Keeler (1970) and Doganis & Thompson (1973, 1974).

Jeong (2005) estimated a translog cost function with three outputs: WLU, passengers and an output index. Using an aggregate input index for 94 US airports in 2003, combined with a cost-of-living-index as a proxy for capital price, he found economies of scale that were exhausted at 2.5 million passengers or 3 million WLU. Martín & Voltes-Dorta (2008) found increasing returns to scale which are not exhausted. Using data from 41 airports across Europe, North America, Asia and Australia for the period of 1991-2005, they constructed a translog long run cost function with labor cost, capital cost and other operating cost (materials and OS work) as input variables. Regarding this, they stated that the flexible functional form is to be chosen over the Cobb Douglas specification. They estimated a single-output (WLU) translog model and a multi-output (ATM & WLU) translog model and were able to conclude that there were differences since the single output model overestimated economies of scale. This is also confirmed in their paper of 2011 (Martín, Román, & Voltes-Dorta, 2011) where they estimated a translog cost function for 36 Spanish airports between 1991 and 1997, using ATM, WLU and commercial revenues at output and labor, capital and materials as input.

In 2011, Martín & Voltes-Dorta (2011b) developed an airport specific methodology to estimate a multi-output long run cost function. They used a pooled database of 161 airports worldwide between 1991 and 2008. Using a hedonically adjusted output vector based on aircraft operations, domestic and international passengers, cargo and commercial revenues and a new method to calculate input prices of labor, capital and materials/OS, they estimated a long run translog cost model. This showed that economies of scale exist but will inevitably be exhausted at some unknown point. However, even the largest airports in their database (i.e. the largest airports in the world) still experience increasing returns to scale. In their more recent paper, Martín & Voltes-Dorta (2011a) used the same analysis and research results to prove that establishing multi-airport systems (which hold airports with the same catchment area) is less efficient than working with individual airports, unless those are heavily congested and cannot be expanded. Using a variable translog cost function, Bottasso & Conti (2010) found economies of scale which tend to gradually decrease with the scale of operations. There are economies of scale present at least up to a scale of 5.6 million passengers, 83.000 ATM or 6.5 million WLU. As of 14 million passengers, 148.000 ATM or 15 million WLU, airports experience diseconomies of scale.

Not all papers have the purpose to analyze the cost structure or existence of cost economies. For example, papers evaluating efficiency or productivity levels often also calculate the cost economies. Here, other estimation methods are used. For example, Salazar de la Cruz (1999) studied airport efficiency by performing a Data Envelopment Analysis (DEA) on panel data from 16 Spanish airports between 1993 and 1995. Taking into account total revenue, returns from infrastructure service, operative returns final returns, number of passengers and total economic cost, he found constant returns to scale for airports with 3.5 to 12.5 million passengers. Larger airports experience decreasing returns to scale.

Using three inputs (labor, capital and material expenses) and three outputs (air movements, passenger and cargo volumes) Martín & Roman (2001) explored the efficiency of Spanish airports in 1997. Constant and variable returns to scale DEA models show that 20 airports experience increasing returns to scale, while 9 airports operate under decreasing returns to scale.

Pels et al. (2003) use stochastic frontier analysis and DEA to determine the production frontiers for air transport movements (ATM) and air passenger movements (APM). In the first model, they use airport surface area, number of aircraft parking positions at the terminal and number of remote aircraft parking positions as input variables. Furthermore, they consider ATM as an intermediate good that is produced and consumed in the production of APM and thus as an input for the APM model, next to the number of check-in desks and the number of baggage claim units. Using pooled cross-section – time series data from 33 European airports between 1995 and 1997, they found that the average airport is operating under constant returns to scale when handling ATM and increasing returns to scale when moving passengers. However, the scale elasticity is decreasing in the number of passengers and thus smaller airports experience strong returns to scale, while larger airports have weak returns to scale. Using the stochastic frontier model, the returns to scale seem to be much stronger compared to the DEA model.

Also Oum et al. (2003) used a different method. Efficiency of 50 major airports worldwide is analyzed using gross total factor productivity (TFP) and results show that larger airports achieved higher gross TFP because of economies of scale.

The literature regarding economies of scale at airports is quite scarce, but literature with respect to economies of scope at airport level is almost non-existent. Only Chow & Fung (2009) did research in that area, finding that economies of scope exist. They analyzed data from 46 airports in 2000 to evaluate the contribution of air passenger and cargo transport to airport efficiency in China. For this, they consider air passenger movements (APM) and air cargo movements (ACM) as primary outputs of an airport and they follow Pels et al. (2003) in treating air transport movements (ATM) as intermediate output in the production of air passenger and air cargo movements. In a first stage, the production function of ATM is estimated using a translog function and the predicted ATM value is used in subsequent estimations of the production of APM and ACM. Inputs used in the first stage are airport surface area, the length of the runways and the number of aircraft parking positions. In the second stage, the inputs are then the predicted value of ATM, the passenger terminal area and car-park area for APM and the surface of the cargo handling facilities for ACM estimation. They also incorporate dummy variables for regional effects and the fact whether the airport is an operation base for major airlines. An extra characteristic taken into account in the estimation of ACM is the proportion of international air cargo.

In addition to this single-output model, they also use a multi-output stochastic input distance function to calculate the technical efficiency indices for each of the airports in the sample. A partial translog input distance function is specified by adding second-order terms of the two output variables (APM and ACM) to the Cobb-Douglas model. Input factors are ATM, terminal area, cargo facilities area, number of airport parking positions, surface area of the airport and the length of the runways. Variables to explain technical inefficiency are a dummy for regional effects, whether the airport is an operation base for major airlines, whether it is an international or regional hub airport and the proportion of international air traffic. Furthermore, the model also allows to test for economies of scope between APM and ACM.

Based on the single-output stochastic production frontier model, they found technical inefficiency in APM and that the average Chinese airport exhibits constant returns to scale. Airports with a larger proportion of international air cargo services prove to be technically more efficient than others.

The multiple-output stochastic input distance function model showed the presence of constant returns to scale and that there are economies of scope among the Chinese airports in moving air passengers and air cargo. Furthermore, technical efficiency levels are higher than those based on APM and ACM alone thus the effect of scope economies cannot be neglected and international hub airports have much higher technical efficiency levels. Major airline-based airports also have higher technical efficiency as do airports listed on stock exchanges.

Reality reveals that indeed airports combine passenger and cargo handling activities. However, literature does not provide a clear answer to the reason(s) behind this: studies regarding output-related cost economies at airports have different outcomes. Most of them show the existence of economies of scale until a threshold, but the most recent studies show that this threshold lies beyond what the biggest airports in the world handle. Martín & Voltes-Dorta (2008) quote Jeong (2005) when explaining this phenomenon: these inconsistent findings are due to the lack of comparable data and the partial view on airport activities. Furthermore, regarding economies of scope, there is too little research carried out to draw some conclusions.

This dissertation provides an answer to this research gap. It will analyze the existence of output related cost economies at airport level by using econometric analysis. Extensive analysis of the air transport sector, the main actors and the airport cost structure allows to get a complete view of the airport activities and resources. Estimating a flexible unrestricted functional form can then shed some light on the existence of output related cost economies[4] at airport level. In this research, a translog cost function and a quadratic (cost) function are estimated in order to analyze the existence of economies of scale and/or scope. The research carried out in this dissertation overcomes the data comparability problems by using a worldwide database with recent data[5].

[4] Research (e.g. Panzar & Willig, 1981) has also shown that economies of scale and scope might influence each other, so it is important to study both type of cost economies.

[5] This however does not imply that there were no data issues. These issues are further addressed in section 6.1.

Research scope and limitations

The CIA World Factbook 2016-17 (2016) reports that in 2013 there were almost 42,000 airports worldwide. Incorporating all of those in this analysis is too ambitious. However, when estimating, the sample needs to be a good representation of reality. Therefore, a worldwide database (ATRS, 2015) is consulted, consisting of 201 observations for the year 2012. Based on the criteria of completeness of data and airports handling both passengers and cargo, a sample of 157 airports worldwide is taken into account. This sample holds 44 European airports, 77 North American airports and 36 airports of the Asia Pacific region.

The airport strategy can be explained largely by examining the financial structure of airports. In this dissertation, the focus is on airport costs, rather than airport revenues. Therefore, the cost structure of the 157 airports is analyzed to get a view on how airport costs determine which strategy airports follow in offering passenger and/or cargo activities. How revenues have an impact the airports' strategy concerning handling passengers or cargo is not studied in this dissertation.

The cost structure of the airport sector can be analyzed by time series data (1 airport, multiple years), cross-section data (multiple airports for 1 year) or panel data (multiple airports over multiple years). In this dissertation, cross-section data are used and cost data of 2012 are analyzed for multiple airports. During the year 2012 the airport sector was stable, which allows to assume that 2012 is a good representation of an average year for the airport sector.

In order to build this research in a correct way, first the market structure, including important stakeholders, needs to be analyzed. This will lead to the revelation of potential sources of or barriers to cost economies. The second part of the dissertation will then deal with the airport cost structure in order to estimate a cost function with which the existence of cost economies can be tested.

Research objective

The goal of this research is to answer the following research question:

Do airports experience output related cost economies (economies of scale and/or economies of scope) which explain why airports combine passenger and cargo activities?

However, next to this research question, the dissertation also takes into account that strategic decisions are not only based on costs, but that also other influencing factors need to be analyzed.

Therefore, in order to get a view on these matters, different issues need to be investigated. First, the research will analyze what the position and role of airports is within the airport sector. This gives insight into which (other) stakeholders might influence the airport and its strategy. Next to these external influences, the airport strategy is also influenced by internal factors. To get a view on this, the organizational structure of the airport needs to be described, leading to the cost structure of an airport and the question whether there are economies of scale and/or economies of scope.

These issues can be summarized into the following sub research questions:

- How are airports positioned in the air transport sector and what is their role?
- What other stakeholders affect the airport and its strategy concerning passenger and/or cargo handling?
- How is the airport's strategy concerning passenger and/or cargo handling influenced by the organizational structure of the airport?
- What does the airport's cost structure look like?
- Do airports experience economies of scale?
- Do airports experience economies of scope?

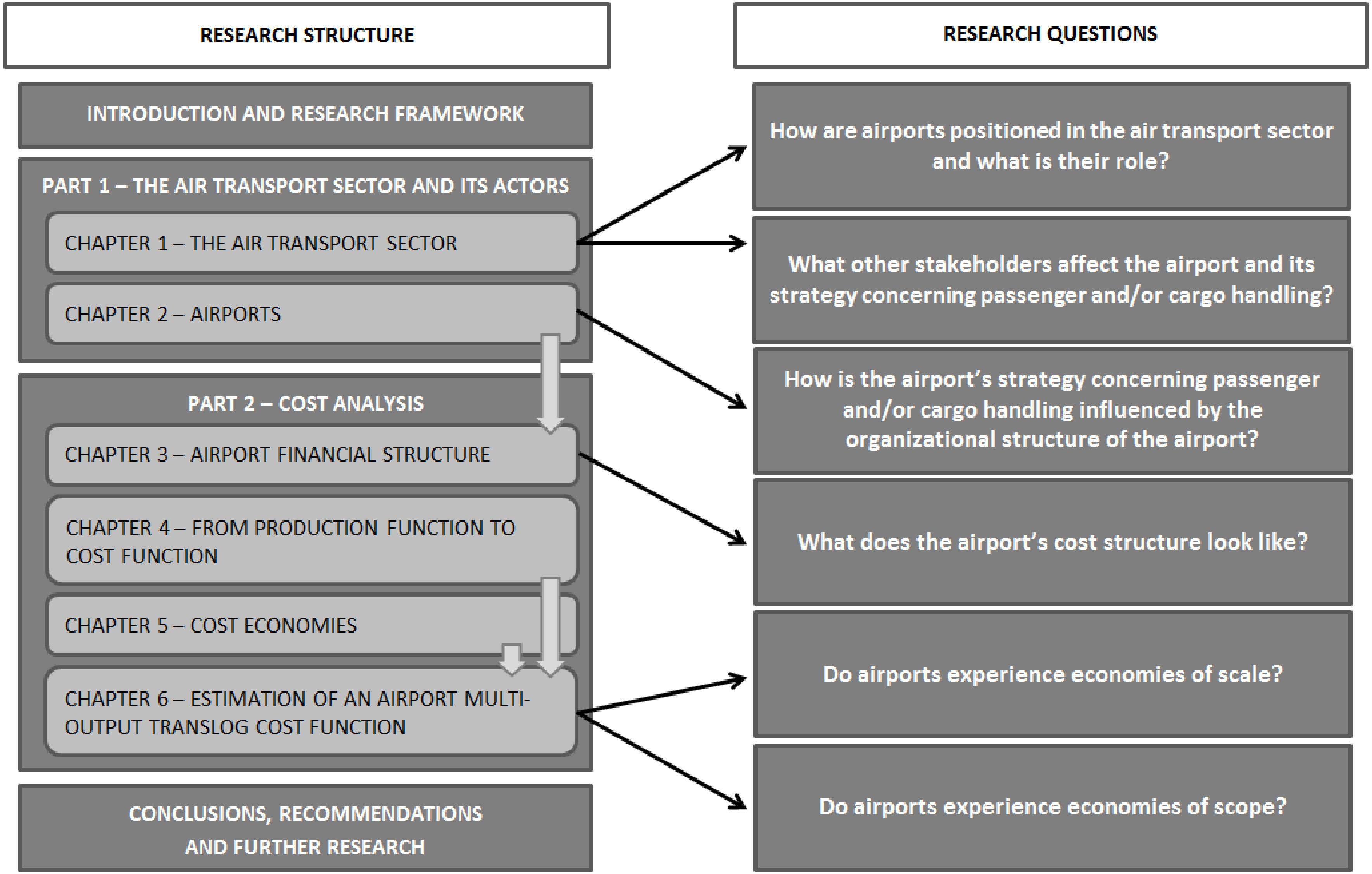
Research structure

As the main goal of this dissertation is to analyze whether airports experience output-related cost economies and also other influencing factors for the airport's strategic decisions regarding passenger and/or cargo activities are studied, the dissertation is structured according to the sub research questions explained above.

In the first part of this dissertation, the air transport sector and its key actors are described. Chapter 1 gives an overview of the macro-economic developments and trends, depicts the organizational structure of the air transport sector and analyses the two-sided market and its key stakeholders (passengers/cargo on the one hand and airlines on the other hand) more in depth. Chapter 2 then explains the organizational structure of airports and how this affects airport capacity, airport activities and the necessary resources, which are the cost drivers.

The second part of this research revolves around costs. In Chapter 3, the airport's financial structure is analyzed, looking into the different costs and how different types of revenue can cover these costs. Chapter 4 and Chapter 5 then explain the theory about cost functions and cost economies to build up to the empirical analysis in Chapter 6 in which the existence of output-related cost economies is tested.

The final chapter (Chapter 7) of this dissertation lists the conclusions in which all the research questions are answered. Also sector recommendations and some recommendations for further research are made.


RESEARCH STRUCTURE
RESEARCH QUESTIONS
INTRODUCTION AND RESEARCH FRAMEWORK
PART 1 – THE AIR TRANSPORT SECTOR AND ITS ACTORS
CHAPTER 1 – THE AIR TRANSPORT SECTOR
CHAPTER 2 – AIRPORTS
PART 2 – COST ANALYSIS
CHAPTER 3 – AIRPORT FINANCIAL STRUCTURE
CHAPTER 4 – FROM PRODUCTION FUNCTION TO COST FUNCTION
CHAPTER 5 – COST ECONOMIES
CHAPTER 6 – ESTIMATION OF AN AIRPORT MULTI-OUTPUT TRANSLOG COST FUNCTION
CONCLUSIONS, RECOMMENDATIONS AND FURTHER RESEARCH
How are airports positioned in the air transport sector and what is their role?
What other stakeholders affect the airport and its strategy concerning passenger and/or cargo handling?
How is the airport's strategy concerning passenger and/or cargo handling influenced by the organizational structure of the airport?
What does the airport's cost structure look like?
Do airports experience economies of scale?
Do airports experience economies of scope?

Part 1 – The air transport sector and its actors

The main goal of this dissertation is to analyze the existence of cost economies (economies of scale and/or scope) for airports which influence the strategic decision making concerning passenger and/or cargo handling. However, several factors can affect whether cost economies exist or not, can explain the source of cost economies or can influence the decision making directly. In order to discover (the sources of) these influential factors, airports will be positioned within the sector in this first (descriptive) part. Therefore, the air transport sector is described (Chapter 1). This includes an overview of macro-economic developments and trends, a view on the organizational structure of the entire sector and a description of the two-sided market with its stakeholders. The second chapter will then analyze the airports more in depth. A definition and typology is followed by an analysis of airport ownership, the determinants of airport capacity, a description of airport activities and the resources needed to perform these activities.

1. The air transport sector

This first chapter will clarify the developments and trends within the air transport sector during the last decades. The developments highlighted depict general evolutions, based on trends over several years. The developments can however differ each year or for each product; yet this does not affect the general trend.

A second section of this first chapter will look more into the organizational structure of the air transport sector, based upon the two-sided market airports are confronted with. Furthermore, also the other main stakeholders of this two-sided market are analyzed.

1.1 Macro-economic developments and trends

Looking at the market development of the last decade, both passenger and cargo traffic rose to high levels. The developed markets of Europe and North America are still strong, but markets in other parts of the world are gaining more market share. For example, Asia-Pacific and the Middle East are large emerging markets.

1.1.1 Traffic growth

ICAO (2015) reports statistical data applicable to the ICAO Member States. In 2015 the number of passengers carried on scheduled services rose to 3.5 billion, which is 6.8% higher compared to 2014. Looking at passenger-kilometers performed, an increase of 7.1% can be noted. The fact that Asia-Pacific airlines carry almost 32% of world traffic, posting a growth of 9.2% in 2015, proves that there is a shift from west to east. Europe accounts for almost 27% of world traffic and North-America for almost 25%, both growing with 5.8% and 5.1% respectively. The Middle Eastern carriers recorded the largest growth with 10.3%, representing 9.2% of world traffic. Latin-America accounted for 5.3% of world traffic and a growth of 7.8%. The remaining world traffic is represented by the airlines from the African region, with a growth of 2.4%.

Table 7: World revenue passenger traffic - international & domestic (scheduled services)

Year	Passengers (millions)	*of which international*	Annual increase (%)	*of which international*	Passenger-km (millions)	*of which international*	Annual increase (%)	*of which international*
2006	2 257	*808*	5.6	*9.3*	4 164 799	*2 515 282*	6.2	*8.1*
2007	2 456	*893*	8.8	*10.5*	4 506 866	*2 732 782*	8.2	*8.6*
2008	2 492	*927*	1.5	*3.9*	4 596 903	*2 817 467*	2.0	*3.1*
2009	2 482	*940*	-0.4	*1.3*	4 548 494	*2 781 529*	-1.1	*-1.3*
2010	2 698	*1 039*	8.7	*10.6*	4 910 282	*3 018 105*	8.0	*8.5*
2011	2 863	*1 128*	6.1	*8.5*	5 233 276	*3 248 078*	6.6	*7.6*
2012	2 996	*1 195*	4.6	*6.0*	5 513 221	*3 447 283*	5.3	*6.1*
2013	3 130	*1 257*	4.5	*5.2*	5 816 045	*3 643 963*	5.5	*5.7*
2014	3 308	*1 338*	5.7	*6.4*	6 163 670	*3 870 383*	6.0	*6.2*
2015	**3 533**	***1 436***	**6.8**	***7.3***	**6 601 465**	***4 141 900***	**7.1**	***7.0***
Europe (percentage of world traffic)	928 (26.3)	*689 (48.0)*			1 765 (26.7)	*1 539 (37.2)*		
Africa (percentage of world traffic)	74 (2.1)	*46 (3.2)*			143 (2.2)	*121 (2.9)*		
Middle East (percentage of world traffic)	187 (5.3)	*153 (10.6)*			606 (9.2)	*579 (14.0)*		
Asia and Pacific (percentage of world traffic)	1 206 (34.1)	*353 (24.6)*			2 108 (31.9)	*1 166 (28.1)*		
North America (percentage of world traffic)	878 (24.9)	*136 (9.5)*			1 629 (24.7)	*562 (13.6)*		
Latin America and Caribbean (percentage of world traffic)	260 (7.4)	*59 (4.1)*			349 (5.3)	*175 (4.2)*		

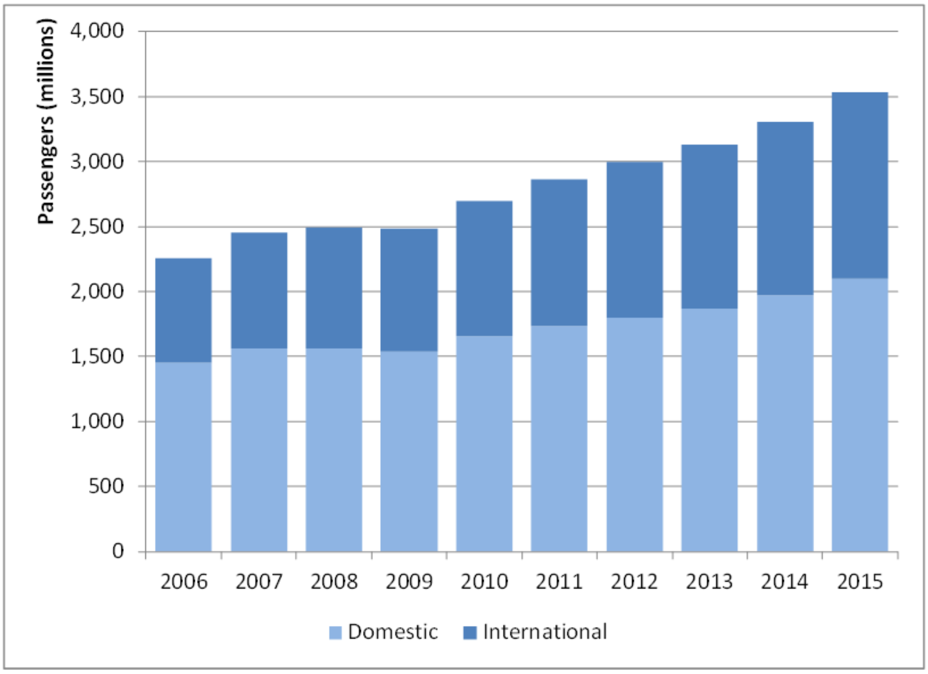
Note – the sum of the individual regions may not match the totals due to rounding.

Source: own composition based on ICAO (2015)

Based on Table 7, Figure 1 and Figure 2, it becomes clear that the growth of international world revenue passenger traffic in general is bigger compared to the total (domestic and international) world revenue passenger traffic. Analyzing the international passenger-km figures, European carriers saw a growth of 5.6%, carrying the largest portion of traffic, being more than 37%. The Asia-Pacific region represents 28% of the international traffic while the Middle Eastern carriers transport 14% of traffic, with a growth of 8.9% and 10.9% respectively. North American carriers report a growth of 3.6%, accounting for almost 14%, while the Latin American region represents 4.2% (due to a growth of 10.2%) and Africa almost 3% (with a growth of only 2.3%) (ICAO, 2015).

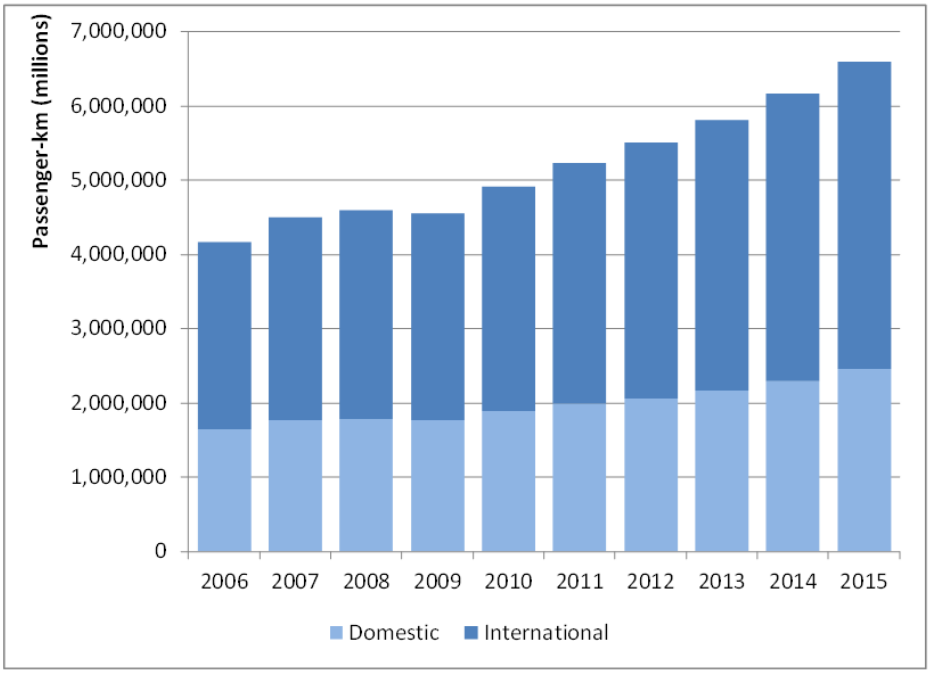
Domestic scheduled passenger traffic grew by 7.3% in 2015, where North America is the largest domestic market (43%) and the Asia Pacific region represents a share of 38%. Carriers of Europe only account for 9%, followed by the Latin American airlines (7%), the carriers of the Middle East and Africa, who together account for 2% (ICAO, 2015).

Figure 1: World revenue passenger traffic - international & domestic (scheduled services) - passengers



Source: own composition based on ICAO (2015)

Figure 2: World revenue passenger traffic - international & domestic (scheduled services) - passenger-km



Source: own composition based on ICAO (2015)

Scheduled total freight rebounded in 2014 after almost 2 years of negative or flat growth. In 2014 an increase of 4.9% can be observed, with approximately 50 million tons of freight carried. In 2015, also a (smaller) growth of 1.8% can be noted, with almost 51 million of tons carried, this due to a slowing global economic growth and an overall decline in trade activity. Also here, the emerging markets have a large market share. Middle East carriers recorded a growth of 12.4% while Asia/Pacific increased by 2.3%. The growth rates from the other regions declined compared to the previous year. North American carriers contracted by 2.5%, while carriers in Europe, Latin America and Africa saw their growth contract by 0.4%, 5.2% and 0.4% respectively (ICAO, 2015).

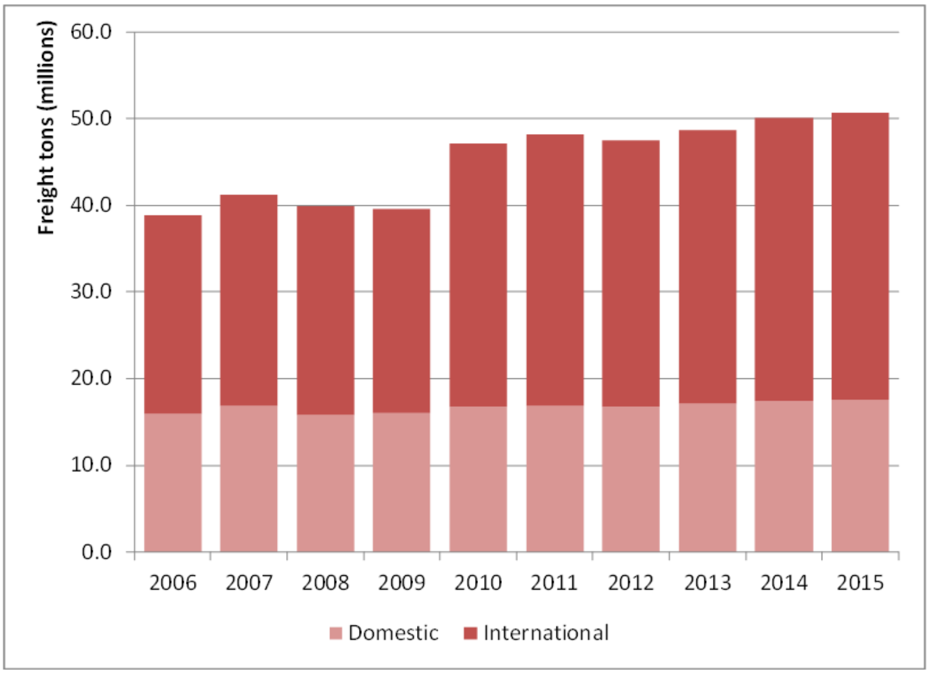
Table 8: World revenue cargo traffic - international & domestic (scheduled services)

Year	Freight tons (excl. mail) (millions)	*of which international*	Annual increase (%)	*of which international*	Freight ton-km (excl. mail) (millions)	*of which international*	Annual increase (%)	*of which international*
2006	38.8	*22.9*	6.2	*6.4*	164 388	*138 910*	6.6	*6.7*
2007	41.2	*24.3*	6.2	*6.3*	172 286	*145 881*	4.8	*5.0*
2008	39.9	*24.1*	-3.2	*-0.9*	170 631	*144 661*	-1.0	*-0.8*
2009	39.5	*23.5*	-0.8	*-2.3*	155 484	*131 929*	-8.9	*-8.8*
2010	47.1	*30.4*	19.2	*29.2*	186 230	*160 672*	19.8	*21.8*
2011	48.2	*31.3*	2.2	*2.8*	186 789	*161 331*	0.3	*0.4*
2012	47.5	*30.8*	-1.4	*-1.6*	184 841	*159 069*	-1.0	*-1.4*
2013	48.6	*31.5*	2.3	*2.2*	185 576	*159 554*	0.4	*0.3*
2014	50.1	*32.6*	3.3	*3.6*	194 215	*167 423*	4.7	*4.9*
2015	**50.7**	***33.1***	**1.2**	***1.5***	**197 549**	***170 508***	**1.7**	***1.8***
Europe (percentage of world traffic)	(N.A.)				43 088 (21.8)	*41 910 (24.6)*		
Africa (percentage of world traffic)	(N.A.)				3 339 (1.7)	*3 262 (1.9)*		
Middle East (percentage of world traffic)	(N.A.)				28 022 (14.2)	*27 943 (16.4)*		
Asia and Pacific (percentage of world traffic)	(N.A.)				78 075 (39.5)	*69 203 (40.6)*		
North America (percentage of world traffic)	(N.A.)				39 294 (19.9)	*23 272 (13.6)*		
Latin America and Caribbean (percentage of world traffic)	(N.A.)				5 731 (2.9)	*4 917 (2.9)*		

Note – the sum of the individual regions may not match the totals due to rounding.

Source: own composition based on ICAO (2015)

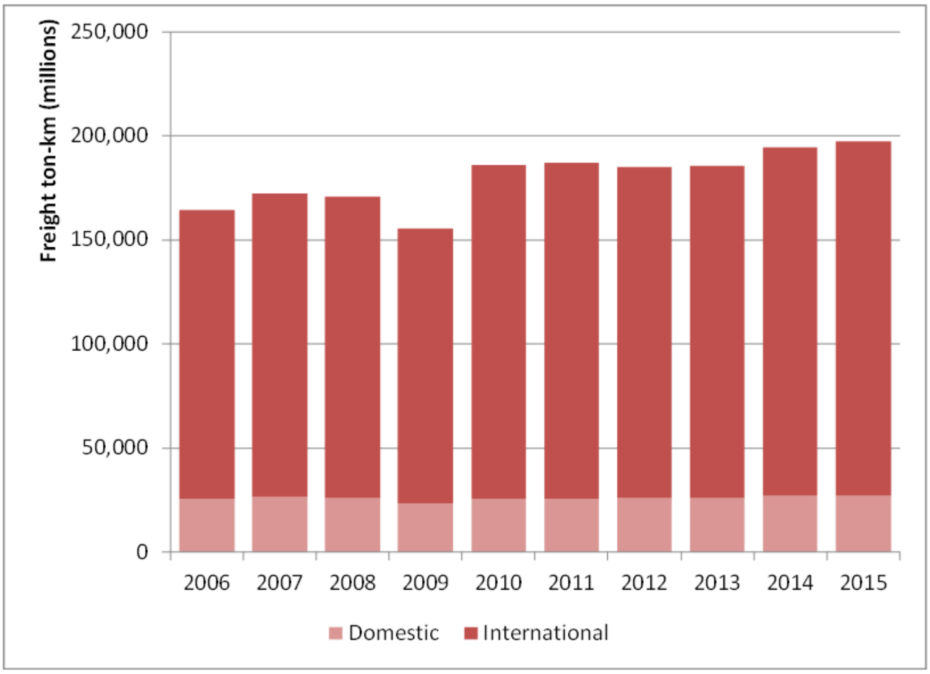
Figure 3: World revenue passenger traffic - international & domestic (scheduled services) - freight tons (excl. mail)



Source: own composition based on ICAO (2015)

Comparing total scheduled traffic to international scheduled freight transport, also for freight the growth numbers of international traffic are larger. Moreover, international freight represented around 86% of total scheduled freight ton-km (see Figure 4). Asia/Pacific airlines carried nearly 41% of scheduled international freight ton-kms, while European carriers accounted for 25% and 14% for North American airlines. The Middle East region represents 16%, meaning that almost 80% of long-haul traffic flowed on the East-West trade lane.

Figure 4: World revenue passenger traffic - international & domestic (scheduled services) - freight ton-km (excl. mail)

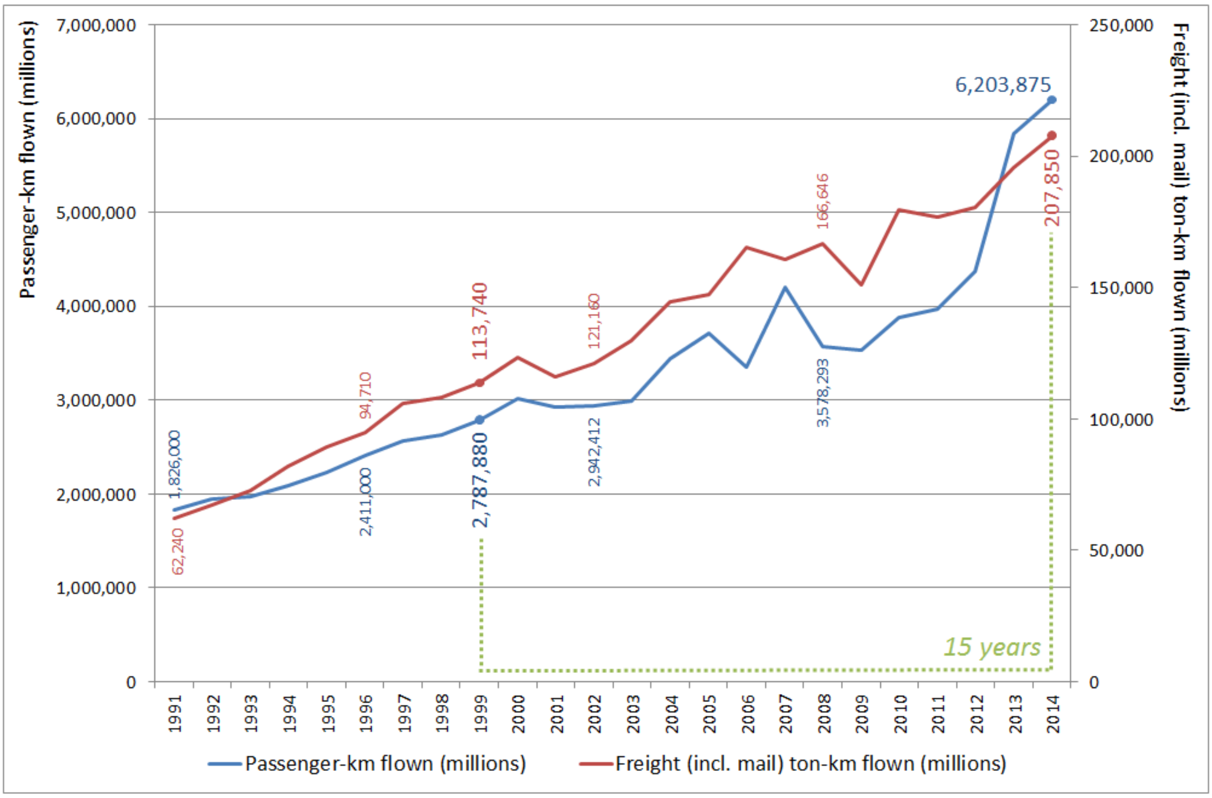


Source: own composition based on ICAO (2015)

As can be deducted from Figure 3 and Figure 4 compared to Figure 1 and Figure 2, air freight has had some difficult years since the crisis, and knew small growth levels. Although air freight (excl. mail) has grown a bit compared to 2014, growth has stabilized, while passenger traffic did grow after the crisis of 2008.

However, in general, air traffic has doubled in size every 15 years since 1977. As Figure 5 shows, the passenger-kilometers flown reached the level of 2,787,880 in 1999 and more than doubled to 6,203,875 in 2014. Freight traffic grew by almost 83% between 1999 and 2014, climbing from 113,740 ton-kilometers to 207,850 ton-kilometers (International Air Transport Association (IATA), 1981 - 2015). Based on the growth numbers as reported by ICAO (2014), it is expected that by 2030, air traffic will double again.

Figure 5: Evolution of passenger-km and freight (incl.mail) ton-km (1991-2014)

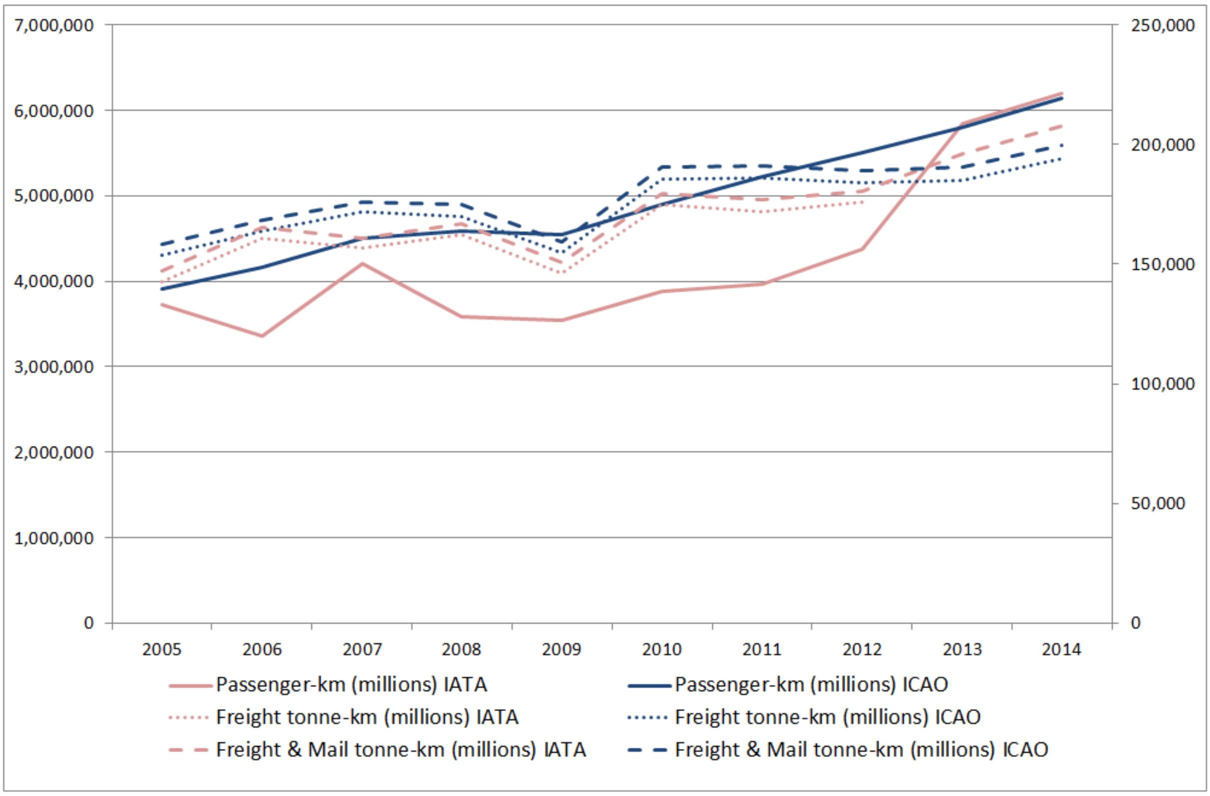


Source: own composition based on IATA (1981 - 2015)

Figure 6 shows the growth pattern of scheduled passengers and freight & mail traffic from 2005-2014. The figures take into account international and domestic scheduled services and are expressed in passenger-kilometers and ton-kilometers as reported by IATA (2005 - 2015) and ICAO (2014). Especially the data from ICAO (2014) show a downfall in 2009 for both passengers and cargo (freight & mail). This can be explained by the external shocks the market experiences. As can be seen on Figure 6, cargo suffered more from the consequences of the financial crisis compared to passengers, but there was a quick recovery. In 2010 the level of cargo even exceeded the level of 2008, was stable for some years and grew again in 2014.

The data of IATA (2005 – 2015) show a rather similar pattern for cargo (freight & mail) but report other, lower numbers in terms of passengers. Moreover, the pattern is also less stable. Remarkably between 2007 and 2013, the numbers deviate quite a lot[6]. Yet, both curves show a rising trend in both passengers and cargo.

Figure 6: Evolution passenger and freight (incl. mail) 2005-2014 – scheduled services, international and domestic



Source: own composition based on IATA (2005-2015) and ICAO (2014)

[6] This could be due to different datasets. The ICAO figures represent data from ICAO members states, while the IATA data are sourced directly from airlines, through direct data submission, and extrapolated in order to reflect the entire industry. The data refer to total scheduled traffic, including low-costs, non-IATA member airlines, dedicated cargo carriers, regional carriers etc. Only non-scheduled traffic that does not have pre-published schedules is not covered.

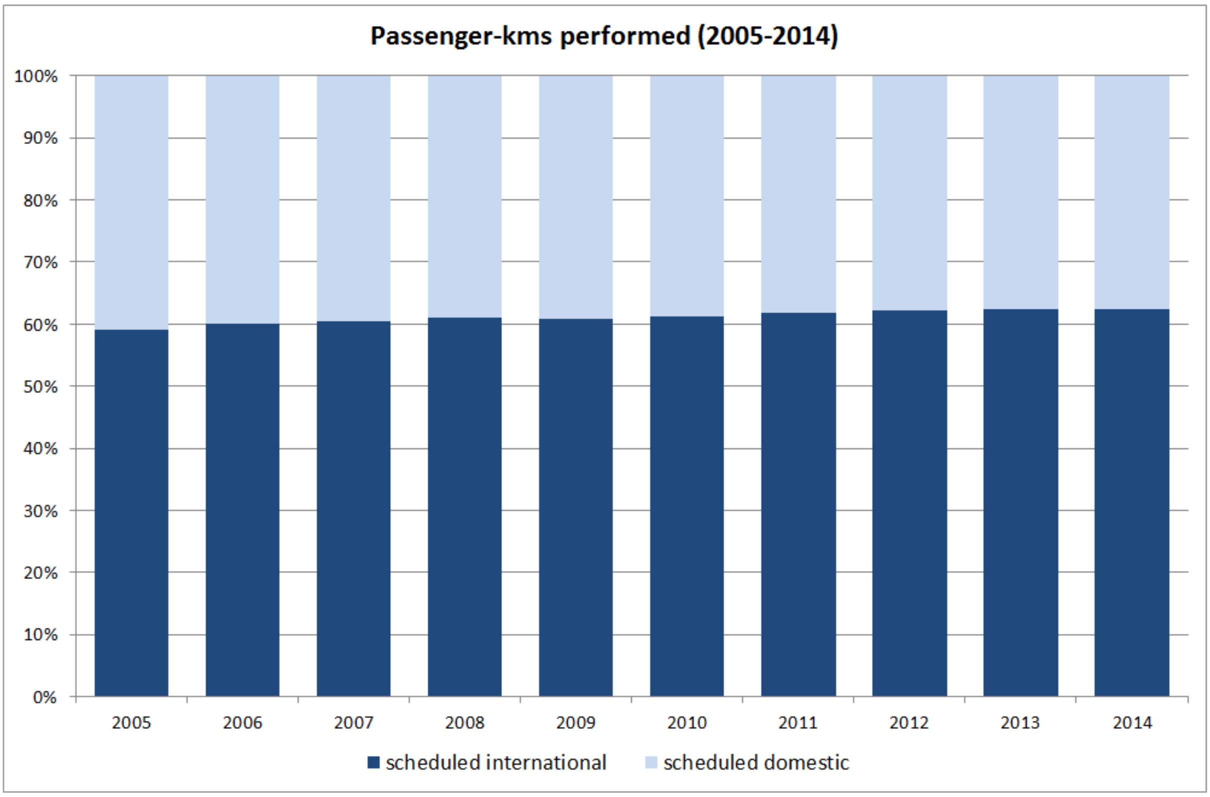
1.1.2 Type of traffic

Looking at passenger-kilometers, the scheduled services as depicted in Figure 6 can be divided in international and domestic traffic.

Figure 7 shows that the last 10 years about 60% of all scheduled passenger traffic (expressed in passenger-km) was international traffic. The balance stays relatively stable, but domestic traffic did lose some ground to international traffic. In 2005 41% of all scheduled passenger traffic was domestic but the share decreased to 38% in 2014 (ICAO, 2014).

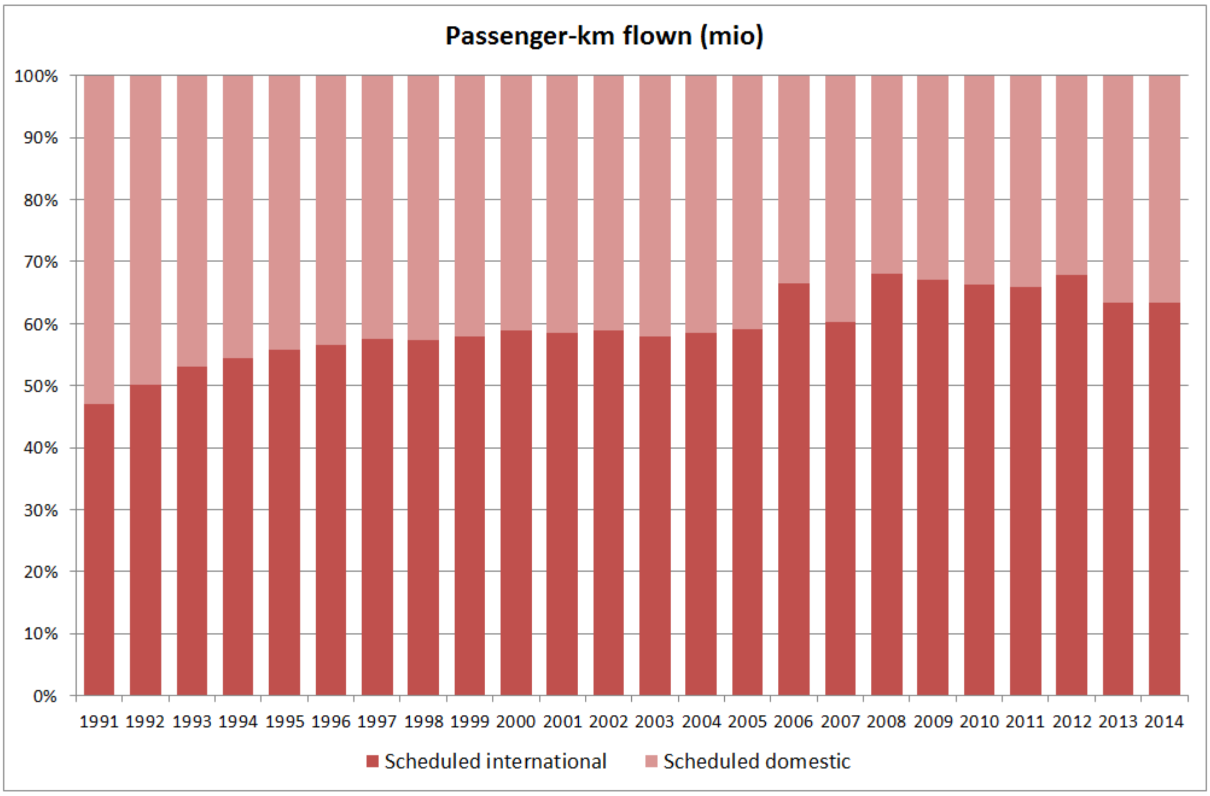
Looking at another source, i.e. IATA (1981 - 2015), it becomes clear that the share of domestic traffic has decreased a lot during the last years. Since 2006, the share of domestic traffic has not risen above 40%, while it was still at a level of 53% in 1991.

Figure 7: Scheduled passenger-km international vs. domestic (2005-2014)



Source: own composition based on ICAO (2014)

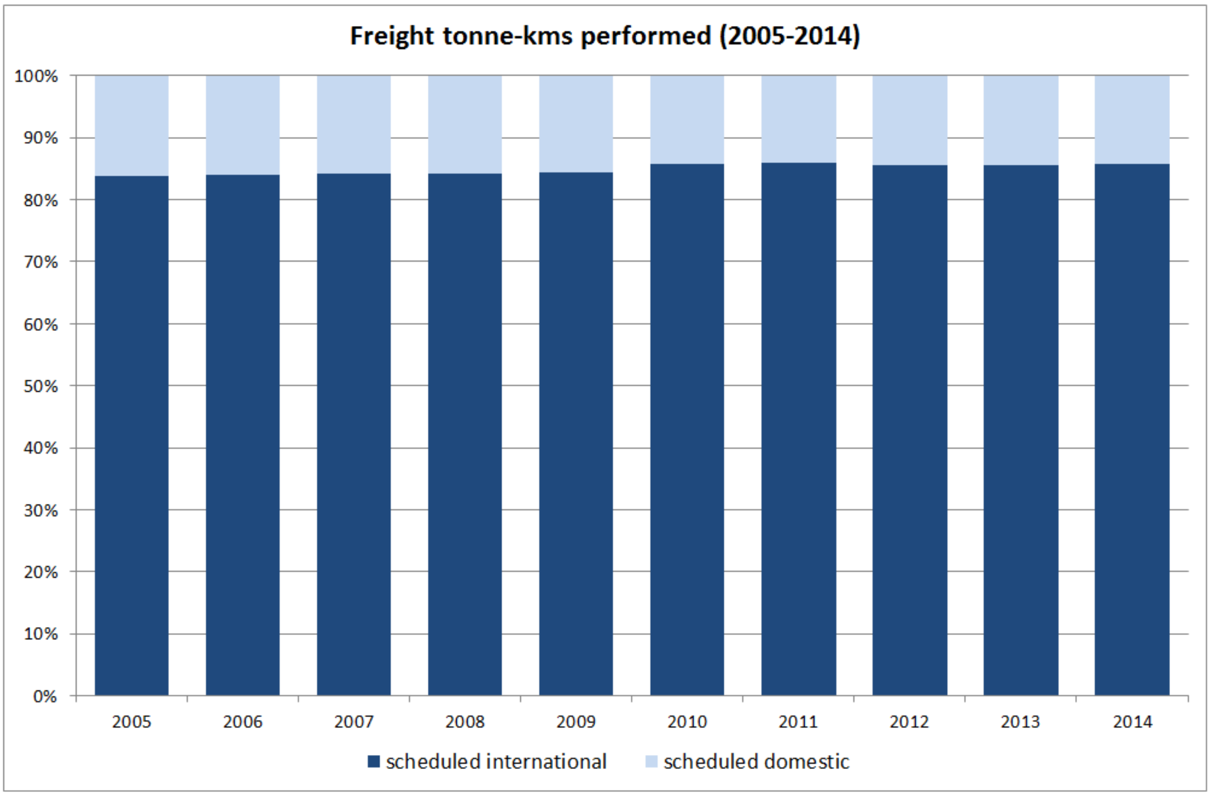
Figure 8: Scheduled passenger-km international vs. domestic (1991-2014)



Source: own composition based on IATA (1981 - 2015)

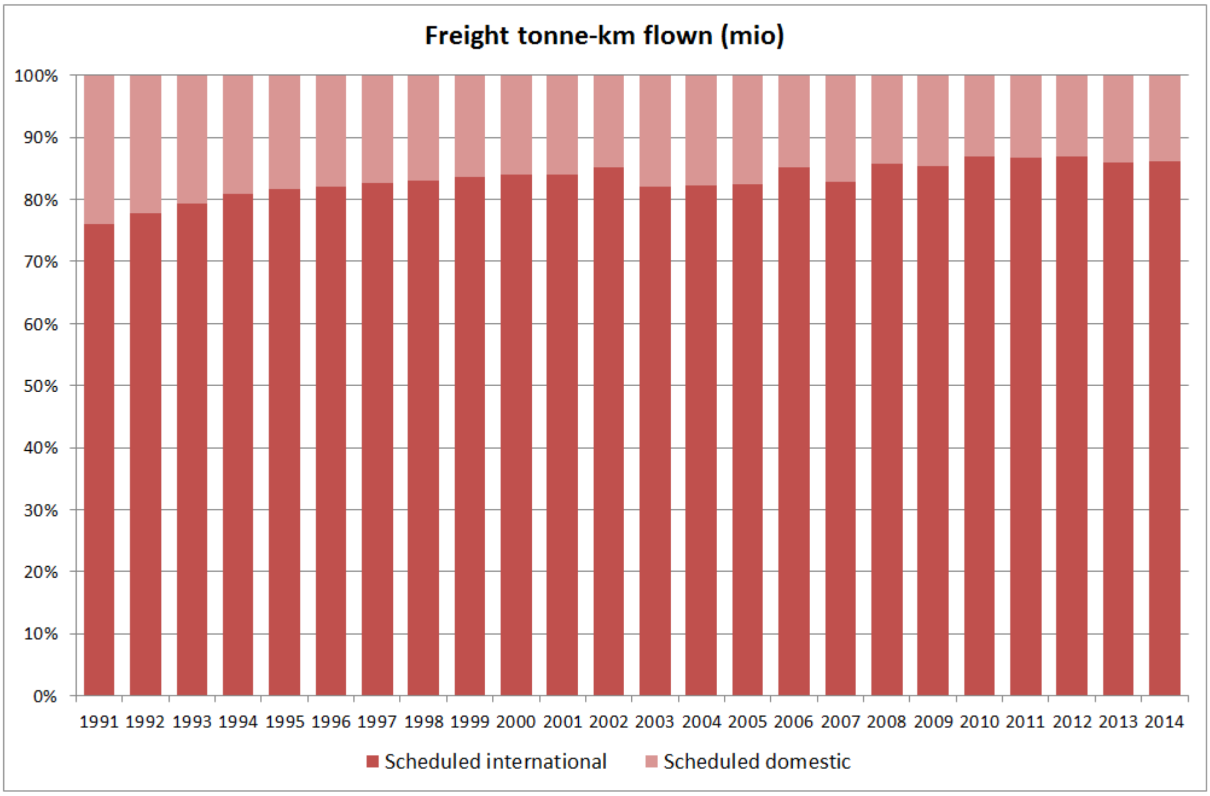
The same comparison can be made for cargo transport (see Figure 9 and Figure 10). Here, the distinction between international and domestic scheduled services, in terms of freight ton-kilometers (incl. freight and mail), shows, as expected, that cargo is shipped predominantly on international routes. Also here, domestic traffic has lost some ground to international traffic, since its share dropped from 16% in 2005 to 14% in 2014 (ICAO, 2014). Looking at data from IATA (1981 - 2015) in Figure 10, the majority of international cargo traffic also clearly shows, but as with passenger traffic, the share of domestic traffic was much larger in 1991 (i.e. 24%).

Figure 9: Scheduled freight ton-km (incl. freight & mail) international vs. domestic (2005-2014)



Source: own composition based on ICAO (2014)

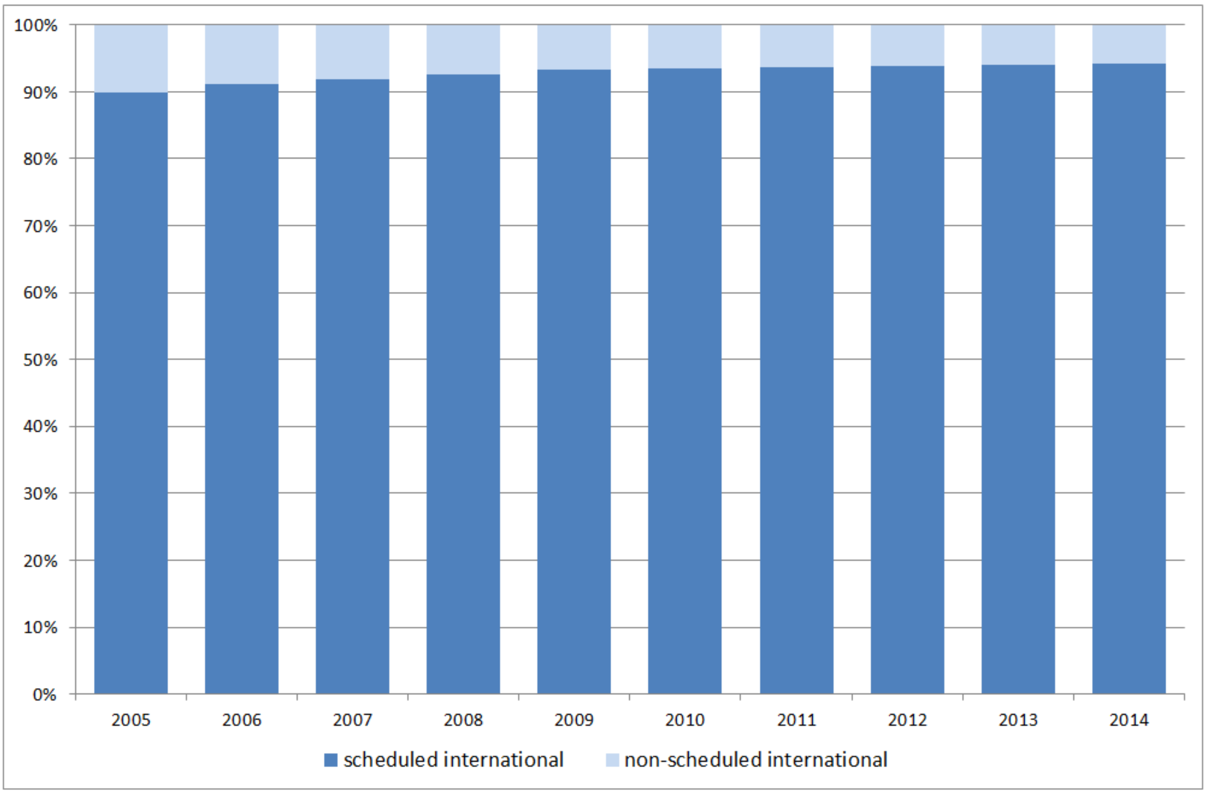
Figure 10: Scheduled freight ton-km (incl. freight & mail) international vs. domestic (1991-2014)



Source: own composition based on IATA (1981 - 2015)

When taking into account international passenger traffic, non-scheduled traffic is losing ground to scheduled traffic (Figure 11). In 2005 still more than 10% of all international passenger traffic was non-scheduled while this share decreased to only 5.8% in 2014.

Figure 11: International passenger traffic (in passenger-km), scheduled vs. non-scheduled (2005-2014)



Source: own composition based on ICAO (2014)

1.1.3 All cargo vs. combi traffic

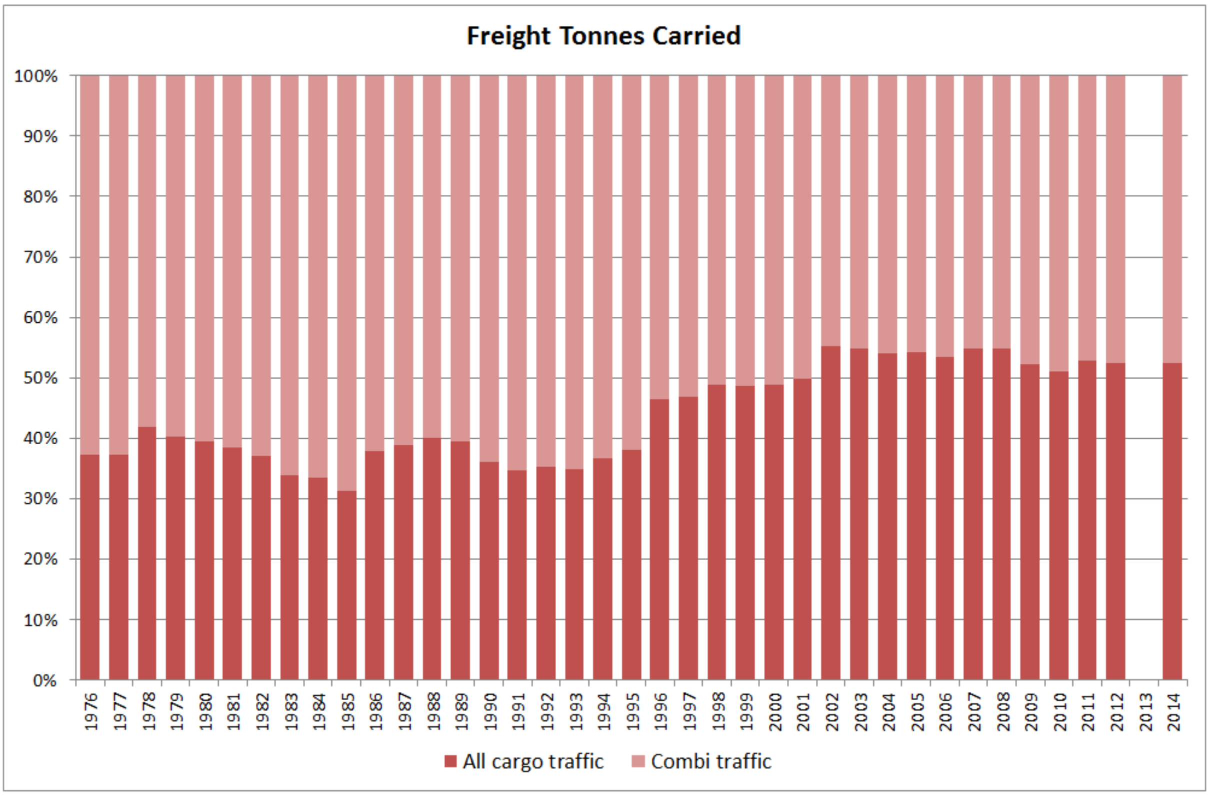
The air cargo market is still growing. Technological progress contributed to the fact that goods can now be transported by air at acceptable prices, which increased the demand for air transport of goods. The ongoing technological progress also brought about a growth of ton-kilometer capacity, which resulted in cargo becoming an opportunity for airlines to fill up free capacity in passenger. Cargo thus also became a market to complement profits. (Zondag, 2006)

Although air cargo was traditionally seen as by-product of passenger transport, it evolved to a mature product. So, next to the use of free belly capacity in passenger aircraft (i.e. combi traffic), the increased market also led airlines to participate in the full freight market, using all cargo aircraft. Transportation of cargo separate from passengers entails different handling, using specialized equipment and shorter transit times which puts pressure on airports and service agents.

Figure 12 and Figure 13[7], based on data from IATA (1981 – 2015), show indeed that in general combi traffic lost some ground to all cargo traffic. In 1976 almost 63% of all tons was carried in combination with passengers. In 2014, this share dropped to almost 48%. Looking at ton-kilometers, the share of combi traffic decreased from about 60% to almost 49%.

However, the last years, combi traffic has gained some market share. The share of all cargo traffic increased until 2008, but decreased after the crisis. As shown before based on the growth figures, for cargo traffic it is more difficult to revive after the crisis. The all cargo market is a volatile market – much more volatile than the combi market – and in times of crisis, airlines are more inclined to first fill up their free belly capacity, before using all cargo aircraft (Kupfer, 2012).

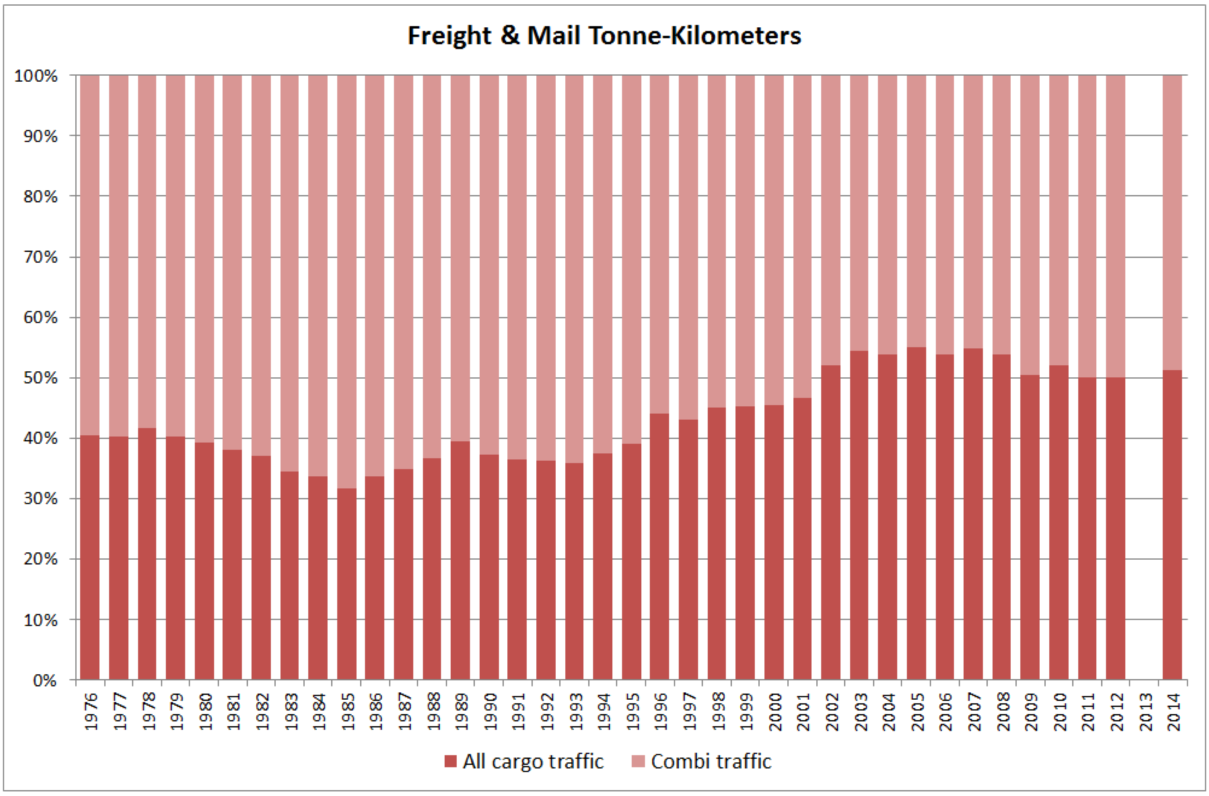
Figure 12: Freight tons carried (all cargo vs. combi traffic)



Source: own composition based on IATA (1981 - 2015)

[7] For both Figure 12 and Figure 13, data for 2013 were not available. As from 2014, IATA reported differently and the numbers for 2014 are those of all cargo/combi traffic on world level. The figures from earlier years refer to all cargo/combi traffic of IATA members.

Figure 13: Freight and Mail Ton-Kilometers (all cargo vs. combi traffic)



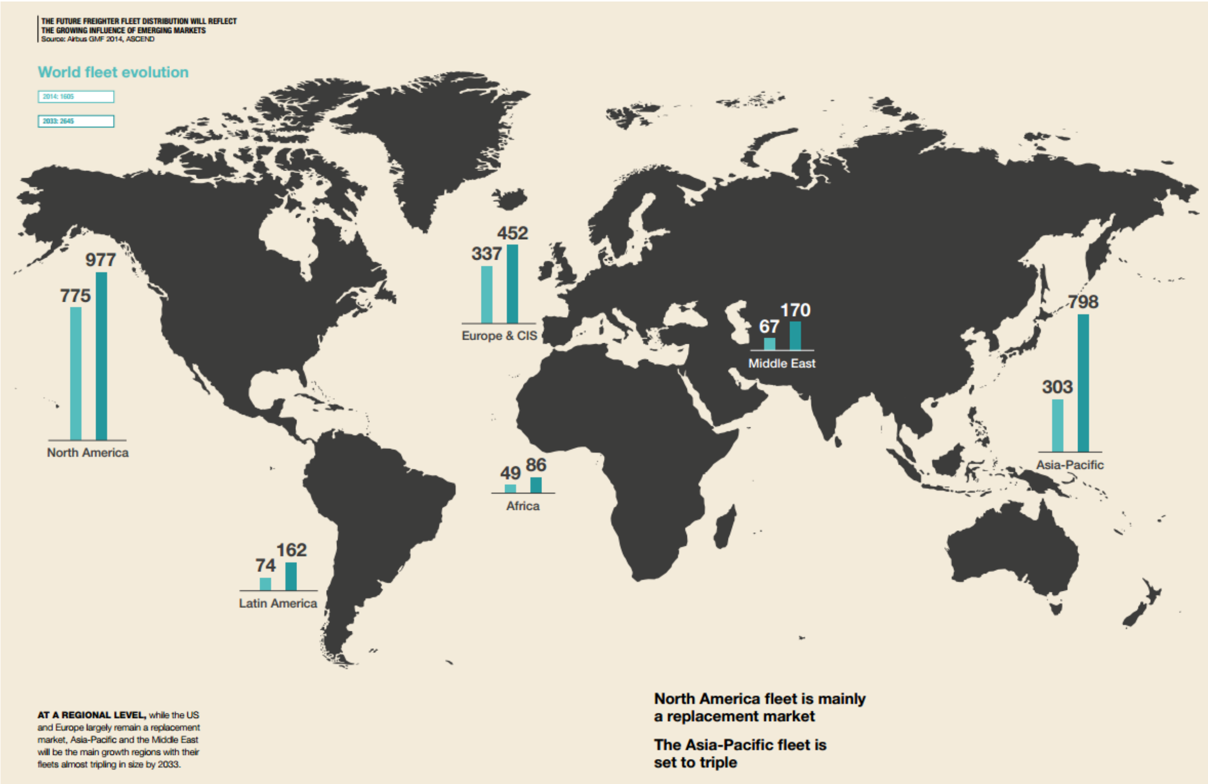
Source: own composition based on IATA (1981 - 2015)

1.1.4 Geographical spread

Looking at the spread of air traffic over the world, it is striking that developed markets such as Europe and North-America are losing ground. Emerging markets, such as Asia-Pacific and the Middle East, gain more and more market share. This entails a shift from west to east, and to some extent to south, in the coming years. Forecasts made by large aircraft constructors such as Airbus and Boeing depict the same story. For example, Airbus (2015) uses the (future) world fleet evolution and distribution as an indicator of the growing influence of emerging markets. North-America and Europe are rather a replacement market, while Asia-Pacific and the Middle East are growth regions who will triple their fleet by 2033. Numbers from Boeing (Table 9) show that the fleet used in Europe and North-America will not double, while other regions (except Commonwealth of Independent States) will more than double their fleet; proving again the emerging markets of especially Asia-Pacific and the Middle East.

Nevertheless, the figures as presented in Table 9 do show that the developed markets are still growing.

Figure 14: Future freighter fleet distribution Airbus



Source: Airbus Global Market Forecast 2014-2033

Table 9: Boeing airplanes in service 2013-2033

		Asia-Pacific	North-America	Europe	Middle-East	Latin America	CIS	Africa	WORLD
2013	Large widebody	290	100	180	100	0	60	10	**740**
	Medium widebody	520	320	360	280	20	20	60	**1580**
	Small widebody	710	730	350	220	120	180	80	**2390**
	Single aisle	3820	3790	3120	520	1160	740	430	**13580**
	Regional jets	130	1710	340	60	80	180	120	**2620**
	TOTAL	**5470**	**6650**	**4350**	**1180**	**1380**	**1180**	**700**	**20910**
2033	Large widebody	270	80	110	270	0	60	0	**790**
	Medium widebody	1500	560	640	770	50	90	70	**3680**
	Small widebody	2250	920	980	570	430	160	260	**5570**
	Single aisle	10850	5950	5930	1680	2840	1350	1000	**29500**
	Regional jets	350	1610	150	70	210	160	90	**2640**
	TOTAL	**15220**	**9120**	**7710**	**3360**	**3530**	**1820**	**1420**	**42180**
	change (2013 – 2033)	278%	137%	177%	285%	256%	154%	203%	202%

Source: Boeing Current Market Outlook 2014

1.1.5 External shocks

As presented in Figure 5, air traffic is a growing sector, which seemed to overcome recent shocks such as the oil crises, the Gulf crisis, 9/11, SARS and the recent financial crisis in 2008.

For passenger transport, this can be (partly) explained by the fact that air transport became more accessible to a larger audience thanks to the lower prices and higher incomes (Oxley & Jain, 2015). Due to global trends such as migration and globalization, people will (need or want to) visit clients in another continent or friends and family that live abroad. This urge to fly is easily fulfilled now that taking a plane is only a few mouse clicks away. Moreover, at industry level, the continuing deregulation drives growth. On the one hand, the increased competition results in low airfares, which makes travelling by air also accessible for the people who are less wealthy. The rise of the low cost model also responded to a demand for which there was no supply before. More and more people around the world are provided with the ability to fly. On the other hand, air travel becomes more attractive since a larger amount of destinations offered by various airlines.

However, Figure 6 showed that air cargo suffered more from the financial crisis in 2008 than did passenger traffic. Also the SARS-crisis had some consequences for cargo transport. It led to the cancellation of passenger flights and thus belly capacity. Therefore, goods were not able to be shipped which, on long term, lowers the reliability (Kadar & Larew, 2004). Given its volatile character, cargo does rebound faster from crisis situations compared to passenger traffic.

Next to these general shocks, the air transport market also experienced drastic sector-specific changes brought about by the deregulation/liberalization. The American Deregulation Act (1978) initiated a market where airlines were free to enter and exit. In a first phase, a lot of newcomers entered the market. This resulted in a higher level of competition, a decrease of concentration and an increased level of efficiency. However, the fierce competition drove a lot of newcomers to business failure, leading to them being absorbed by competitors through mergers and alliances. The number of players decreased, the market shares increased leading to a return to concentration as from 1985. (J. P. Keeler & Formby, 1994)

The deregulation had different consequences for prices and profit but also for operations at airports.

- The most striking consequences were related to prices/tariffs. Some sources hint that the deregulation could lead to price increases while other sources show how deregulation could lead to decreasing prices. For example, Borenstein (1992) stated that, after deregulation, a lot of mergers and acquisitions led to an increase in concentration. These larger airlines could possibly benefit from economies of density but might also become dominant and then charge higher prices. On the other hand, the rise of low cost carriers, who were now also free to enter the market, caused a downward pressure on the tariffs (Sinha, 2001).
- Changes in price levels also affect the profit made. Expectations would be that due to the increase in supply, competition rises and efficiency would thus have to increase. This could lead to an increase in profit. Yet, on the other hand, increased supply and thus increased competition could also lead to lower prices and thus to less profit. Also here, observations made in literature disagree. Gomez-Ibanez, Oster, & Pickrell (1983) and Van Scyoc (1989) found that profits decreased mainly due to low economic growth and increasing fuel prices. They also found that deregulation did not affect the profit margins of airlines. While, on the other hand, Morrison & Winston (1986) found that the advantages of competition (being efficiency, flexibility and freedom) exceed the downward pressure on the profits leading to an increase in profits.
- One of the induced effects of the deregulation is the fact that airports suffered from delays. The increased number of airlines[8] offering their services, leads to congested airports.

Following the American example, the European air transport market also wanted to step away from governmental regulation, but encountered some problems since European airlines where mostly property of governments, subsidized and bound to national regulation. Next to that, the American example could not simply be copied. Contrary to the USA which comprises only one domestic air transport market, Europe consists of different countries. All different legislations need to be adapted and deregulation would need to take place on an international level. Therefore, the European air transport market was rather liberalized than deregulated, meaning that some form of regulation is still present. The liberalization was introduced in

[8] The increased number of airlines offering their services, is not only due to deregulation. As shown before, also the economic growth leads to a growth in the air transport sector.

three different stages which gradually introduced multilateral agreements entailing airlines that can fly any route within Europe. Also here, low cost carriers arose. These new carriers were attracting new customers, rather than stealing them away from incumbents. The increase in suppliers led to improved services and a larger offer of destinations.

The air traffic control, however, was still nationally organized and thus fragmented and inefficient, leading to delays. The Single European Sky (SES), introduced in three stages, would blur the boundaries leading to increased efficiency, lowering of costs, improved safety standards (see also section 2.3.3 "Airspace – Single European Sky).

1.2 Organizational structure of the sector

In this section, the complex reality with which an airport is faced, will be explained. Not only are airports confronted with different stakeholders with whom they have to interact, they are also facing a two-sided market in which they are the platform where airlines and their customers interact. Airports will thus try to attract the two sides of the air transport market.

1.2.1 Different stakeholders

Air transportation involves a lot of companies – which can be partners to each other. The airport represents the platform around which air transport revolves. It is the place where airlines and other aeronautical service providers meet their customers, but also where passengers spend their waiting time shopping, working, eating, drinking, …

Bearing this in mind, a division between landside and airside activities and stakeholders can be made. In this dissertation, airside stakeholders are those whose actions are related to the actual flight and aircraft, e.g. ground handling or fuel services. Landside stakeholders offer services which are related to air transport but do not come in contact with airside operations, e.g. check-in, parking or retail.

On the one hand, there are internal stakeholders which are (physically) present at the airport site. Analogously to ACI Europe (2004), there are three different types of internal stakeholders, as depicted in Table 10[9].

[9] Next to these internal stakeholders, also passengers and cargo represent an important stakeholder at the airport. However, since they are rather grouped individuals or goods than one stakeholder, they are not mentioned in Table 10.

Table 10: Internal stakeholders of an airport

Airline/service	Commercial	Administration
Airlines Ground handling agents Flight catering Fuel services Cargo operators Aircraft maintenance	Retail shops Duty and tax free shops Restaurants Car park companies Car hire companies	Airport company Security Police Immigration Customs Air Traffic Control (agent)

Source: own composition based on ACI Europe (2004)

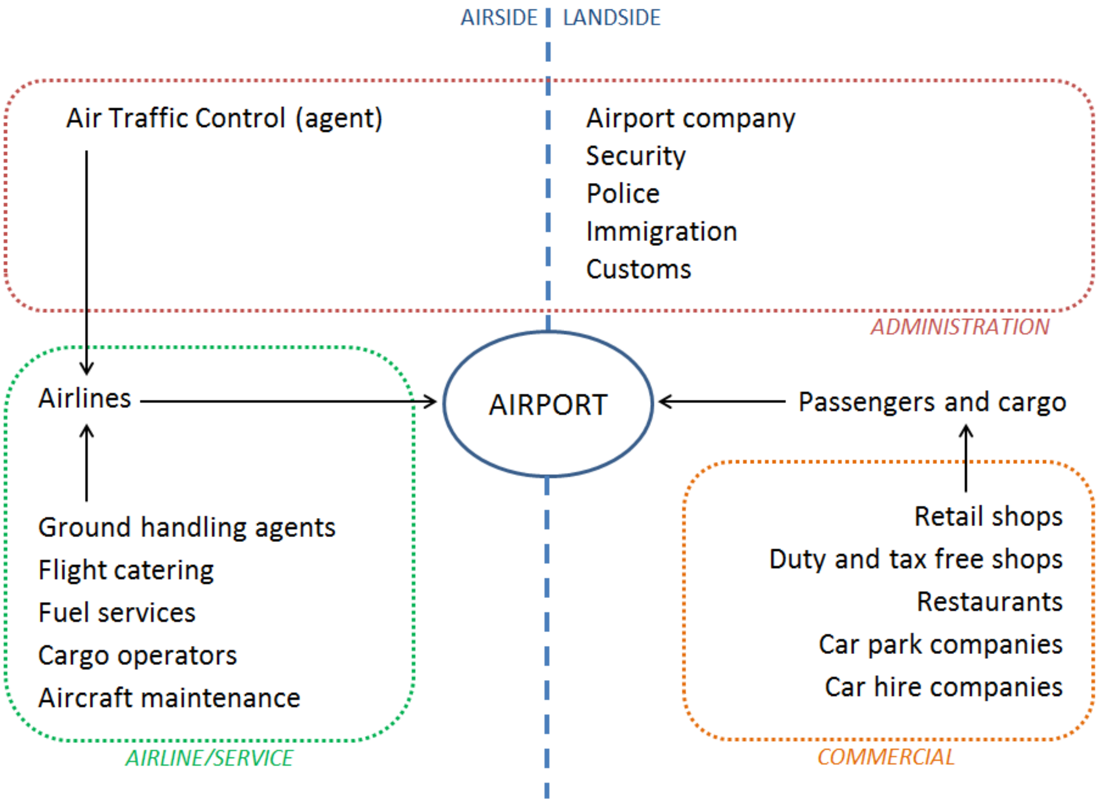
The airline/service stakeholders are airside stakeholders. This category comprises the airlines and the service providers which are directly related to the flight or the aircraft.

The airlines are the stakeholder which perform the flights, but are also responsible for check-in, baggage claim, boarding etc. Before take-off and after landing, ground handling companies perform their services. For example, towage with push-back trucks to the parking stand, passenger bridge or stairs positioning, baggage and cargo loading and unloading, cleaning, … Services such as fueling and catering can be offered by separate service providers, but are in some cases also provided by the ground handling agents. At cargo handling airports, cargo operators are also present. Cargo forwarders are vital since they take all arrangements to ship goods between shipper and beneficiary. Furthermore, consolidators, break bulk agents, warehouse operator etc. can also be present. And finally, aircraft maintenance is the stakeholder which deals with maintenance and repair of the aircraft when they are not flying.

On the landside, there are commercial stakeholders catering to the passengers' extra needs. Retail, duty and tax free shops and restaurants provide their services during the time passengers wait to board their plane. Also parking companies or car hire companies offer their services on landside.

And finally, also administrative stakeholders are present. The airport company deals with the management of the airport, while the security staff, the police, immigrations office and customs are responsible for the safety. The air traffic control agent (ATC) is responsible for airside safety guiding aircraft safely to the airport and back into the airspace.

Figure 15: Internal stakeholders of an airport



Source: own composition

Above, possible stakeholders are mentioned. To which extent they are actually present at an airport, is different for each airport. Influential factors are amongst others the size and scope of the airport. For example, on some airports there are also stakeholders dealing with crew training or providing general aviation services.

Next to these internal stakeholders, the airport is also confronted with external stakeholders. Investors (and in some cases also governments) provide the airport with capital or are involved with the management. Airports also have to comply with the legislation and regulation governments impose.

Air transport related companies are not necessarily present at the airport site, but are indeed important for the airport. An example is the manufacturer of aircraft parts (Kupfer & Lagneaux, 2009). Also other (surrounding) companies can affect the market since they influence the goods that are shipped.

And finally, other airports (nearby) might bring about competition or can act as complementing partner, thus influencing the market.

1.2.2 Two sided market

The situation as depicted in Figure 15 also reveals that, in the air transport sector, the airport is the platform around which air transport revolves. It is the place where airlines and their customers meet. Given this, an airport (company) then tries to attract both airlines and their customers, which entails that airports are confronted with a two-sided market. Both sides can thus influence the airport strategy and operations and therefore, it is necessary to get more insight into what this two-sided market entails.

Two-sided markets are roughly defined as markets in which a platform enables interactions between end-users and tries to get the two sides on board by appropriately charging each side. In doing so, platforms attempt to make, or at least not lose, money. (Rochet & Tirole, 2006)

Considering only this definition, any market would be two-sided, since buyers and sellers are indeed brought together for the market to exist. Evans (2003) however clarifies that there are three elements to the structure of the two-sided market: the two sides and the platform which allows them to find each other and interact. Rochet and Tirole (2003) add that the ultimate benefit derived by the two distinct sides comes from interacting through a common platform. Moreover, Rochet and Tirole (2006) stress that a two-sided market is one in which the volume of transactions between end-users depends on the structure and on the overall level of fees charged by the platform. A market is two-sided if the platform can affect the volume of transactions by charging more to one side of the market and reducing the price paid by the other side by an equal amount (Rochet & Tirole, 2006).

Appold and Kasarda (2011) stress the network economies that come with two sided markets: the larger the number of participants, the greater the benefits to each. For example, larger passenger volumes create greater opportunities for airlines. Therefore, also regulation is affected by this complex market structure, because the platform managers can increase the number of participants on one side by manipulating the prices the other must pay to participate in the platform.

There are numerous examples of two-sided markets. Concerning videogames, the gamer (one side) buys a game of the game publisher (other side) and plays it using the console designed by the platform. Or when considering electronic payments, the cardholder (one side) settles a transaction with a merchant (other side) through the platform of payment cards. Also airports are good example: the customers (passengers or cargo shippers) approach airlines on the platform of the airport. And indeed, the airport (company) charges both sides of the market and can, by doing so, influence the number of passengers/cargo and airlines handled. In normal conditions, the higher the number of airlines present, the higher the number of passengers/cargo, and vice versa.

This argument, however, needs a footnote. Some sources are critical about the fact that an airport is a two-sided market. After all, in this type of market, the element of pricing which affects the two sides is key. However, in airports, non-aeronautical pricing does not affect the airlines (unless there is a single till tariff policy – see section 3.2.3). Given this, an airport can be considered as being part of an imperfect two-sided market, where the passengers and/or cargo are the end users.

Nevertheless, as stressed by Appold and Kasarda (2011), the theory of the two-sided market provides a coherent strategic framework for understanding the challenges and opportunities facing airports (and airport cities). So when considering the offer of passenger and/or cargo activities at an airport, the airlines present are of great influence and its strategies need to be taken into account since they can be influential. Here, the airports have to face the question what affects what: on the one hand, airlines want to be present at an airport if the airport has a large market to serve, i.e. a lot of (potential) passenger and/or cargo traffic present. However, on the other hand the demand (passengers and/or cargo) is attracted by the airlines present at the airport.

This two-sided market clearly explains the place of airports within the airport sector. Now, it is important to also clarify the other stakeholders that are part of that two-sided market, being the passengers/cargo on one side and the airlines on the other side.

1.3 Passengers & Cargo – the transported entities

In Table 10 and Figure 15, passengers and cargo are described as one stakeholder in the airport sector, but they are the only stakeholder that, in most cases, is not a company or institution. Passengers or cargo are individuals or goods, they are the entities that are being transported[10].

A lot of distinctions can be made. As already indicated, the most basic one is the distinction between people (or "passengers") and goods (or "cargo[11]"). This is the division which is carried throughout this dissertation when analyzing the existence of cost economies[12].

However, it is important to bear in mind that there are many different types of passengers and cargo. These different types of passengers or goods have different needs and might thus influence the resources necessary for handling and catering, e.g. the equipment needed and used.

1.3.1 Passengers

In this section, the different types of passengers are described. Furthermore, also the passenger flow through the airport is discussed. Given the fact that different types of passengers have different needs, other resources or equipment is needed or used. This is analyzed when describing the impact of different types of passengers on the airport operations.

---

[10] In case of cargo, those goods are obviously not even a stakeholder, they cannot make decisions. Here, the shippers and other cargo actors are the stakeholders. Even though they are indeed companies, their shipment is often only a (small) part of a bigger shipment and therefore, their influence is not direct; they depend on the decisions of the other cargo stakeholders.

[11] In this dissertation, the term "cargo" refers to transport of freight and mail. If mail is excluded, obviously, the term "freight" is used.

[12] Given the fact that there are many different types of passengers and cargo, the basic division as used in this dissertation entails the use of an aggregate measure of output.

1.3.1.1 Types of passengers

With regards to passengers, distinctions can be made based on different grounds such as the type of journey they take, whether the airport is the passengers' final destination or the reason for travelling.

A first possible a distinction by type of journey is that between domestic and international traffic. Domestic traffic travels generally on short flights, even within one country, while international traffic is mostly characterized by long haul flights[13].

Furthermore, there is a difference between origin-destination traffic and connecting passengers. Origin-destination passengers (or point-to-point passengers) depart from or arrive at an airport with the aim of taking one direct flight. Connecting passengers, on the other hand, are those passengers for whom the airport is not their final destination. Here, a distinction between transit and transfer passengers can be made. In this dissertation, transit passengers are those passengers which do not leave the aircraft after landing, but wait until e.g. extra passengers are boarded, to take off again. Transfer passengers are those passengers whose only business at an airport is to transfer from one flight to another, within 24 hours of arrival at the airport. They thus leave the aircraft with which they arrived and board again for a connecting flight. Concerning connecting passengers, a further subdivision can be made. There are connecting passengers travelling with the same carrier on both flights (even if one of those flights is operated by a code share or alliance partner) or transfer passengers travelling with different carriers. Moreover, there are those with an airside connection (i.e. with bags that are automatically transferred from one flight to another) or those who have to collect their bags and check in again. Then there are connecting passengers transferring between domestic routes, between a domestic and an international route or those between international routes, etc. (Civil Aviation Authority, 2008)

Third, a distinction can be made based on the reason for travelling. There is a difference between business travelers, leisure travelers and travelers which are visiting friends or relatives (VFR). For business travelers, time is money, therefore, their value of time is very high and they want to make as much use of the obligated waiting time as possible. Moreover, they have a high willingness to pay for their air travel and do not respond notably on flight ticket price changes since they often do not have to pay for their tickets themselves. For

[13] However, the distance covered for domestic flight within a large country (such as China or the USA) can be longer than those of international flights between countries that lie close together.

leisure travelers or VFR, the time constraint is smaller. For example, leisure travelers are willing to arrive quite late in the evening. The willingness to pay for air transport, is often not that high; leisure travelers are very sensitive to changes in airplane ticket prices and any price increase will result in a lower demand. The advantage that comes with leisure or VFR travelers, is that they plan their trips ahead and thus the demand is predictable, while business travelers take the decision to travel more last minute.

1.3.1.2 Passenger flow through the airport

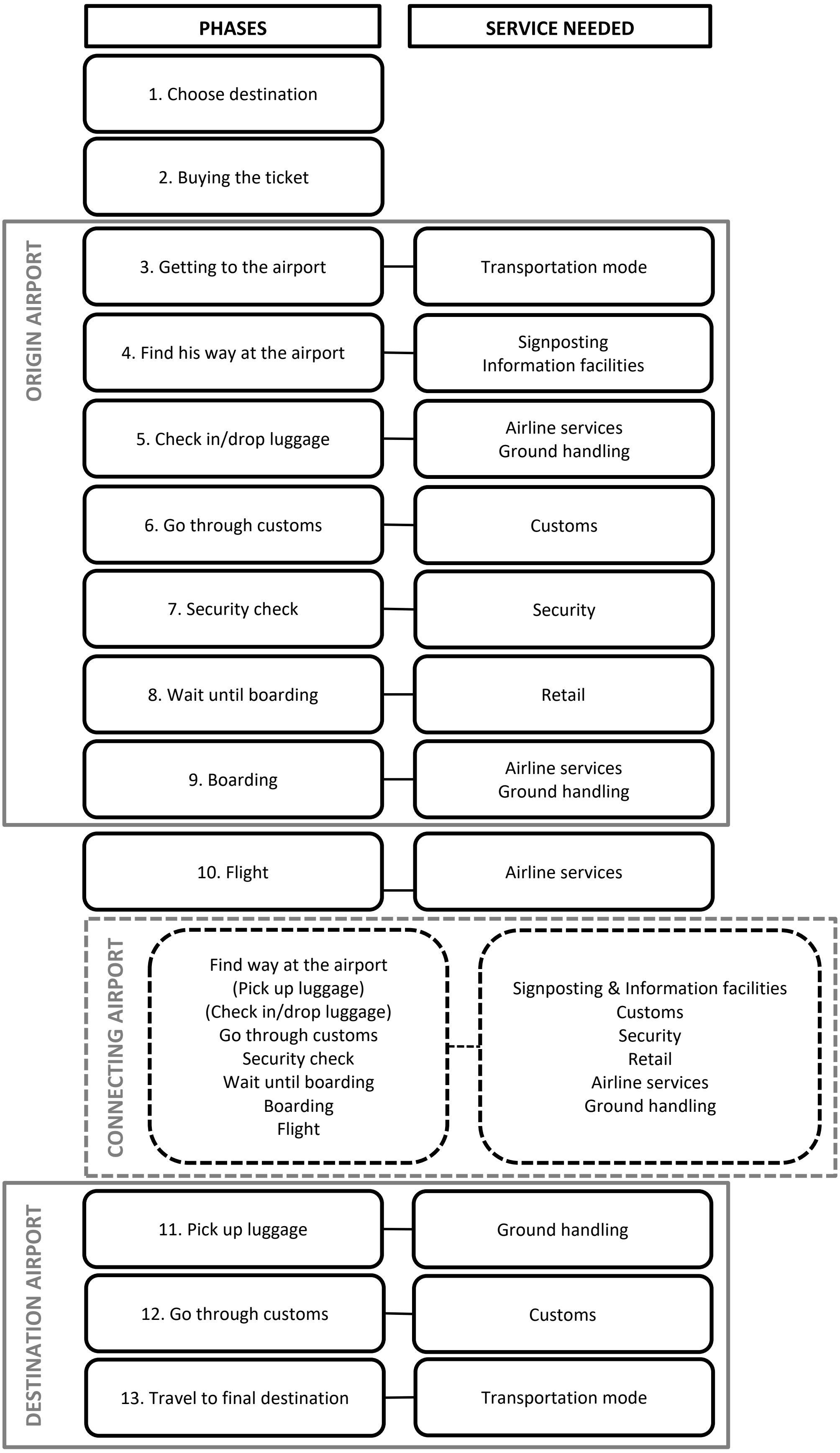
When a passenger decides to travel by plane, he goes through different stages or phases. When assuming that the passenger travels to his destination using a direct flight, there are 13 of these stages.

As depicted in Figure 16, first, he chooses his destination and buys his ticket. This all happens at his place of origin. After that, his journey starts and he has to get to the origin airport. Arriving at the airport, the passenger has to find his way to the check-in counter and gate through signposting and other information facilities. When the passenger has checked in and has delivered his luggage, he has to pass through customs and security. Then he has to wait until he can board. While doing so, he can make use of the retail facilities the airport offers.

After his flight, when he arrives at his destination airport, he has to pick up his luggage and go through customs again. Then he can travel to his final destination, using any transportation mode. (Struyf, Meersman, Pauwels, Van de Voorde, & Vanelslander, 2011)

For connecting passengers, as opposed to passengers traveling with a direct flight, the phase of the flight holds two or more flights, possibly including some waiting time and luggage pick-up and check-in at the transfer airport, depending whether the passenger is a transit of transfer passenger.

Figure 16: Different stages of a passenger travelling by plane



Source: own composition, based on (Struyf et al., 2011)

For each of these stages, the passenger comes in contact with a different (internal) stakeholder, providing a service. There are the airlines for the check-in and flight, customs, security officers, retail providers, ground handling agents for the baggage handling and possibly some transport mode provider. The airport is responsible for some of these services. For example, the security staff is often provided by the airport itself and the airport is also responsible for signposting and other information facilities. Obviously, the airport (management) also has to provide the infrastructure in and on which this all happens.

1.3.1.3 Impact on airport (operations)

The fact that there are different types of passengers has consequences for the resources needed at the airport since they have different needs and expectations.

When taking into account the type of journey, there is a difference between domestic or international passengers. Concerning the latter, airport managers have to realize that those international passengers often speak different languages, which has consequences for e.g. the signposting. Moreover, they probably use different currencies which entails that it might be useful to provide the airport with some facility for currency exchange.

Furthermore, origin-destination passengers have different expectations compared to connecting passengers. For example, the time they spend on the airport, waiting for their (connecting) flight, might differ. Then, they have a higher need for retail or food and beverage facilities. The level of connecting passengers at an airport can be influenced by the airlines strategy. If an airport is an hub airport, the level of connecting passengers will also be higher. Also then, good signposting is essential. A study from the Civil Aviation Authority (2008) showed that at airports with capacity constraints, the level of connecting passengers will be lower due to the fact that they generate lower yields compared to point-to-point passengers[14].

Given the different willingness to pay between business and leisure travelers, the airport has to adopt their pricing strategy. On operational level, since for business travelers time is money and they will want to spend their waiting time as productive as possible, they are also in need of business lounges, a good wifi-connection etc. If the level of leisure travelers is higher (e.g. at airports located at touristic destinations), the retail has to be abundant.

[14] A second explanation for this phenomenon might as well be that large airlines prefer less congested airports to serve as their hub.

1.3.2 Cargo

Also for cargo, this section will describe the characteristics and different types of cargo, the way cargo is handled at an airport and what impact this all has on airport (operations). Furthermore, this section also addresses the trucking of air cargo, i.e. transportation of cargo by road, under airway bill.

1.3.2.1 Cargo characteristics

The shipment by air of many different products can be summarized under the name of air cargo. It comes in different dimensions, weights and values and it requires specific handling and storage. (Dewulf, Van de Voorde, & Vanelslander, 2009; Kupfer, Meersman, Onghena, & Van de Voorde, 2011)

Regarding cargo, there is a lot of competition between the different modes. Wensveen (2011) states that "*it costs far more to operate an airplane than to run a truck*, *ship or railroad car*"[15], meaning that the cost per unit of air cargo is larger than that of any other transport mode. Therefore, there has to be a compelling reason for customers to use air services. The speed with which air cargo can be transported, is advantageous. Due to the short delivery time, air cargo suits perfectly with the Just In Time principle. So, using air transport to carry cargo also offers the possibility to eliminate the cost of carrying inventory. (Wensveen, 2011)

Another advantage of air cargo is the safe and secure way in which the freight and mail is transported. Air transportation is a mode with a low risk of damage to the goods thanks to the fact that there is no en route handing and that there are little periods in which the goods are under minimum security. (Wensveen, 2011)

Although the high transport expenses can be traded off against cost savings on other fields, the cost of air cargo is still high. Only a limited number of goods are shipped by air (Kadar & Larew, 2004). In terms of weight, Boos (2015) states that in Germany 2% of all tonnage is transported by air. However, in monetary value, 30% of all transported goods are transported on a flight. Martini (2015) indicated that in the US in value 25-30% of all goods transported are air cargo but that they only represent 1% of all tons transported. This shows that goods transported by air are of high value in monetary terms. However, also goods with a high value

[15] Air transport experiences competition from land modes for travel distances of 1000 miles or less.

of time are shipped on a flight. For example, computer companies regularly ship by air because the added cost of air transportation is more than offset by getting the product to market and into service earlier. Shippers of perishables - such as fresh fruits, flowers and fish - use air transport because they have no other way to reach their worldwide markets. (Wensveen, 2011)

To generalize, Wensveen (2011) concluded that shipping commodities by air is the most desirable form of distribution when one or more of the following characteristics is present:

- When the commodity is
  - Perishable
  - Subject to obsolescence
  - Required on short notice
  - Valuable relative to weight
  - Expensive to handle or store
- When the demand is
  - Unpredictable
  - Infrequent
  - In excess of local supply
  - Seasonal
- When the distribution problems include
  - Risk of pilferage, breakage of deterioration
  - High insurance costs for long in-transit periods
  - Heavy or expensive packaging required for surface transportation
  - Need for special handling or care
  - Warehousing or stocks in excess of what would be needed if air cargo were used

Another characteristic that has to be added here, is for the transportation of cargo, the airplane is not only a chosen mode, but also a necessity. Remote regions with bad transport infrastructure or islands often do not have the option to transport cargo in any other way than through air.

An important characteristic on which cargo is different from passengers, is that the demand is asymmetrical. Passengers travelling to their destination have in most cases also a return trip booked, while cargo flows are more one-way. For example, the Middle East imports a lot of goods from the Western countries, but the export is mostly (crude) oil, which is transported by pipelines (Macário & Van de Voorde, 2010). A solution to this, is to set up triangular routing. (Dewulf et al., 2009; Kupfer, 2012; Pollack, 1977)

Moreover, cargo is also very volatile. The volume to be shipped is not known until the very last minute and also depends on other factors such as the number of passengers on board. (Kadar & Larew, 2004)

As for any freight transport, the size of the consignments is dependent on the measurements of the vehicle. For air freight, the cabin door size and cabin cross-section of the main deck of the aircraft will determine what size of consignment can be accommodated (Shaw, 2011). Air cargo can be transported in loose packages or transported on pallets which, for example can only be 1m63 high due to the measurements of aircraft loading doors. When transporting air cargo in containers, these have to be especially designed for air freight. Those aircraft Unit Loading Devices (ULDs) are contoured to the aircraft fuselage. Some ULDs are 2m44 or 3m in height. These containers can either be owned by the airlines and made available to the shipper on request, are purchased by the shippers for regular use or are rented from various sources (Wensveen, 2011).

1.3.2.2 Types of cargo

Concerning cargo, a difference between general cargo and express cargo can be made.

General cargo is the most common type of cargo; it has the highest share of revenue ton-kilometer, being about 84% (Kupfer, 2012). It holds individual shipments from many different customers, grouped together into one shipment/aircraft. The shipments often are of large volume, with a relatively low monetary value. Given its heterogeneous nature, general cargo is often transported by non-integrated air cargo service providers. Its transport entails diverse procedures that have to be followed, complex operations and information complexity regarding regulatory restrictions etc. (Onghena, 2013).

Express cargo shipments, on the other hand, are more homogeneous. This is cargo where the time value is even higher than for general cargo. For example packages that need to be at their destination the next day (such as documents, parcels, merchandise goods). The express cargo are often small in size, with a high monetary value and high willingness to pay. Express cargo is often transported by integrated cargo operators.

1.3.2.3 Cargo flow – before and at the airport

As can be seen in Figure 17, air cargo always starts its journey at the shipper from where it is transported either to the airport directly or to a warehouse (for consolidation). This transportation can either be organized by an integrator, which provides an integrated door-to-door service for cargo, using their own ground fleet, own terminals, own long-haul truck fleet (for transportation between terminals) and own air fleet (for transportation between airports) (R. W. Hall, 2002). Or it can be done by a (separate) transport company, often appointed by a forwarder.

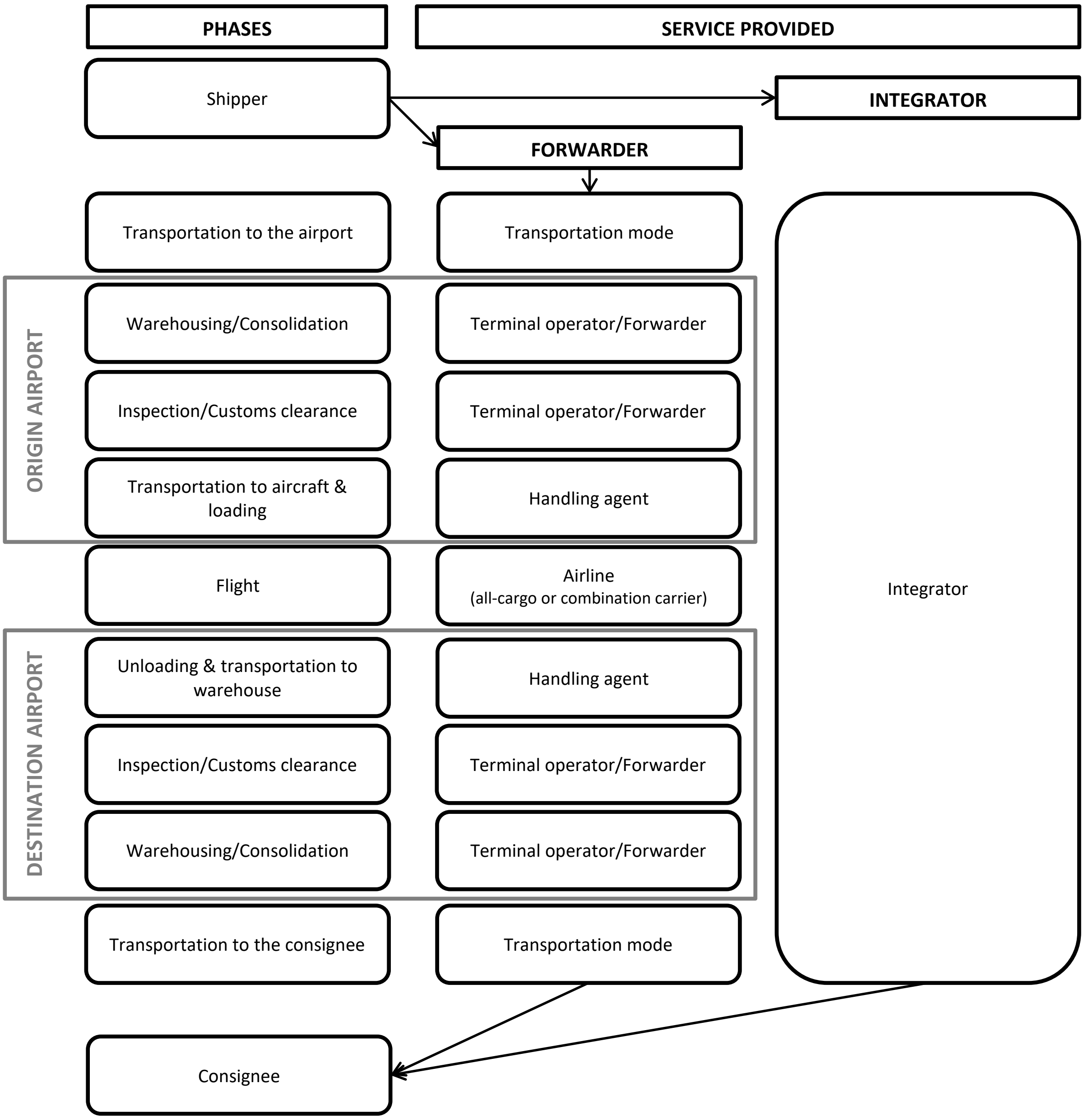
Arriving at the origin airport, the cargo can be stored in warehouses or consolidated before it is placed in the aircraft by a handling agent, who is also responsible for the transportation between terminals and apron. The transportation of the cargo by air is then done by an airline, either as part of the integrated service the integrator offers or by an all-cargo airline or combination carrier appointed by the forwarder.

When arriving at the destination airport, the handling agent unloads the aircraft, transport the cargo from apron to terminals where it can be stored again or consolidated into other consignments before it is transported to its final destination. Also here, the transportation can be done either by the integrator or by a transport company, possibly appointed by the forwarder. Before and after air transportation, the cargo might have to be inspected and has pass customs clearance.

So, to conclude, when a shipper wants to send some cargo, in most cases, he either appoints an integrator of a forwarder to organize the air transport of the goods. The integrator offers a door-to-door service on its own, while the forwarder acts as a booking agent, managing the entire cargo shipment process, by appointing airlines and other transportation providers[16]. The airlines, which can be represented by general sales agents, offer airport-to-airport services as subcontractors and often have no commercial relationship with the end customers. (Dewulf, 2014)

[16] The forwarder can also offer other services such as warehousing or customs clearance. Moreover, also some other cargo services (e.g. un- and repacking) which are normally carried out by the airline or the handling agent, can also be done by the forwarder. This trend has come up due to dissatisfaction regarding slow handling. (Kupfer, 2012)

Figure 17: Different stages of cargo travelling by plane



Source: own composition

1.3.2.4 Impact on airport (operations)

The airport is the place where the actual transportation of cargo by air starts, they are the infrastructure providers to airlines. Airports have to compete each other by offering seamless flows: good slots, good facilities and a good connectivity (Dewulf, 2014). Airports are judged based on their performance (ground and other services), value (rates, value added programs, …), facilities (apron, warehouses, …) and the regulations that apply.

Depending on which airlines the airports serve, and thus which types of goods are most commonly transported through the airport, the airport has to offer different resources. Especially airports which are mainly served by integrators and thus handle a lot of express cargo, have to have some specific characteristics. They have to be geographical centrally located, be rather uncongested and have to have good access to road and hinterland. Given the time sensitive nature of the express cargo, the airports also preferably offer 24h services and have sufficient infrastructure to handle incoming and outgoing aircraft simultaneously (Allaz, 2005). Integrators tend to link their services to one airport which is their hub and on which they have invested in some infrastructure.

When airports are served by airlines that transport live animals, they have to have resources to deal with that type of cargo. Also when perishables or refrigerated cargo is transported through the airline, dedicated resources have to be available.

At some airports, there is a dedicated area for the handling of cargo. This entails that (most of) the airside infrastructure is used by both passenger and cargo operators, but that after landing, cargo is handled separately from passengers. The handling of cargo then involves other resources and stakeholders. For example, cargo is then handled by other ground handlers than those responsible for passenger aircraft handling. Brussels Airport, for example, has a dedicated cargo zone, i.e. Brucargo, which holds cargo warehouses, offices and even a cargo apron and freighter parking stands. Cargo transported in the belly of passenger aircraft is thus transported to the cargo-zone after unloading it from the aircraft and is handled there.

A separate cargo site is an interesting option for airports which are served by a lot of all-cargo aircraft or for airports where a lot of extra cargo activities (e.g. consolidation) are carried out.

1.3.2.5 Trucking of air cargo

A lot of air cargo is also transported by road. Road transport is used for hinterland distribution from airports, but also for feeder traffic to airports and for transportation of air cargo between airports. In the latter case, the cargo is transported under airway bill and is called Road Feeder Services (RFS). The importance of RFS is growing worldwide and especially between the large hub airports in Europe. Airlines decide to complement their air network with RFS since trucking is cheaper than flying, more flexible and on short and medium distances often faster due to its door-to-door nature (Grandjot, Roland, & Roessler, 2007). Next to these advantages, RFS also play an important role in the hub- and-spoke networks of airlines since they are used to feeder the large hub airports from the small, regional spoke airports.

1.4 Airlines

The airlines are the other stakeholder of the two-sided market the airport is confronted with. Since airlines are companies, they also follow a certain strategy. This strategy can influence that of the airport and therefore, the organizational structure of airlines is described here. The types of airlines are described, followed by the types of aircraft they use (i.e. their production factor “capital”) and the organization of their networks. These elements are linked with the output related cost economies that they experience and thus the influence they might have on the airport and its economies of scale and/or scope.

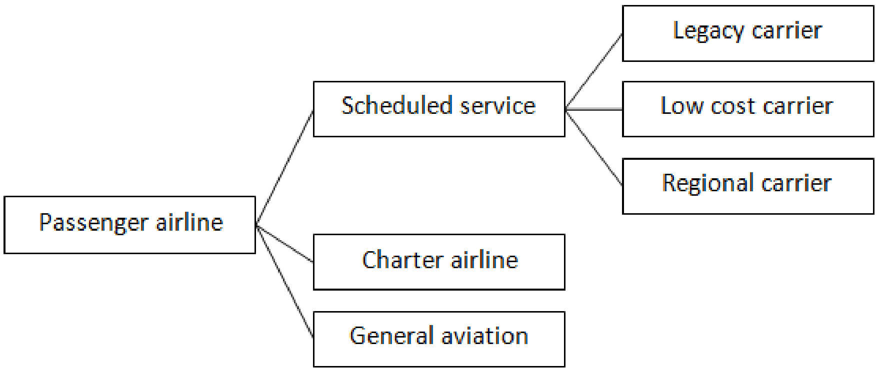
1.4.1 Airline typology

Airlines can be classified according to many variables: the customers they serve (passengers and/or cargo), the distances they fly (short, medium or long haul), the frequency of their services (scheduled or non-scheduled)… Given the fact that in this dissertation the emphasis lies on the interaction between passengers and cargo, this division shall be retained. Nevertheless, the other variables will be discussed briefly.

1.4.1.1 Passenger airlines

Obviously, passenger airlines are airlines that transport passengers. The largest passenger airlines offer scheduled transport services, meaning that it is open to the general public and operated according to a published timetable or with such a regular frequency that it constitutes an easily recognizable systematic series of flights (Eurocontrol, 2015a).

Figure 18: Types of passenger airlines



Source: own composition

Legacy airlines (or traditional passenger carriers) such as Brussels Airlines, Lufthansa, Air France or KLM operate on short, medium and long distances, often using a hub-and-spoke system (see section 1.4.3). Also low cost carriers or "no frills" carriers (such as Ryanair, Vueling or EasyJet) offer scheduled services, but they operate often from secondary airports[17] and on short or medium distances through a point-to-point system (see section 1.4.3). Regional carriers[18] are airlines that perform short distance flights between secondary airports using smaller aircraft to feeder for big airlines.

Next to scheduled services, organized flights without a fixed schedule are known as charter airlines. A typical example of chartered flights used to be the tour operators which sold "holiday packages" combining the flight, the hotel and possible activities within one booking. However, due to the emerging low cost carriers (LCC), the charter airlines had to adapt their

[17] It needs to be mentioned here that more and more low cost carriers also offer their services from larger airports. For example, Ryanair caused a lot of commotion when announcing that they would also offer flights from (and to) Brussels Airport, Rome Fiumicino and Lisbon.

[18] Regional carriers can be part of a legacy carrier. The same goes for low cost carriers.

business model and they now also sell flights separately. Examples are Jetairfly and Thomas Cook Airlines.

A third type of passenger airline is "general aviation". They offer private transport, often using small business jets. Also other non-commercial flights, such as sports aircraft or gliders are general aviation.

Most of the large(st) passenger airlines are part of an alliance, i.e. informal or formal arrangements between two or more companies with a common business objective (Czinkota & Ronkainen, 2004). Although alliances entail some risks, such as decreasing flexibility, emergence of a dominant partner, risk of takeover etc., there are also many advantages, being larger networks and thus better resistance against demand fluctuations, access to technology and know-how, … (Castro, 2002) This entails a convenience for the passengers in terms of connectivity (due to, amongst others, code share agreements) and advantage for airlines which increase the (market) power they have over the airports.

There are three big passenger airline alliances: Star Alliance (27 members[19] on 20/11/2016), Oneworld (14 members[20] on 20/11/2016) and SkyTeam (20 members[21] on 20/11/2016).

1.4.1.2 Cargo airlines

Traditional cargo carriers are only responsible for the air transport of cargo from airport to airport. The all-cargo airlines (or full freighter airlines, which are non-integrated), such as Cargolux, transport only cargo, mainly focusing on general cargo. They hold a freighter-only fleet and operate on scheduled and non-scheduled basis. An all-cargo airline can also be a subdivision of a passenger airline. Lufthansa Cargo is an example of this.

Next to these full freighters, express carriers and couriers handle express cargo. For these goods, speed is crucial. The largest difference between these two is that express carriers many

---

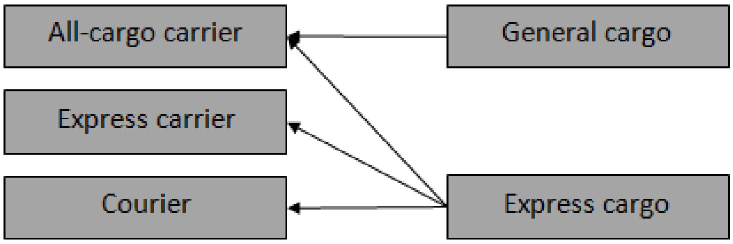
[19] Star Alliance members on 20/11/2016: Adria, Aegean, Air Canada, Air China, Air India, Air New Zealand, ANA, Asiana Airlines, Austrian, Avianca, Brussels Airlines, CopaAirlines, Croatia Airlines, Egyptair, Ethiopian, Eva Air, Polish Airlines, Lufthansa, Scandinavian Airlines (SAS), Shenzhen Airlines, Singapore Airlines, South African Airways, Swiss, TAP Portugal, Thai, Turkish Airlines and United.

[20] Oneworld members on 20/11/2016: airberlin, American Airlines, British Airways, Cathay Pacific, Finnair, Iberia, Japan Airlines, LATAM Airlines, Malaysia Airlines, Qantas, Qatar Airways, Royal Jordanian, S7 Airlines and SriLankan Airlines.

[21] SkyTeam members on 20/11/2016: Aeroflot, Aerolíneas Argentinas, AeroMéxico, Air Europa, Air France, Alitalia, China Airlines, China Eastern, Czech Airlines, China Southern, Delta, Garuda Indonesia, Kenya Airways, KLM, Korean Air, Middle East Airlines – Air Liban, Saudia, Tarom, Vietnam Airlines and Xiamen Air.

have small packages on board while couriers are rather specialized in last mile transport over short distances.

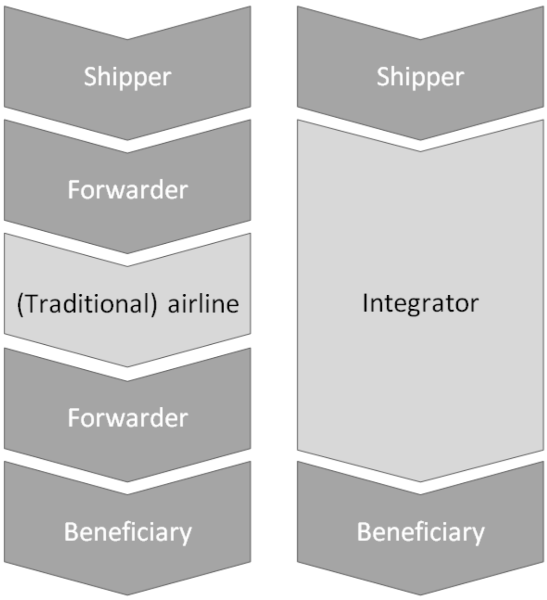
Figure 19: Types of cargo airlines



Source: own composition

As opposed to traditional carriers transporting between airports, integrators provide transport of general and express cargo from door-to-door, thus also provide pre- and post-haulage using their own ground fleet of pick-up/delivery trucks and long-haul truck fleet for moving cargo between their (own) terminals.

Figure 20: Traditional cargo carriers vs. integrators



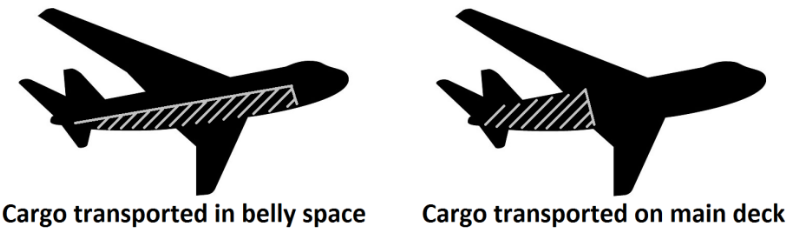
Source: own composition

Also for cargo airlines, alliance membership has quite some advantages. For example, alliances allow carriers to extend and optimize their network. Furthermore, the transshipment process, where the risk on delays is great, can be improved and traditional cargo carriers can stay competitive with integrators (Onghena, 2013). However, as opposed to passenger airline alliances, there is limited consolidation and only one[22] rather small alliance, being SkyTeam Cargo (11 members[23] on 20/11/2016). This is due to the non-transparency which is larger in the cargo sector than in the passenger sector, also involving a larger lack of trust among partners (De Wever, Martens, & Vandenbempt, 2005). The cargo market is thus a rather fragmented sector, meaning that the airline customers (forwarders and shippers) have a lot of buying power (Kadar & Larew, 2004).

1.4.1.3 Combination carriers

The third type of traditional cargo carrier are combination carriers, which combine the transportation of passengers and cargo, either in the belly[24] of the airplane or on the main deck, separated from the passengers.

Figure 21: Cargo in the belly vs. on the main deck



Source: own composition

Taking cargo on board, is for many airlines ideal to fill up free capacity and increase their profits. However, airlines must not want to use the spare capacity against all prices, because this would cause a downward pressure on the prices (Kadar & Larew, 2004).

Since combination carriers transport passengers as well as cargo, the airlines have to take into account the characteristics of both customers, which might conflict. Kadar & Larew (2004) state that cargo is still very dependent from passengers. In 2001, 48% of all cargo worldwide

[22] Until 2008, the second cargo alliance WOW Alliance consisted of 2 members: SAS Cargo Group and Singapore Airlines cargo. Also Lufthansa Cargo and JAL Cargo were former member of this alliance, but the alliance failed completely when Lufthansa Cargo withdrew itself.
[23] SkyTeam Cargo members on 20/11/2016: Aeroflot Cargo, Aerolíneas Argentinas Cargo, AeroMéxico Cargo, Air France/KLM Cargo, Alitalia Cargo, China Airlines Cargo, China Cargo, China Southern Cargo, Czech Airlines Cargo, Delta Cargo and Korean Air Cargo.
[24] Also passenger airlines can transport cargo in the belly of the aircraft.

was transported in the belly of a passenger aircraft. Since the focus of combination carriers is mostly on passenger transport, the airline will decide about routing, frequency etc. taking the passengers' preferences into account rather than those of the cargo shippers. Also, regarding capacity, combination carriers will decide on the aircraft chosen by taking into account how many passengers are willing to join the flight. This entails that the most important costs such as fleet and landing charges are thus driven by the passengers on board.

Depending on the amount of passengers on board, the free capacity for cargo[25] is then calculated, taking into account the volume of baggage, the free volume, the Maximum Take Off Weight (MTOW), etc. Furthermore, the amount of cargo that can be transported, depends upon the size of the aircraft: wide-bodied aircraft have a sizable lower deck to hold cargo, but narrow-bodied aircraft only have limited cargo capacity. For example, low-cost carriers using narrow-bodied aircraft have very limited lower deck cargo capacity once their usually full passenger loads and their checked bags have been taken into account. They then leave as little as 0.5 to 1 ton for cargo (Morrell, 2011). Wide-bodied aircraft can carry 25 tons or more of containerized and palletized cargo in its lower hold. Other wide-bodies have a cargo capability of 12 tons or more, depending on the passenger payload and the fuel needed (Shaw, 2011).

To determine passenger capacity only the weight is important. For cargo, also the volume counts. Moreover, there are some other differences airlines need to take into account when deciding to transport passengers and/or cargo. Cargo can be transported through many possible routes and consignments can be separated, while passengers want to get to their destination as soon as possible, together with their baggage and travel companions. Moreover, passengers book their flight well in advance as opposed to cargo shipments which are booked only a couple of hours before takeoff (Sandhu & Klabjan, 2006).

---

[25] The capacity available on an airplane, is measured in number of seats for passengers, but for cargo the weight and volume is important to take into account. The load factor is the output indicator comparing potential capacity to the used capacity. For passengers, the Revenue Passenger Kilometer (RPK), being the amount of kilometers all passenger fly for which the airlines receives revenue, is compared to the Available Seat Kilometer (ASK, i.e. the number of seats available and multiplied with the kilometers the aircraft covers). Analogously for cargo, the Revenue Ton Kilometer (RTK) is compared with the Available Ton Kilometer (ATK) to calculate the load factor. Not all capacity used, however generates income. For example, goods for development aid are flown but do not generate income. Freight Ton Kilometer (FTK) represents the amount of cargo carried, regardless the fact that it generated income or not.

Important to mention here, is that demand can be predicted, but the actual capacity needed is often unknown. Therefore, airlines overbook some flights in order not to fly with some empty seats. However, this entails that airlines are often confronted with spilling: when demand exceeds capacity, not all passengers can be appointed a seat. Moreover, a specific passenger niche market, i.e. business travelers, also book quite late. Although airlines would not want to miss out on the higher price business travelers are willing to pay, they must sometimes refuse high fare reservations due to prior low fare bookings. This is their spill rate.

Although passengers and cargo are thus very different, Boos (2015) adds to this that indeed passengers and cargo transport cannot do without each other. Cargo is dependent on passenger transport since, on average, this accounts for 89% of the revenue. But with cargo in the belly, more routes become profitable.

However, the biggest challenge for airlines, when combining passengers and cargo is that there is an imbalance concerning flows. Free capacity in passenger flights that is taken up by cargo, might not be filled on the return flight due to the asymmetric cargo flows. (Macário & Van de Voorde, 2010) Moreover, not all types of cargo are allowed in combination with passengers (Kasarda & Green, 2005).

1.4.2 Types of aircraft

As stated before, depending on the type of aircraft airlines chose for their flight, a different amount of passengers and/or cargo can be taken on board. Which aircraft airlines use, depends upon their planning. Here, they take into account the economic impact, the distance to fly, the frequency of flights, the airports they will serve, the connections and the network (Bhadra, 2010). Airlines usually own some aircraft of different sizes in order to be able to adapt their services to the uncertain (future) market (Wei & Hansen, 2007). Nevertheless, it might be of interest to have some degree of fleet standardization, meaning that an airline possesses, for example, ten aircraft of the same type. This in order to cut down on costs of maintenance, training, ground handling, etc. Moreover, when buying in bulk, an airline can receive a discount from the aircraft constructor (O'Connell, 2011). Airlines can thus realize economies of scale when buying aircraft.

Different aircraft are classified depending on their size and range. The size of the aircraft is described using some indicators such as weight, number of seats or cargo capacity. The range is the maximum distance that can be flown having a reasonable amount of passengers and/or cargo on board, without extra fueling. To indicate the range, terms such as “long haul” or “short haul” are used. An aircraft that is labeled as “large, long haul” is thus a large aircraft which can fly a long distance. On the contrary, a “small, short haul” aircraft is small and flies short distances.

Within one class, there are different aircraft possibly coming from different constructors. For example, a Boeing 737-800 and an Airbus 320 have the same characteristics (single aisle, two engines, same range and about 150 seats).

Cargo aircraft is classified according to the range and the loading capacity (in tons).

Boeing (2016) forecasts that in 20 years, there will be an in-service fleet of over 45,000 airplanes. To achieve that, more than 39,000 new airplanes will be needed, of which 71 percent will be single-aisles. Airbus (2016) on the other hand predicts demand for 33,070 new aircraft. The single-aisles represent 71 percent of units, while wide-bodies represent 54 percent of value.

Regarding the wide-body aircraft, decisions on ordering are based upon the versatility and thus the possibility to open new routes, go longer distances and provide the right amount of seats for the market. Boeing (2016) sees a move from larger wide-body aircraft to smaller wide-bodies. Airbus (2016) on the other hand predicts a trend towards larger aircraft, both in single-aisles and wide-body sectors, which is in line with the developments at world’s major airports where the average number of passengers per departure continues to rise.

New airplanes do not only add to the market, some of them are also to replace older models, e.g. due to maintenance requirements or high fuel costs. In the next 10 years, the number of aircraft entering the replacement zone will double. Boeing (2016) forecasts that airplane replacement will form 43 percent of demand during the next 20 years, which is somewhat higher than the 40 percent as forecasted by Airbus (2016).

Regarding cargo Boeing (2016) states that both passenger airplanes as well as dedicated freighters can carry air cargo. The lower-hold cargo capacity on passenger flights has been expanding, but dedicated cargo services offer shippers reliability, predictability and control over routing and timing. Therefore, freighters are expected to continue carrying more than half of global air cargo in order to satisfy the demanding requirements of the market. Airbus (2016) on the other hand stresses that belly capacity is increasing faster than cargo traffic (due to healthy passenger traffic growth) but that this is not always in line with the cargo intensive flows, thus stimulating dedicated freighter operations.

The type of aircraft landing on an airport has some consequences for the airport. For example, if airports are served by large aircraft, this has consequences for the airport configuration: the runway has to have the proper dimensions to receive large aircraft. (Pai, 2010)

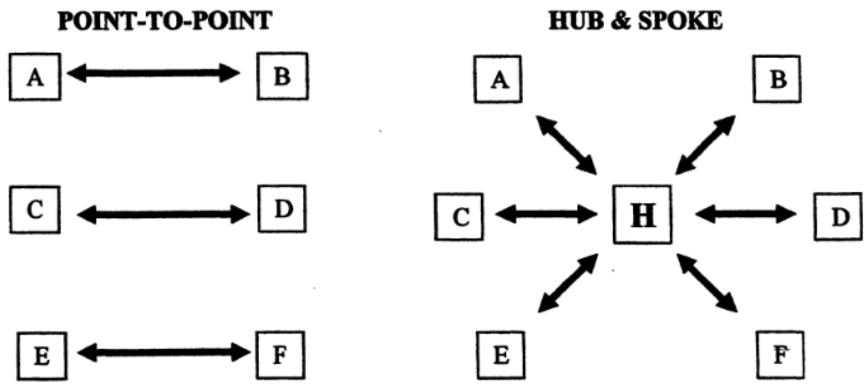
1.4.3 Organization of airline networks

As for any mode, also air transport involves air transport networks. There are many different ways in which these can be organized. One possibility is a point-to-point network where the airports are the origin or destination. For airlines operating in such a network, the travel time is minimized and handling of baggage is kept to the minimum. Moreover, the airlines do not need to take into account other flight schedules.

Another way transport networks can be organized, is as a hub-and-spoke network, where feeder flights are directed to one central hub. The advantage is that the network is in this way much more elaborate, although the transfer at the hub entails extra waiting time, extra handling and thus time loss.

Cargo as well as passengers can be transported through both types of network. For example, cargo integrators can fly cargo to a hub airport in case the volume is too low for an origin-destination flight. Then, the cargo is unloaded, bundled and sent off to their final destination. From the airports point of view, however, this transshipment activity is not very different from other cargo handling.

Figure 22: Point-to-point and hub & spoke architecture



Source: Cook & Goodwin (2008)

For airports, the networks of "their" airlines determine the amount of transit passengers compared to origin-destination passengers. Since these types of passengers have different needs, the transport networks also have an impact on the airports that are served. For example, given the extra waiting time of transit passengers, the airports will want to provide services to entertain the transit passengers.

1.5 Intermediate conclusion

This chapter showed that there are a lot of potential influences on the airport's strategy regarding passengers and cargo. Since the passenger market as well as cargo market are characterized by a growth on long term, both markets are interesting for airlines as well as airports. The shift towards the east (and to some extent towards the south) however alters the market which can result in challenges, i.e. (increased) competition, as well as opportunities, being (more) growth potential.

Airports might thus be inclined to try and attract passengers and cargo. Given their position in the two-sided market, they can do so by (adapting) their pricing strategy. They, however, also have to bear in mind that depending on which type of passengers or cargo they handle, this has some consequences for the airport (operations).

Since airlines are also part of that two-sided market, the strategy of the airlines influences the airport's strategy. Passenger airlines as well as combination carriers (can) combine the transport of passengers and cargo. Literature review revealed that airlines experience scope effects thus the combination of passengers and cargo leads to a decrease in costs compared to the separate transport of both commodities. Therefore, combining passengers and cargo is interesting cost wise. Moreover, literature showed that airlines experience constant returns to scale, but increasing returns to density. Meaning that for airlines it is more interesting to increase the density of their network rather than to increase the scale of their operations[26]. They can do so by increasing their flight frequencies or by the use of larger aircraft. This way they can transport more passengers and/or cargo on their existing network.

Increasing flight frequency however is dependent on the slots the airline has (see section 2.3.1), while using larger aircraft entails large costs in case new aircraft is bought. Moreover, there is a time lag for the delivery of new aircraft. Airlines can avoid this problem by switching aircraft between routes, if possible. For example, aircraft that is never fully booked on one route can be exchanged by the aircraft that is overbooked on the upcoming route.

Airlines increasing their network density obviously entails a larger passenger and/or cargo influx for the airports that are served by those airlines. The economies of scope which airlines experience enlarge the chance that passengers and cargo are combined by airlines.

Airports are thus possibly “forced” to handle both passengers and cargo because of the airlines serving the airport. However, keeping the two-sided market in mind, airports can still influence the passengers, cargo and airlines they want to handle by charging them appropriately. The question thus remains who is more powerful and who influences whom: the airlines or the airport?

[26] Obviously, the density of a network can only be increased up until a certain point. At some level, airlines will have to expand their network if they want to increase the scale of their operations further.

2. Airports

The previous chapter showed external reasons that affect the airport's strategy to combine passengers and cargo. However, the airport operational or financial structure might also give them reason to combine both commodities.

To discover these internal reasons, the airport structure and operations are described in this second chapter. Since the airport is the focus of research in this dissertation, first, a definition and typology are given (section 2.1). Section 2.2 gives an overview of airport ownership and management, while section 2.3 analyses airport capacity. Sections 2.4 and 2.5 describe the airport activities and resources necessary to perform those activities. Leading to an analysis of the airport cost structure in part two of this dissertation (Chapter 3).

2.1 Definition and typology

In the context of the two-sided market, the airport is the platform where airlines and their customers meet. And within the Convention of Chicago[27], the concept "airport" is defined as "*a delimited area on land or water used for departure, arrival or movement of aircraft, potentially including building, installations and material*".

Although this definition is rather concise, it comprises many different types of airports. An airport typology can be drawn up based on different characteristics. A classification based on the purpose leads to a differentiation between civil and military airports.

Second, there is a difference in airports regarding the network effects. As shown before, an airport can be an origin-destination airport, where passengers start or end their journey, or a transit airport, i.e. an airport where passengers travel to in order to catch a connecting flight. Mayer & Sinai (2003) define hub sizes depending on the number of connecting flights. A third way to classify airports is to look at the scope. An airport is classified as national or international, depending on the destinations offered. Sometimes, also the term "regional airport" is used. However, the term "regional" refers to the distance flown, while

[27] The Convention of Chicago (7th of December 1944) was a meeting of 54 national governments where international cooperation regarding uniformity in rules, regulations, procedures and organizations for civil aviation was assured. For this purpose, 96 articles were drawn up. The Convention was only obtained with the signature of 26 countries. Today, 188 countries have signed the Convention, with the main purpose being the definition of standards and recommended practices. The organization ICAO (International Civil Aviation Organization) originated from the Convention of Chicago.

“(inter)national” indicates the geographical location of origin and destination[28]. A fourth possible distinction can be based on the technical characteristics. The performance and the dimensions of the aircraft provide them with a Aerodrome Reference Code. By use of a code number and letter, airports are classified on whether or not they can receive a type of aircraft; this depends for example on the dimensions of the runway (ICAO, 2013).

Another possible classification variable is the equipment present. Some airports have instrument runways, which are equipped to guide takeoff and landing. A distinction can also be made based on the focus airports have, being either passengers, cargo or both. This influences the resources needed. For example, in case the airport also handles cargo, some specific inspection resources might have to be installed. If passengers are absent at an airport, for example retail becomes redundant.

Finally, the typology might also differ depending upon the amount of output they generate.

2.2 Airport ownership and management

Originally, airports where built by governments, either national, regional or local. Also the management was then undertaken by the state, directly or through a public sector administration. Yet, since the 1980’s, there was a movement towards private sector involvement and corporatization of the management. This in order to raise funds for the public sector (through the sale of the assets), with the assumption of increase efficiency and with the opportunity to support the investment in airport infrastructure. The upcoming trend of privatization however increases the need for regulation (see also section 3.2.3).

The extent to which the private sector is involved, varies greatly among airports. ICAO (2008) stated that the most common form of airport ownership is an autonomous airport entity, stepping away from government ownership. However, a study, carried out by Steer Davies Gleave for DG Move European Commission (2016), showed that 15 percent of all airports

[28] National flights are flights that have their origin and destination within one country, while regional flights are flights that are performed over a short distance. National flights can thus be regional flights and vice versa, but not necessarily. In large countries, such as the US, a national flight is not necessarily a regional flight. For example, flights from Miami to Los Angeles are national but not regional. Flights from Miami to Orlando are national and regional.

worldwide are fully privatized, 18 percent are in public-private partnership but still 67 percent are owned by the public sector. Yet, the privatized airports account for 50 percent of passenger traffic worldwide, which shows that mostly major airports are privatized.

The management style of the airport in public ownership is rather bureaucratic, with an emphasis on conformity to regulation (DG MOVE, European Commission, 2016), while the involvement of private interests in airport operations strengthens the trend towards commercialization (ICAO, 2008). This entails a focus on enhanced revenue generation or a greater effort to increase the level of non-aeronautical revenues[29] (e.g. retail, parking), while also managing the operating costs through reducing the in-house workforce, a.o. through outsourcing of activities such as ground handling, terminal services or airport security. Moreover, those private airports also want to improve performance with respect to service quality. (DG MOVE, European Commission, 2016)

Research shows that US airports are typically owned and operated by a public authority (with some outsourcing to airlines or other contractors) and that also in the future, full privatization continues to be very rare. In Europe, on the contrary, the movement towards additional private sector involvement continues and in Asia and some parts of the Middle East, programs for privatization have been launched.

Another trend that will remain is those of the major airport investment groups. They act as private investors, often in partnership with financial institutions or investment funds. Good examples of this are Aéroports de Paris or Fraport. These airport owning groups often work with an airport operator for the management of the airport and some investor providing financing. This trend also entails more and more uniformity regarding airport ownership and airport management: more and more (major) airports are owned by the same group and thus are managed in the same way.

[29] This obviously is also dependent on other factors such as the regulation/tariff policy applied and the potential for non-aeronautical revenues which is linked to the type of customers the airport serves and the space available. (DG MOVE, European Commission, 2016)

Irrespective of the different types of airports, the type of ownership or the type of management, all airports are organized using a Master Plan. This document describes the airports' long term vision, as a guide for further development. The Master Plan comprises the lay-out of the airport and the accessibility, prioritizes the plans of improvement, looks at the environmental impact and the financial viability. It actually describes the airport capacity. How the airport uses this capacity, determines its performance.

2.3 Airport capacity

The airport's maximum capacity is determined by the characteristic which is the bottleneck. Such a bottleneck can be found on many different levels. The lay-out of the airport is a first important variable which can determine the airport capacity. The airside infrastructure, the lay-out of the airport buildings, the airspace and the connection with the hinterland can also affect the amount of aircraft, passengers and/or cargo the airport can handle.

2.3.1 Airside infrastructure

Concerning airside infrastructure, being runways, taxiways and the apron (incl. parking stands), a first possible determinant of airport capacity is the lay-out of the runways. The options for take-off and landing are restricted by whether the runways are parallel or not and by the wind direction. In case of parallel runways, independent operations are possible. Moreover, aircraft should take off with head wind and avoid side winds. Also the vortex should be taken into account. Aircraft engines cause rotating air behind the aircraft, endangering following aircraft. Therefore, airplanes should keep a distance when landing or taking off and this causes some "time loss".

Slot allocation

Furthermore, runway capacity distribution is based upon slots. A slot is a permission to use the runway (and other airport facilities) at a given time, for which the rules and regulations are based on IATA principles (see IATA Worldwide Slot Guidelines (2015)). These slots are, on a primary market, distributed by an independent coordinator, to the airlines wanting to offer their services from an airport for one season, being about 6 months. Incumbents can benefit from historic rights. These "grandfather rights" entail that, if allocated slots are used 80% of the time, they will be allocated to the airline again the next period. Holders of grandfather rights have also the benefit of first choice over others if slots need to be changed in time or place. There are differing views on the issue of grandfather rights. On the one hand, new entrants claim that they deny them the opportunity to enter the market and compete against major carriers. But incumbent carriers, i.e. holder of the grandfather rights, argue that the system maintains stability and continuity in scheduling. (Pagliari, 2001)

Unused slots end up in the slot pool, as do newly created slots through increases in hourly schedule limits, slots returned voluntarily and slots otherwise unclaimed by anyone. Those slots are then allocated free of charge by the slot coordinator, twice per year. In an effort to encourage competition and new entry, 50% of the slots are allocated to newcomers. However, a large percentage of these slots are believed to be of limited commercial value and the number of slots available may not be sufficient to secure the scheduling of a new route. (Matthews & Menaz, 2003)

Transferring slots is only allowed under specific conditions, but redistribution between airlines (or slot trading on a secondary market) is encouraged. This can be through slot exchange or monetary trading[30] and grasps also the economic importance of slots.

The current system of slot allocation at most airports is widely viewed to be economically inefficient because it does not adequately reflect the scarce nature of airport slots and does not include an explicit mechanism for ensuring that slots are allocated to those who attach the highest value to them. A number of alternative systems can be proposed: they could be priced to better reflect their value and opportunity cost, auctioned so that the actor who can best utilize the resource is the optimum bidder or, as mentioned before, traded on a secondary market following an administrative allocation, whereby the trading of slots could enable achievement of a more efficient outcome. (Matthews & Menaz, 2003)

A straightforward approach to pricing would be to differentiate the price between periods (i.e. different times of the day, different days of the week and during different months of the year) entailing more efficient use of scarce airport capacity since the demand for slots is rescheduled. Also slot trading improves efficient allocation of scarce airport capacity since the users of grandfather rights are then confronted with the true opportunity cost of the slots held. (Matthews & Menaz, 2003)

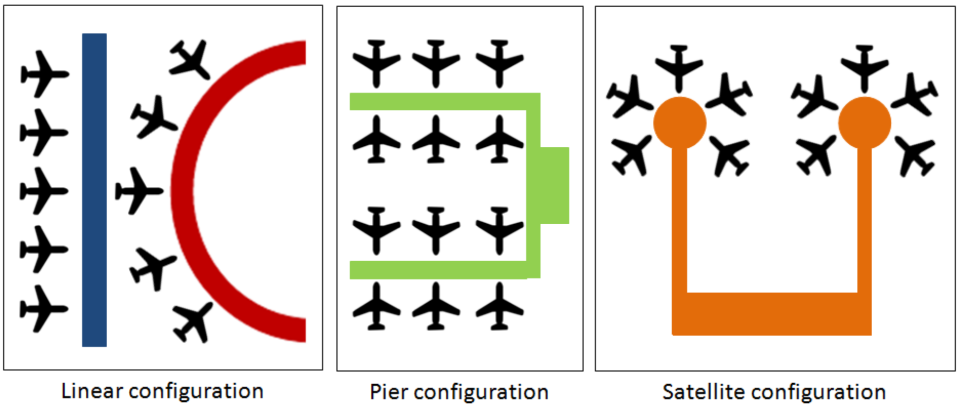
[30] Such a market has existed for a number of airports in the USA since the mid-1980's but a secondary market involving monetary payments remains illegal in the EU. (Matthews & Menaz, 2003)

2.3.2 Airport buildings and site

A second possible capacity determining factor is the lay-out of the airport buildings (incl. equipment). The airport building configuration determines the number of aircraft that can be served. There are several configuration options (see Figure 23) . In case of a linear configuration, the walking distances are kept small and the costs for security, check-in are raised and those of retail are lower. This option is fitted for small airports with limited number of aircraft. Airports with several piers offer the possibility to, for example, board passengers on both sides of each pier, therefore multiplying the number of aircraft that can be handled. Satellite stations have a similar configuration, but gates are located at the end of the piers, offering an even larger capacity. A disadvantage of these configuration is however the long walking distances passengers have to cross.

Airports can also have remote stands to which passengers are transported by busses. These remote stands offer a solution in case of peak traffic and are cheaper than bridges.

Figure 23: Airport building configuration



Source: own composition

The lay-out of the airport site also determines the airport capacity. If an airport holds separate cargo site (see also section 1.3.2.4), all cargo facilities are located separately from the passenger facilities, meaning that the capacity to handle cargo is larger, a.o. due to the fact that the operations are more efficient.

2.3.3 Airspace – Single European Sky

Another possible capacity influencing variable, is the airspace, which is under control of the air traffic controller. Airspace is limited by some regulated restricted zones on the one hand and by its own organization on the other hand. The restricted zones are dedicated to military aviation and thus off limits for other air traffic. The way the airspace is organized involves predetermined routes on which can be flown. The airspace above a country is supervised by the national air traffic controller. In Europe, this has led to fragmented air traffic control and inefficiencies and delays. In combination with the growth of air transport this caused congestion. Therefore, 38 countries (27 European and 11 non-European countries) opted for the Single European Sky (SES). The SES is a cross-border cooperation that organizes the European airspace into nine functional airspace blocks, according to traffic flows rather than to national borders, and thus taking into account the operational needs. In 1999 the European Commission took the first steps aiming to create additional capacity and increase the overall efficiency of the air traffic management system (Decuyper, 2015; Eurocontrol, 2015b). The second and third packages ("Single European Sky II" in 2009 and "Single European Sky II+" in 2013) changed the focus from capacity to performance in general and refined the approach, mitigating overlaps in legislation (European Commission, 2015).

Next to this, the airspace is also limited by the regulation regarding noise and by the weather.

2.3.4 Connection with the hinterland

Lastly, the connection with the hinterland could have some influence on the capacity. Airports are accessible through private transportation (e.g. car) or by using public transport (e.g. train, bus, tram). Here, the network leading to the airport and the travel time are crucial. In case of private road transport, also the available parking spaces are important. For public transport, the comfort of travelling, the frequency, the ticket price and the distance to the airport building are of influence. Given the fact that airports are often located at more distant sites and that congestion increases, the travel time rises.

Also for cargo, a good accessibility is very important. In her dissertation, Kupfer (2012) stated that good connection with other modes of transport is necessary, but good access to road networks in particular is seen as important by airlines. Cargo airlines want to be able to access the market. Gardiner et al. (2005) showed that market access is even more important than the proximity of the market itself, since good market access expands the catchment area and enables cargo consolidation from a wider area. Furthermore, Kupfer (2012) also stresses that road access is especially important to smaller regional airports specialized in cargo traffic. Those airports are often also congestion free on the airside (as opposed to many large(r) airports) so a low congestion level on the landside would increase their competitive advantage.

Nowadays, all airports are accessible by road. However, also access by other modes has to be considered. Kupfer (2012) refers to Page (2003) when stating that airports that neglect trucking and rail could miss out on about 80% of the opportunities to attract cargo.

This is obviously also linked to the issue of trucking air cargo (see section 1.3.2.5).

2.4 Airport activities

Given their capacity, airport management will set up activities to attract customers. They do this in cooperation with the stakeholders mentioned in section 1.2.1 (being airline/service stakeholders, commercial stakeholders and administrative stakeholders).

Since the main role of an airport is to serve as platform where the airlines and their customers meet, the core activity the airport offers it that of aviation. This entails that the airport management facilitates air travel through establishing the contact between the transport providers and their customers (i.e. passengers and/or cargo). The role of the airport is then providing the aeronautical infrastructure and services to both the airlines and their customers. The airport can choose to offer this themselves and/or rely on the third party providers (i.e. air traffic control, ground handling companies, fuel providers, catering companies, companies in charge of maintenance and repair and cargo operators).

The last few years, in line with the movement toward more private sector involvement, the airport business environment has evolved, meaning that airports also pay more and more attention to other activities, next to their main activity of aviation. So, jointly with the commercial stakeholders, the key activity of aviation is complemented with providing consumer products and services. Guaranteeing accessibility through providing parking spaces, offering food and beverages and some possibility for shopping is part of the commercial service the airport offers.

Airports might also engage themselves in the activity of developing and managing real estate. Buildings developed can be rented out as office space or for other purposes.

Which activities the airport offers and to what extent they rely on third party providers differs between airports. For example, a lot of regional airports have little to no commercial space, while some big airports develop into airport cities – incorporating industrial parks on site and huge landside development projects – or even hemispheric hubs – which also include regional intermodal operation terminals (Kasarda & Green, 2005; Marques & Galves, 2008).

The activities in itself are no cost drivers. The costs the airports bear, depend upon the resources needed for the activities.

2.5 Airport resources

The resources required for the airport activities can be divided into three different categories: physical infrastructure, human resources and other resources.

All airport customers have some basic needs regarding infrastructure which have to be fulfilled. For the airlines and service stakeholders, this involves aeronautical infrastructure, i.e. the core of the airport: runways, taxiways, apron, parking spaces for aircraft, etc. These assets are often provided by the airport itself and therefore available in most (if not all) airports. As already mentioned before (see section 1.3.2.4), some carriers might require some additional infrastructure. For example, in order to ship live animals, an airport has to be equipped with an inspection station dedicated to this type of cargo. Next to that, also landside infrastructure is indispensable. Passengers passing through the airport directly need landside infrastructure to access the airport and an airport building in which they can spend their time waiting until the flight departs. The terminal building holds services and infrastructure provided by the airport: check-in desks, safety and security, baggage claim units, gates, etc. Furthermore, also other buildings beside the airport terminal such as offices and warehouses might be needed by the carriers.

The resources listed above are indispensable, basic resources which the airport cannot do without if it wants to offer the activity of aviation. As stated before, airports might also offer infrastructure to complement the activity of aviation. For example, some of the floor space of the terminal might be occupied by shops or locations for food and beverage. Also here, the type of customers the airport serves is often determining for the complementary resources (see section 1.3.1.3).

Next to these tangible assets, airports can rely on human resources. Staff members are needed to make the airport operational. Here, it is important to bear in mind that quite some personnel handling passengers and/or aircraft is not employed by the airport itself, but by the third party providers such as the airlines for the check-in, the ground handlers for the baggage handling, the retailers for the shops, etc. Next to this operational staff the airport also employs also maintenance staff and administrative staff.

And finally, there are other resources which are essential. Most importantly is the resource "land", a resource the airport can clearly not do without. Moreover, providing airport activities also requires some energy (such as electricity, water, gas). Furthermore, the airports are also in need of materials etc. to perform their activities.

Table 11: Overview of airport resources

Infrastructure (airside & landside)	**Human resources**	**Other resources**
(amount of) Control tower(s) Runway (area) Taxiway (area) Apron (area) (amount of) Parking places aircraft Fuelling equipment Catering equipment De-icing equipment Storage/warehouse (area) (Pax/cargo) safety & security infrastructure Terminal (area) – Retail & offices (amount of) Gates (amount of) Baggage belts/claim units (amount of) Check-in (desks) (%) Retail (area) (amount of) Parking places	(amount of) Employees – operational, maintenance, administrative	Airport area (= land) Energy Other; such as materials etc.

Source: own composition

Given the fact that the airport does not offer all resources itself, it does not have to bear all the cost itself. In part two, an overview of the airport financial structure will be given.

2.6 Intermediate conclusion

The organizational structure of the airport holds a lot of elements that influence each other. The type of airport determines which customers or service providers the airport will attract or will need to attract. This influences the activities the airport offers and thus which resources are needed.

The type of ownership influences the management style and this might influence the activities the airport focuses on.

The resources available determine the airport capacity, which – in its turn – affects how many customers the airport can handle. Depending on the number of customers or the type of customers, other activities or extra resources are needed. For example, large passenger airports are in need of (a lot of) retail, while large cargo airports require warehouses and other cargo equipment.

To summarize, the organizational structure of the airport determines the resources needed. And since these resources come with costs, the organizational structure also affects the financial structure and thus the potential existence of cost economies.

Part 2 – Cost analysis

This part deals with the cost related topics. The financial structure of an airport will be described (Chapter 3) before addressing the theoretical background of cost functions and cost economies (Chapters 4 and 5). This all with a view on understanding (the methods used in) the empirical analysis.

Chapter 6 then explains the econometric analysis that is carried out to estimate a translog cost function and a quadratic (cost) function for airports. These estimations reveal the results regarding the existence of economies of scale and economies of scope at an airport.

3. Airport financial structure

The resources needed for the activities, as described in section 2.5, represent the cost drivers at an airport. The three categories of resources (physical infrastructure, human resources and other resources), reflect three categories of costs: capital costs, labor costs and other costs (or "soft costs"). The costs incurred can then be borne relying on aeronautical and non-aeronautical revenue or other funds.

3.1 Airport costs

Before going deeper into the airport costs, first the difference between costs and expenses needs to be explained. When a company, in this case an airport, invests in some asset, this entails a (single) expense, a cash flow. However, this acquired resource then represents costs for several years. For example, the acquisition of a (terminal) building entails a cash flow of several thousands (if not millions) of euros (or any other currency), but represents in the balance sheet a capital cost for several years, e.g. the depreciation of the building.

Based on the resources a company uses, there are three types of costs: capital costs, labor costs and other costs.

Capital costs are costs incurred by the ownership of infrastructure, being land and buildings as well as machinery etc. Next to these infrastructure related costs, salaries of staff represent the labor costs. Here, a difference between three types of personnel can be made: operational staff, maintenance staff and administrative staff.

Finally, there are other costs which are not capital or labor costs. These costs are classified under the heading of "soft costs" and are, for example, energy (electricity, water, gas) costs, material costs (furniture etc.) or costs for general airport services such as cleaning.

Some of the costs described above, can be clearly attributed to a certain output; these costs are direct costs. Other costs, e.g. administrative labor costs, need to be allocated to the different outputs. These costs are indirect costs.

The classification of costs as described above applies for all possible companies, so also airports. However, it is important to bear in mind that the actual costs can be different for each company. Costs borne by one airport might not exist in other cases. For example, the resource "land" is in some cases provided for free by the government, but there are also examples (e.g. Brussels Airport) where the airport has to acquire the land. This then represents an expense and costs.

The three types of costs described above are all related to one another: acquisition of the resources entails expenses and capital costs, but those resources need to be operated and maintained (which causes labor costs and soft costs). In a setting where there are different stakeholders present, working together, different stakeholders might bear different costs. For example, one stakeholder can be responsible for the acquisition of the resources, hereby bearing the expense and capital costs, while another stakeholder is in charge for the operation and maintenance, bearing the labor and soft costs.

This is also the case for airports. Also here, there are different stakeholders present (see section 1.2.1). Often, the airport is in charge of provision and maintenance of the infrastructure, while some service provider is responsible for offering the service itself. Then, the capital costs are borne by the airport, the labor costs and soft costs related to maintenance are borne by the airport but the service provider bears the labor costs related to the operation. Moreover, the service provider also pays a price to the airport for the use of capacity.

In some cases, the service provider might be entirely responsible for the service/activity offered and has to bear all the costs. Table 12 offers an overview[31] of what is explained above. The resources needed are presented in the first column, taking into account the different stages of an airport visit. The second column then shows who is responsible for providing the resources, bearing the capital costs.

The stakeholder responsible for the maintenance of the resources, bearing the accompanying labor costs and soft costs, is listed in column 3.

The last column then indicates who is in charge for the operation of the resources, bearing the labor costs that come with this.

[31] The overview in Table 12 describes the situation as applicable in most cases/airports. There are many different varieties possible. For example, also airlines or forwarders can build their own terminal or warehouse on airport ground, which they e.g. have leased. Or in some cases, the airport itself might act as handling company.
Moreover, there might be differences between different continents; e.g. the situation for European airports might be different from that for US airports or airports from Asia.

Table 12: Cost structure of an airport

Resources needed	Stakeholder responsible for… Provision of resources → *Bearing capital costs*	Maintenance of resources → *Bearing labor costs & soft costs*	Operation of resources → *Bearing labor costs*
Land	Government/airport	Airport	*(N.A.)*
Arrival at the airport			
Entry roads	Airport	Airport	*(N.A.)*
Parking	Airport	Parking company	Parking company
Public transport service	Airport/Transport provider	Airport/Transport provider	Transport provider
Check-in and baggage			
Terminal[32]	Airport	Airport	*(N.A.)*
Check-in facilities	Airport	Airport	Airline/handling company
Baggage conveying and sorting facilities	Airport	Airport	Airline/handling company
Security			
Security service	Airport	Airport	Airport
Passport control and customs	Airport	Airport	Police/customs
Food and shopping			
Restaurants and shops	Airport	Concessionaires	Concessionaires
Gate and boarding			
Gates	Airport	Airport	Airline/handling company
Flight			
Runway/taxiways/ apron/ aircraft parking	Airport	Airport	*(N.A.)*
Air traffic control/ control tower	Airport	Airport	Air traffic controller
Fueling equipment	Fueling company	Fueling company	Fueling company
Catering services	Catering company	Catering company	Catering company
De-icing equipment	Handling company	Handling company	Handling company
Cargo			
Warehouses[33] **and storage**	Airport	Airport	Cargo handling company
Inspection stations etc.	Cargo handling company	Cargo handling company	Cargo handling company
Other buildings			
Offices	Airport	Airport	Company who rented the office
Safety (incl. bird control)	Airport	Airport	Airport and relevant authorities (e.g. fire department)

Other resources: Airport management & administration → labor cost for the airport
Energy (electricity, water, gas, …) → soft costs for the airport
Land → (in some cases) capital cost for the airport

Source: own composition

[32] This is a special case: as stated before (see footnote 31), in some cases terminals can also be built by other stakeholders such as airlines..

[33] Also warehouses can be built by another stakeholder.

As can be deducted from Table 12, the airport is responsible for the provision of most resources and thus has to bear the capital costs that come with this. Also the maintenance of those resources is, in most cases, done by the airport who then bears the labor and soft costs. The services (operation of the resources), however, are often outsourced to a third party, who then bears the labor costs.

The costs as presented here will serve as input variables for the cost function. In order to develop a cost function for an airport, insight is thus needed in the costs the airport bears itself. Being, the total capital costs (related to the different resources provided by the airport), the total labor costs borne by the airport (caused by maintenance or operation of resources) and also the total soft costs (due to the maintenance of the resources). Moreover, the unit costs will have to be calculated. To come to this, the total (capital/labor/soft) costs will have to be divided by some amount of resources, thus the amount of resources representing the costs will also have to be found. For example, to calculate the labor unit cost, the total labor cost will be divided by the amount of employees (employed by the airport itself). The same goes for capital units and units causing soft costs.

Because all airports might represent different costs, it is important to include a large sample for the estimations to level out any outliers.

3.2 Airport revenue

The costs the airport bears, can be funded by its own revenues. Regarding the operational revenue, a distinction can be made between aeronautical and non-aeronautical revenues.

3.2.1 Aeronautical revenue

Aeronautical revenue stems from the activities directly related to the activity of aviation: landing and take-off charges paid by airlines, passenger charges, income from air traffic control, parking and hangars, cargo fees etc. The aeronautical revenue depends thus on the number of movements, passengers and cargo an airport serves and the charges. By the aeronautical revenue, the airport can influence its two-sided market. However, the height of the charges cannot always be chosen freely, often airport charges are subject to regulation.

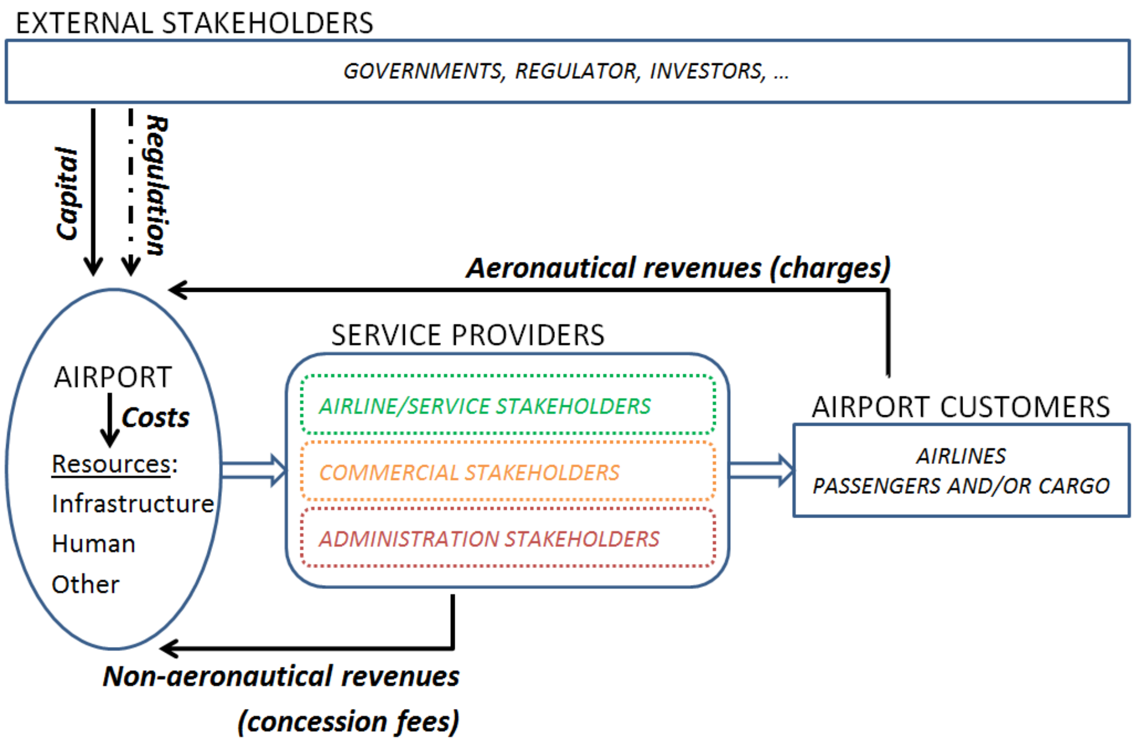
3.2.2 Non-aeronautical revenue

On the other hand, there is non-aeronautical revenue generated by other activities the airport is dealing with. For example, rent from offices or commercial spaces as well as concession fees and rents from third party providers are non-aeronautical revenues.

If these operational revenues do not suffice to cover all costs, airports can often also rely on capital (through funding or financing), either coming from private or public investors.

In this dissertation, funding is defined as an amount of money, often provided on the base of an agreement and linked to one specific project or cost, in most cases free of charge. E.g. donations made by governments. Financing on the other hand is money which is provided with the expectation to be repaid, often including some interest. E.g. loans from banks or capital from shareholders.

Figure 24: Airport financial structure



Source: own composition based on (Macário & Van de Voorde, 2012; Schaar & Sherry, 2010)

3.2.3 Regulation

In some cases, industries are characterized by such economies of scale and scope that the average costs tend to fall over the entire range of industry output. Then, the industry operates under cost conditions that give rise to a natural monopoly. (Lipczynski, Wilson, & Goddard, 2009) This entails that production by a single firm results in lower unit costs than would be the case with production by several companies. However, that company may be inclined to abuse its market power and restrict output and to increase prices in order to realize a much larger profit than one might reasonably expect as a “normal” return on capital.

This could also apply to airports. Given the two-sided market, the airport mainly has power over the airlines and their customers in terms of pricing. The study of Meincke (2002), as cited by Graham (2010), also mentions an airport operator has the most control in pricing. Given the fact that transport activities are considered to be public services[34], authorities and regulators want to prevent this (potential) abuse of power. The purpose of regulation is then to prevent such situations from occurring. It can induce the natural monopolist to be cost efficient and to increase output to a level that maximizes economic prosperity.

The question can be raised whether an airport is indeed a natural monopoly which would abuse its power. The papers of Kupfer et al. (2013; 2011) go deeper into this when analyzing the need for regulation in the case of Brussels Airport. However, the reasoning described there, can also be generalized. Based on its geographical location, an airport can be considered not to be a natural monopolist. For example, if it is located amidst large airports of a region, there is competition nearby. Furthermore, there is a concentration movement towards alliances among some of the airport customers and the pressure of the commercialization of the airline industry. Moreover, there is the growing evidence that airports are a good example of the law of diminishing returns to scale. (Kupfer et al., 2013; Kupfer, Meersman, Pauwels, et al., 2011)

Next to this, airports might have no incentive to abuse potential market power. For one, they limited market power due to the strong airport customers (being airlines in alliances), but they

[34] Public services are services provided of general interest, helping others with a specific need. They are not necessarily provided by public institutions, but are often associated with human rights and irrespective of income. Air transport services are a good example of a public service in case of an island: then the inhabitants need to be able to rely on air transport to keep in contact with other parts of the world. Especially for goods, which can be sometimes time sensitive, the aircraft is the only option.

are also confronted price sensitive passengers and the competition to attract low cost and cargo carriers. The fact that the aeronautical exploitation is combined with an extensive commercial zone leads to the incentive to attract as much traffic as possible. (Kupfer et al., 2013; Kupfer, Meersman, Pauwels, et al., 2011)

This would lead to believe that, for airports, regulation is in fact not necessary. However, some monitoring remains necessary to safeguard the general good. Moreover, the European Directive 2009/12/EC on airport charges explicitly prescribes that there should be an independent supervisory authority to safeguard the principles underling the airport charging system.

However, to be able to achieve a situation where the airport is cost efficient and output is increased to a level that maximizes economic prosperity, the regulator would have to have perfect knowledge of the industry's parameters and that knowledge is often lacking. Therefore, a set of incentives may be devised to nudge the regulated company toward a socially optimal output level. (Kupfer et al., 2013)

There are two main types of regulation, being structural regulation and behavioral regulation. Structural regulation focuses on the market structure – for example, dividing a company in different complementary units – and behavioral regulation tries to conduct the behavior of the company.

There are four types of behavioral regulation:

- Rate of return regulation;
- Price cap regulation;
- Revenue sharing agreement;
- Monitoring.

When rate-of-return regulation is applied, the regulator lets the airport set a price which covers its costs and has a mark-up to make some profit. However, this way the airport has no incentive to lower its costs. Price cap regulation sets a maximum price that companies – airports – can charge, with a correction for productivity profits. With pure price caps, the costs of reference airports are taken into account as a benchmark. Hybrid price caps are based on the costs of the regulated airport itself. Another option is a revenue sharing agreement. If this is applied, then the tariffs can evolve according to the growth of passengers in a certain period. If the regulator chooses the system of monitoring, he supervises the airport. That way, he can sanction the airport in case its market power is abused (Niemeier, 2009; Struyf et al., 2011).

Now the issue of tariff policy remains. This defines how the airport can set its prices so that maximum profit is guaranteed and still the limitations of the regulation are met. In this respect, a distinction between the single till and dual till approach can be made. Under single till, the revenues from commercial activities and concessions are incorporated into the total airport revenues and on this basis, the aeronautical charges are calculated. They can thus cross-subsidize the regulated activities, i.e. aviation related activities. This approach introduces potential distortions – it might influence the investments in aeronautical or commercial activities. This can lead to perverse situation at congested airports. For example, Bottasso and Conti (2012) state that capacity-constrained airports tend to lower aeronautical charges in order to remain under the price cap, since more revenue is made on the non-aeronautical side. Graham (2010) also acknowledges that if the airport operates under single till, a growth in commercial revenues may be compensated for by a reduction in aeronautical charges, which may help the airport to remain competitive in prices. This could then falsely indicate an excess in capacity.

Alternatively, in the dual till approach, aeronautical charges are determined on the basis of the costs incurred in aeronautical activities. This is more in line with ICAO Standards (2012) defending the user-pays principle. Also here, there is a potential distortion. For example, how should costs which are shared between commercial and aviation-related activities be treated? And which facilities are seen as necessary for providing aeronautical services? (Kupfer et al., 2013)

It becomes clear, that there is no such thing as one general regulation, not all airports are thus regulated the same way. Next to the type of regulation and the tariff policy, also the duration of the regulated period, whether the regulator is independent or not and the issue of whether the regulation is ex-ante (where the regulator takes the initiative to prevent problems) or ex-post (which only is applied in case of complaints or problems) can differ.

3.3 Intermediate conclusion

This chapter showed that airports have to bear a lot of the infrastructure and maintenance related costs. Here lies a potential source of economies of scale. As indicated in relation with the two-sided market, the charges and fees are an important tool for airports which they can use to attract customers and thus to maximize the scale of their operations. Some sources even refer to the “power” the airports have. Although some sources prove that airports not necessarily have this power and are certainly not inclined to abuse the power they have, regulation applied will impose certain limitations on the price setting, and thus influence the potential cost economies airports experience.

The source of economies of scope lies in the fact whether the costs made are joint costs or not. In most cases, the (inevitable) costs of aeronautical infrastructure are joint since both passenger and cargo airlines use the runway, taxiway and apron. However, as indicated, some airports have separate cargo sites and then only the runway is used for both passengers and cargo. The landside infrastructure provided by the airport (i.e. buildings etc.) and for which the airport bears the capital costs, are different for passengers and cargo. Passengers use the terminal building and its facilities, while cargo is in need of warehouses and storage. These capital costs are thus not joint.

Concerning human resources, the airports are responsible for the maintenance of the infrastructure, but the operational activities are often outsources. Labor costs borne by the airport for administration etc. are made irrespective of the type of customers present and can thus be considered as joint costs. The same applies to the soft costs borne by the airport.

Based on this chapter, an obvious source for economies of scale can thus be found. This strengthens the hypothesis that airports experience economies of scale. However, while there are some joint costs present, also a lot of separate costs can be listed. Whether airports experience economies of scope is thus still unclear. An econometric analysis is necessary to get a view on the existence of economies of scale and scope.

4. From production function to cost function

The core task of any company is to produce products or services. Their financial goal[35] in doing so, can be either cost minimization or profit maximization. Nonetheless, the way the production is organized to achieve that goal, can be captured in a production function. This represents various “recipes” on how to maximize the quantity of output using the inputs available, influenced by the (exogenous) technological conditions. (Besanko & Braeutigam, 2010)

A production function is represented as the quantity of output (Q) that is dependent on the quantity of inputs (in this case labor L and capital K). Obviously, also other inputs (such as materials) can be included in the production function.

$$Q = f(L, K, \dots)$$

The inputs can be substituted by one another. To which extent this is possible, is represented by the elasticity of substitution: if the elasticity is large, there is a great opportunity to exchange one input for another and still maintain the same level of output. Production in a given firm can also be characterized by returns to scale. This represents how the increase of inputs used changes the quantity of outputs that can be produced. In case of increasing returns to scale, the output multiplies by a factor greater than that with which the inputs were increased. For example, if using twice as many inputs results in more than double output, the production is characterized by increasing returns to scale. On the other hand, if doubling the inputs results in an output which is only 1.5 times more, there are decreasing returns to scale. An output which doubles in case of double input, represent constant returns to scale (Besanko & Braeutigam, 2010).

[35] Companies can also have other goals. For example, social welfare maximization or striving for social corporate responsibility.

4.1 Duality between production and cost function

The use of these inputs comes with costs. In most cases, analysis of the costs is a tool on which decisions are based. Therefore, the production of a given firm is often analyzed through cost analysis instead of analysis of the production function.

The cost function obviously is related to the production function. There is a dual relationship between the two functions. This implies that the cost function of a firm contains sufficient information to characterize production completely (D. W. Gillen et al., 1990). So, both functions contain the same information about production possibilities.

4.2 Different types of costs

Cost can be categorized in many different ways. One option is to link them to the resources used (as is done in section 3.1 for airport costs). However, there are many other ways in which the costs can be categorized.

- Explicit vs. implicit costs
- Fixed or variable
- Sunk costs
- Aggregate vs. disaggregate

Looking at the financial flows within a company, there are on the one hand explicit costs. These represent actual monetary outlays, for example when buying infrastructure, machinery or when paying for electricity. On the other hand, there are also implicit costs which represent the value of sacrificed opportunities. For example, most companies have infrastructure or machinery which is not used 24/7 and thus can be rented out during non-operational hours. If companies choose not to do so, it means that there is missed income and this is an implicit cost. The costs linked to the fact that money which is spent cannot be used for other purposes are called opportunity costs.

Costs can be fixed or variable, depending on whether the amount changes if the output level changes. For example, the rent on the building or depreciation of the infrastructure are fixed costs since they will not change in case of more outputs. On the other hand, the electricity costs do change if machines need to (work longer in order to) produce more output and are therefore variable costs. Labor costs are also often an example of variable costs.

Furthermore, there is a difference based on whether the costs are sunk costs or not. Sunk costs are those which have been incurred and cannot be avoided, no matter what decision is made. Those costs can also not be regained or recovered (Besanko & Braeutigam, 2010). For example, often the costs of setting up the building are seen as sunk costs. However, buildings could be rented out or sold and in that case, (part of) the costs can be regained – so these are not sunk costs. Using an airport as an example, the costs of installing a runway can be seen as a sunk cost since the space cannot be used for other purposes.

Aggregate costs include all the costs while disaggregate costing only takes into account part of the total costs. For example, disaggregate cost analysis looks at the unit costs of (intermediate) activities, rather than the total cost of all the production activities (Oum & Waters, 1996).

The sum of all costs gives the total cost. If the total cost is divided by the quantity of outputs, the average cost (AC) is calculate. The marginal cost (MC) represents the extra cost that is incurred to produce one more unit of output. This can be calculated differentiating the total cost function to (that) output.

4.3 Cost functions

Now the basic theory regarding costs and the link with production (functions) is explained, this chapter will go more into cost functions.

4.3.1 Long term vs. short term

Regarding cost functions, a distinction can be made between long-run cost specifications and short-run cost specifications. On the long term, the (number of) inputs used by a firm are adjustable. Looking at several years, companies can make new investments, can buy extra resources. The resources are variable and so are the costs. However, making investments takes time and thus on the short term, some inputs are fixed which entails that also a large proportion of the costs is fixed.

Before estimating a specification, the decision on short-term or long-term needs to be taken. This depends upon the inputs into the model. For example, capital is one of the inputs which is obviously fixed on the short term. However, if the capital costs are represented by analyzing depreciation data, then the capital costs are related to the level of production. Moreover, Oum & Waters II (2000) state that a general guide can be that when time series data are used, elasticity estimates can be interpreted as short-run values. Due to the limited time, firms have to adjust their consumption of resources as the price and quality attributes change. However, in case of cross-section data estimates can be interpreted as long-run values due to the wide variations across firms in their adjustments to the current prices and quality attributes. Wide variations across firms allows the consideration of factors to be variable.

4.3.2 Types of cost functions

To insure the duality with the production function (Goldberg, Hanweck, Keenan, & Young, 1991) and in order to be well-behaving, any cost function must satisfy some regularity conditions. Caves, Christensen, & Tretheway (1980) list those conditions as being: non-negative, real-valued, non-decreasing, strictly positive for positive output and linearly homogeneous and concave in input prices for each output. Also the study of Georgia Institute of Technology (2001) stipulates that a cost function with a quasi-fixed factor must satisfy the conditions of linear homogeneity in factor prices, symmetry in factor prices, monotonicity and concavity. Further the paper of Segal (2003) refers to the regularity conditions as continuity, symmetry, linear homogeneity in prices, monotonicity in prices and outputs and concavity in prices.

Continuity of the cost function and of its first and second derivatives leads to the second cross derivatives to be symmetric. Linear homogeneity ensures that, if input prices are multiplied by the same scalar, the cost-minimizing bundle does not change. Monotonicity in prices requires that total costs increase as prices increase, while monotonicity in outputs requires positive marginal costs. For a concave function, if the price of an input increases, the proportion increase in total costs is no higher (because of the substitution among inputs). (Segal, 2003)

There are several types of cost functions that apply to these conditions. A cost function which is frequently used, is the Cobb Douglas cost function.

$$\ln C = \ln \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln P_i + \sum_{i=1}^{m} \alpha_Y \ln Y_i \tag{1}$$

where: P_i = the price of input i
Y_i = the i^{th} output

This functional form is a linear function. Oum & Waters II (2000) stress that indeed a lot of textbooks draw cost functions as linear due to the fact that it is pictorially convenient and easy to estimate. However, as indicated in the literature review, the Cobb Douglas cost function and other linear functions have different limitations regarding cost economies and elasticities. The elasticities of total cost with respect to output and with respect to factor prices are constant, the share of expenditure of each factor of productivity is constant and the elasticity of substitution is unity (Braeutigam, 1999). Also the log linear function is characterized by constant cost elasticities, a substitution elasticity which is unity and the fact that the degree of returns to scale is unchanged between very small and very large firms (Oum & Waters, 1996).

Thanks to the advances in econometric and computational techniques, more elaborate functional forms can be estimated and interpreted. The restrictions of (log) lineair functions are overcome by flexible functional forms, allowing the analysis of cost economies.

Examples of such flexible functions are the generalized Leontief cost function which was first introduced by Diewert (1971). Hall (1973) combined this with the generalized linear form for the production function to build the "hybrid Diewert" multiproduct cost function. Also in 1971, Christensen, Lau & Jorgensen (1971) introduced the translog cost function, which is a member of the class of functions known as "general quadratic flexible forms" (D. W. Caves, Christensen, & Tretheway, 1980). Oum et al. (1996) also mention the quadratic mean of order-r function as first described by Denny (1974) and the generalized Cobb-Douglas cost function which Diewert (1992) defined.

The most popular flexible functional form is the translog cost function. The translog function is a flexible functional form, providing a second-order Taylor series approximation in logarithms to an arbitrary cost function around a certain point (Pels & Rietveld, 2000b). This entails that this functional form is a good approximation for a cost function that comes from about any production function (Besanko & Braeutigam, 2010). Moreover, it is easy to estimate and interpret. And since it is a generalized form of the Cobb Douglas cost function, the translog cost function is constructed analogously, but overcomes the limitations as described before, allowing cost economies (Oum & Waters, 1996).

Berndt (1996) writes the most general form of the (single output) translog cost function as follows:

$$\ln TC = \ln \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln P_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln P_i \ln P_j + \alpha_Y \ln Y + \frac{1}{2} \gamma_{YY} (\ln Y)^2 + \sum_{i=1}^{n} \gamma_{iY} \ln P_i \ln Y \quad (2)$$

where: TC = total cost of producing Y
P_i & P_j = prices of inputs i and j (of n inputs)
Y = output

As stated before, a cost function comes with restrictions (symmetry, linear homogeneity of degree 1 in input prices and an adding up condition) which, for a translog function, can be written as follows:

- Taking the function as described by Berndt (1996) into account, the symmetry restriction implies that $\gamma_{ij} = \gamma_{ji}$.
- The translog function should be linear homogenous of degree 1 in input prices which means that $\sum_{i=1}^{n} \alpha_i = 1$ and $\sum_{i=1}^{n} \gamma_{ij} = \sum_{j=1}^{n} \gamma_{ji} = \sum_{i=1}^{n} \gamma_{iY} = 0$.

- Moreover, there is the adding up condition which entails that the sum of all cost shares equals one ($\sum_{i=1}^{n} S_i = 1$). By differentiating equation (2) with respect to input prices and applying Shepard's lemma[36], the following cost shares can be obtained:

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{P_i}{C} * \frac{\partial C}{\partial P_i} = \frac{P_i}{C} X = \alpha_i + \sum_{i=1}^{n} \gamma_{ij} \ln P_j + \gamma_{iY} \ln Y \qquad (3)$$

where: $\sum_{i=1}^{n} P_i X_i = C$ and cost shares $S_i \equiv \frac{P_i X_i}{C}$

To be attractive in empirical applications, a flexible form should be linear homogenous in input prices for all possible price and output levels and should be parsimonious in parameters (D. W. Caves et al., 1980). Due to the log metric on the input prices and total cost, the translog cost function is linear homogenous. This precondition ensures the existence of a dual relationship between the cost an production function. Compared to the Hybrid Diewert and the quadratic cost function, the translog cost function is the only cost function that satisfies this precondition without any restrictions. A second precondition is that the number of parameters to be estimated is small. The disadvantage of the translog function is that there are a large number of coefficients to be estimated, however, the restrictions allow some degrees of freedom which lowers the number of parameters to be estimated (Oum & Waters, 1996).

In this research, the existence of cost economies is analyzed. Therefore, the translog cost function, which imposes no a priori restrictions to the coefficients, is a good functional form to be used since it allows cost economies.

Given the multiple outputs airport are confronted with, the cost analysis and the investigation on the existence of cost economies requires a multi-output cost function.

[36] Sheppard's lemma reflects the relationship between the long-run cost function and the input demand function: the rate of change of the long-run total cost function with respect to input price is equal to the corresponding input demand function. It also applies to relationship between short-run total cost functions and the short-run input demand functions (Besanko & Braeutigam, 2010). Mathematically, it entails that if the cost function is differentiated with respect to the input price, the quantity of input is found (Segal, 2003).

4.3.3 Multi-output translog cost function

The translog cost function can be transformed into a multi-output cost function in order to be able to analyze the existence of cost economies. Following Braeutigam (1999), a translog cost function for m outputs and n inputs can be written as follows:

$$\ln TC = \alpha_0 + \sum_{i=1}^{m} \alpha_i \ln Y_i + \sum_{i=1}^{n} \beta_i \ln P_i + \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m} \alpha_{ij} \ln Y_i \ln Y_j$$
$$+ \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} \ln P_i \ln P_j + \sum_{i=1}^{m}\sum_{j=1}^{n} \gamma_{ij} \ln Y_i \ln P_j \qquad (4)$$

where: TC = total cost of producing $Y_i, \ldots, Y_m$
Y_i & Y_j = outputs i and j (m outputs)
P_i & P_j = prices of inputs i and j (n inputs)

Also here, the set of restrictions (linear homogeneity in factor prices, symmetry and adding up of cost shares) applies.

4.3.4 Multi-output translog cost function applied to airports

Regarding airports, literature describes many different outputs. Some studies take only passengers and cargo into account, while other also state that non-aeronautical revenue is not to be ignored. Then, there are also studies who look at airport movements as a type of output.

However, as shown in section 1.4.2, there are many types of aircraft, all with different dimensions and loading capacity. For example, a movement of a standard body can carry no more than 45 tons of cargo, while a medium wide-body accounts for 40 to 80 ton. A large wide-body is able to transport more than 80 tons of cargo (Van de Voorde & de Wit, 2013). The landing or take-off of a standard body aircraft or of a large wide-body aircraft both represent one aircraft movement, but do have different implications (for the airport). Using thus only the one nominator (i.e. aircraft movements) would lead to biases. Moreover, as Pels et al. (2003) state, aircraft movements can be considered as an intermediate output for passengers and cargo. Taking also movements into account would potentially lead to double counting and this must be avoided. Therefore, airport movements is an output that will not be taken into account in this dissertation.

The same goes for non-aeronautical revenue. Firstly, this output is expressed in monetary terms while the amount of passengers and cargo are numerical values. And second, it is arguable whether non-aeronautical revenues are necessarily related to the core business of the airport, i.e. the activity of aviation and thus an aeronautical activity. Furthermore, taking into account non-aeronautical revenue would not influence the potential economies of scope between passenger and cargo.

Including other variables, such as fleet characteristics for each airport might influence the results. For example, airports that receive large aircraft need different infrastructure and equipment than airports handling small airplanes. However, the infrastructure and equipment of each airport is set to accommodate the largest aircraft that they receive. Therefore, different aircraft landing at one airport does not further affect the infrastructure and equipment. Taking the different types of aircraft handled into account would thus not have a large influence on the results. Furthermore, since the scope of the data sample is large, including airports with different characteristics (see section 6.1.3), the different types of infrastructure and equipment are taken into account, minimalizing the risk on biased results.

Bearing this in mind, in this dissertation only passengers and cargo are used as outputs. However, as shown in section 1.3, there are many different types of passengers and cargo. The question to be raised is thus how many outputs should be included in the multi-output cost function. As Oum & Waters (1996) state, one possible solution is to use an aggregate output measure, usually an output index. This, however, might lead to over- or underestimation (Braeutigam, 1999). Another possibility is to increase the number of outputs in the cost function, but incorporating too many outputs makes the estimation of the cost function difficult or impossible.

Therefore, in this dissertation, two outputs will be taken into account – number of passengers and tons of cargo (incl. freight and mail) – to analyze the existence of economies of scale and/or scope.

For the specification of the airport cost function, three inputs will be taken into account: capital costs, labor costs and other costs. These three categories reflect all the inputs the airport needs to perform its activities. However, as already stated in section 3.1, it is important to include only those costs which are actually borne by the airport can be taken into account. The costs will then have to be expressed as unit costs.

The multi-output translog function for airports, can then be written as follows:

$$
\begin{aligned}
\ln TC = {} & \\
& \alpha_0 + \alpha_{PAX} \ln PAX + \alpha_{CARGO} \ln CARGO + \beta_R \ln R + \beta_W \ln W + \beta_M \ln M \\
& + \frac{1}{2}\alpha_{PAXPAX} (\ln PAX)^2 + \frac{1}{2}\alpha_{CARGOCARGO} (\ln CARGO)^2 + \frac{1}{2}\beta_{RR}(\ln R)^2 \\
& + \frac{1}{2}\beta_{WW}(\ln W)^2 + \frac{1}{2}\beta_{MM}(\ln M)^2 + \alpha_{PAXCARGO}(\ln PAX)(\ln CARGO) \\
& +\gamma_{PAXR} (\ln PAX)(\ln R) + \gamma_{PAXW} (\ln PAX)(\ln W) + \gamma_{PAXM} (\ln PAX)(\ln M) \\
& +\gamma_{CARGOR} (\ln CARGO)(\ln R) + \gamma_{CARGOW} (\ln CARGO)(\ln W) \\
& +\gamma_{CARGOM} (\ln CARGO)(\ln M) + \beta_{RW}(\ln R)(\ln W) + \beta_{RM}(\ln R)(\ln M) \\
& +\beta_{WM}(\ln W)(\ln M) \qquad (5)
\end{aligned}
$$

where: TC = total cost of producing passengers and cargo
PAX = number of passengers handled
$CARGO$ = number of tons of freight and mail handled
R = input price of capital (cost per unit of capital used)
W = input price of labor (cost per unit of labor used)
M = input price of other inputs (cost per unit of other inputs used)

The cost shares can be specified as:

$$S_R = \beta_R + \beta_{RR} \ln R + \beta_{RW} \ln W + \beta_{RM} \ln M + \gamma_{PAXR} \ln PAX + \gamma_{CARGOR} \ln CARGO \qquad (6)$$

$$
\begin{aligned}
S_W = {} & \beta_W + \beta_{WW} \ln W + \beta_{RW} \ln R + \beta_{WM} \ln M + \gamma_{PAXW} \ln PAX \\
& +\gamma_{CARGOW} \ln CARGO \qquad (7)
\end{aligned}
$$

$$S_M = \beta_M + \beta_{MM} \ln M + \beta_{RM} \ln R + \beta_{WM} \ln W + \gamma_{PAXM} \ln PAX + \gamma_{CARGOM} \ln CARGO \qquad (8)$$

where: S_R = share of capital cost in total cost
S_W= share of labor cost in total cost
S_M= share of other costs in total cost

The set of restrictions can be translated, taking into account these inputs and outputs.

- The symmetry restriction ($\beta_{ij} = \beta_{ji}$) involves:

  $\beta_{RW} = \beta_{WR}$
  $\beta_{RM} = \beta_{MR}$
  $\beta_{WM} = \beta_{MW}$
- Since the translog cost function should be linear homogenous of degree 1 in input prices, given Y ($\sum_{i=1}^{n} \beta_i = 1$ and $\sum_{i=1}^{n} \beta_{ij} = \sum_{j=1}^{n} \gamma\beta_{ji} = \sum_{i=1}^{n} \gamma_{iY} = 0$), the following restrictions apply:

  $\beta_R + \beta_W + \beta_M = 1$
  $\beta_{RR} + \beta_{RW} + \beta_{RM} = 0$
  $\beta_{RW} + \beta_{WW} + \beta_{WM} = 0$
  $\beta_{RM} + \beta_{WM} + \beta_{MM} = 0$
  $\gamma_{PAXR} + \gamma_{PAXW} + \gamma_{PAXM} = 0$
  $\gamma_{CARGOR} + \gamma_{CARGOW} + \gamma_{CARGOM} = 0$
- Moreover, there is the adding up condition which entails that the sum of all cost shares equals one ($\sum_{i=1}^{n} S_i = 1$) which results in: $S_R + S_W + S_M = 1$

  As D.W. Caves et al. (1980) state, the share equations sum to unity and, one of the equations needs to be dropped in order to avoid singularity problems. The estimations are invariant to the equation deleted.

  $$S_R = \beta_R + \beta_{RR}(\ln R - \ln M) + \beta_{RW}(\ln W - \ln M) + \gamma_{PAXR}(\ln PAX) + \gamma_{CARGOR}(\ln CARGO) \quad (9)$$
  $$S_W = \beta_W + \beta_{WW}(\ln W - \ln M) + \beta_{RW}(\ln R - \ln M) + \gamma_{PAXW}(\ln PAX) + \gamma_{CARGOW}(\ln CARGO) \quad (10)$$
  $$S_M = 1 - S_R - S_W \quad (11)$$

  Parameters/coefficients of the omitted share equation S_M (α_M, γ_{MM}, γ_{RM}, γ_{WM}, γ_{PAXM} and γ_{CARGOM}) will now not be directly estimated. However, they can be estimated indirectly by re-arranging the homogeneity restrictions (Berndt, 1996):

  $$\beta_M = 1 - \beta_R - \beta_W \quad (12)$$
  $$\beta_{MM} = \beta_{RR} + \beta_{WW} + (2 * \beta_{RW}) \quad (13)$$
  $$\beta_{RM} = -(\beta_{RR} + \beta_{RW}) \quad (14)$$
  $$\beta_{WM} = -(\beta_{RW} + \beta_{WW}) \quad (15)$$
  $$\gamma_{PAXM} = -(\gamma_{PAXR} + \gamma_{PAXW}) \quad (16)$$
  $$\gamma_{CARGOM} = -(\gamma_{CARGOR} + \gamma_{CARGOW}) \quad (17)$$

  This can then be incorporated in the translog cost function, which reduces the number of parameters to be estimated from 21 to 15.

Based on this specification with all its restrictions, a cost function can be estimated. This function can then be used to calculate the output related cost economies. In the next chapter (Chapter 5) the theory regarding cost functions is explained and in Chapter 6, the cost function is estimated and based on the results[37], the output related cost economies are calculated.

[37] Chapter 6 will reveal that the estimation cannot approximate reality enough to calculate all cost economies. Therefore, a second cost function (i.e. quadratic (cost) function) will be estimated.

5. Cost economies

As shown in the previous literature review some research has been carried out regarding economies of scale in the airport industry. This research focuses mainly on overall economies of scale (Martín et al., 2011; Martín & Voltes-Dorta, 2008, 2011b). The research with respect to economies of scope at airports, on the other hand, is very scarce.

5.1 Lessons from other sectors

In order to be able to calculate cost economies, lessons can be learnt from general research. For example, Bailey & Friedlaender (1982) explained in their paper how multi-output industries can be analyzed, looking at the cost concepts, barriers to entry, contestability and natural monopoly.

Also research in other sectors uses cost functions to analyze cost economies in different industries. For example, Pulley & Braunstein (1992) estimate a composite cost function, which is a combination of a quadratic output structure with a log-quadratic input price structure, to analyze the US banking industry. For this industry, or the financial industry in general, a lot of papers have been published. Murray & White (1983) used a translog cost function to study the financial institutions in British Columbia. Gilligan et al. (1984) studied banking in the US, while Zardkhoori & Kolari (1994) analyzed saving banking in Finland. The research scope of Lang & Welzel (1996) was cooperative banks in Germany, Cavallo & Rossi (2001) gained insight in the banking sector for all Europe and Iimi (2004) studied banking in Pakistan. All these authors analyzed the sector relying on translog cost function estimates. The banking sector was also investigated using more elaborate translog cost function specifications. Glass & McKillop (1992) used hybrid translog for banking in Ireland, while Clark & Speaker (1994) and Harimaya (2008) relied on a generalized translog specification to analyze banking in Chicago and regional banks in Japan (respectively).

However, also other sectors beside banking were under study and relied on the (advanced) translog cost function. Kim (1987a, 1987b) used a translog cost function to analyze the water supply industry in the US and a generalized translog cost function for analysis of US the railroad industry. Goldberg et al. (1991) studied the US securities industry using a translog model and the research scope of Smet (1998) was secondary education of Flanders, using a quadratic cost function and a generalized translog cost function. The US Federal Reserve

Payment Process was investigated by Adams et al. (2002), while Segal (2003) studied the US Life Insurance Industry, both using a translog cost function. Weng & Wang (2004) estimated a translog cost function for the tourist hotels of Taiwan and Van Cayseele & Wuyts (2007) investigated the securities settlement and depository industry in Europe.

This (non-exhaustive) overview shows that, as in the air transport industry, the translog cost function is also in other sectors commonly used. Moreover, the papers listed here also estimate multi-output translog cost functions. Therefore, the techniques applied in these papers or in other general research can be translated onto this research, with respect to the airport industry.

5.2 Elasticities

Companies try to minimize their costs (amongst others) by acquiring the necessary resources at the lowest prices. How many resources will be acquired, depends on the needed quantity but also on the price of the input. For example, if the price of labor would increase, companies might want to cut back on the amount of labor they use. The price elasticity of demand for labor would show how much the quantity of labor would change if the price of labor changes.

$$\epsilon_{L,w} = \frac{\frac{\Delta L}{L} \times 100\%}{\frac{\Delta w}{w} \times 100\%} = \frac{\Delta L}{\Delta w} \times \frac{w}{L}$$

where: $\epsilon_{L,w}$ = price elasticity of demand for labor = percentage change in cost minimizing quantity of labor with respect to 1% change in the price of labor

L = quantity of labor

w = price of input labor

Analogously, this can be drawn up and calculated for every input used. The price elasticity of demand for inputs is closely related to the substitution elasticity. If the substitution elasticity is small, there is little substitution possible. Then there is no other option than to use the input (of which the price changes) and thus the change in price will have little impact on the demand.

Besides the influence of price, some firms can minimize their costs due to characteristics of their cost structure. Changes in output (i.e. an increase/decrease or change of the output mix) have an influence of the (total) costs of a company.

The cost elasticity of output measures how much the costs change in case output increases or decreases by 1%. This concept is used to calculate the economies of scale a company experiences. However, in transportation the distinction between economies of scale and economies of density has to be made.

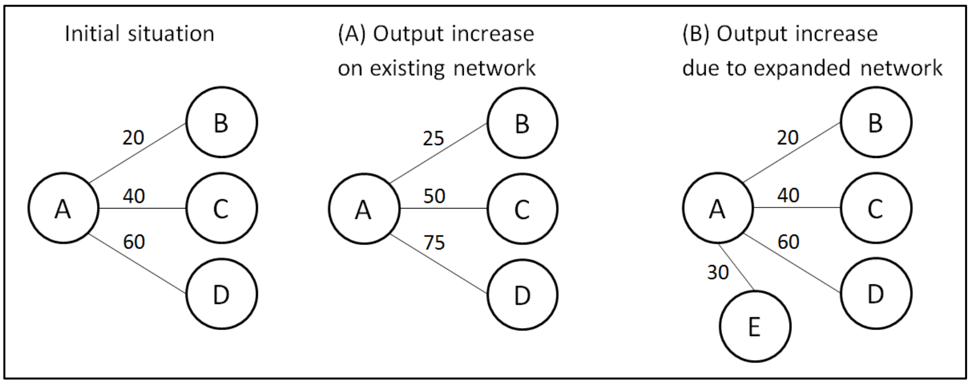
Furthermore, the costs of a company can also be influenced by the composition of the outputs, by the output mix. That is measured by looking at economies of scope.

5.3 Economies of scale vs. economies of density

If the inputs available are not used at their full capacity, it is interesting to increase the scale of production. That way, the input costs can be spread over a larger output and the long run average costs decrease. In this case, production of 1% extra output would not lead to 1% increase in costs and the company experiences cost benefits, known as "economies of scale".

However, in transportation, the question often occurs what the reason behind the increase in output is; whether there is more output using the same network of services or whether the output increased (by) expanding the network (Braeutigam, 1999[38]).

Figure 25: Economies of scale vs. economies of density



Source: own composition based on (Braeutigam, 1999)

[38] To explain the theory of economies of scale and economies of density, this dissertation relies on Braeutigam (1999). Obviously, there are also other sources explaining this matter (such as Basso & Jara-Díaz, 2006; D. W. Caves, Christensen, & Tretheway, 1984; D. W. Gillen, Oum, & Tretheway, 1990) but they refer to the same theory and concepts.

If the cost advantages are due to the output increase, holding production technology, input prices and the network constant (i.e. situation A in Figure 25), then the term "economies of density" applies, because there the size of the network is constant, but the density increases.

The degree of economies of density (S_D) can be calculated by taking into account the elasticity of total cost with respect to output[39] (ϵ_{C,Y_i}) (Braeutigam, 1999).

$$S_D = \frac{1}{\sum_{i=1}^{n} \epsilon_{C,Y_i}}$$

If S_D >1, economies of density would be observed, meaning that the costs increase with less than 1% if output increases with 1% on a given network. Diseconomies of density occur when S_D <1 and then the costs increase with more than 1% if output increases with 1% on a given network. If S_D =1, there are constant returns to density and costs would increase with a same percentage as output (Braeutigam, 1999).

For example, in aviation, given a network of destinations, large airlines offer more flights (per day) compared to smaller airlines and can thus spread certain costs.

Economies of scale entail also that long run average costs decline if the output increases, but the network is no longer fixed (see situation B in Figure 25). Economies of scale occur if 1% increase in output and/or network size entails an increase in costs <1%, holding production technology and input prices constant.

$$S_S = \frac{1}{\sum_{i=1}^{n} \epsilon_{C,Y_i} + \epsilon_{C,N}}$$

To calculate the degree of economies of scale (S_S), the cost elasticity with respect to the number of nodes ($\epsilon_{C,N}$) is also taken into account. Economies of scale, constant returns to scale or diseconomies of scale occur as S_S is greater, equal or less than 1 (Braeutigam, 1999).

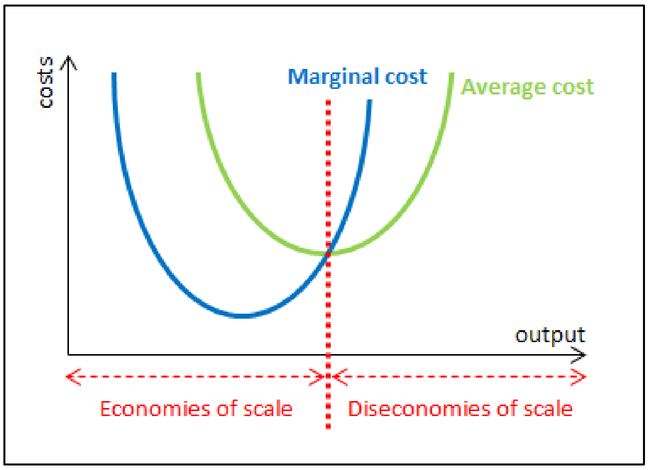
Economies of scale occur often with companies that have indivisible inputs, i.e. inputs that cannot be scaled down if output would decrease. For example, an airport investing in a runway can divide the (infrastructure) costs more if it receives more airplanes.

The concept of economies of scale is also closely related to the returns to scale, earlier mentioned (beginning of chapter 4). Economies of scale show what effect an increasing output

[39] The elasticity of cost with respect to output represents by which percentage the costs change if the output changes by 1%.

has on unit costs, while returns to scale show the relation between the number of inputs and outputs. Economies of scale occur in case of increasing returns to scale (i.e. output which multiplies by a factor greater than that with which the inputs were increased), while diseconomies of scale occur in case of decreasing returns to scale.

Figure 26: Economies of scale



Source: own composition

When dealing with a cost function in which network characteristics are not included (as is the case for an airport cost function), economies of scale are calculated as the inverse of the cost elasticity with respect to output. This elasticity is the ratio of marginal to average costs. As stated above, economies of scale appear when average costs are declining and this is the case when MC<AC. So when marginal cost exceeds average cost, there are diseconomies of scale.

5.3.1 Economies of scale for multi-output firms

The concept of economies of scale can be extended to multi-output firms, but a firm producing more than one output can change its scale holding the output mix constant or by adopting different growth rates for different outputs. Therefore, a distinction needs to be made between ray economies of scale and product-specific economies of scale. (Moschandreas, 2000)

Ray economies of scale

Ray (dis)economies of scale indicate at what percentage total cost increases as the scale of the firm increases by 1%, holding the output mix constant. This is a straightforward extension of the definition of single product economies of scale, so it can be measured by the ratio of average and marginal cost.

The marginal cost can be calculated for each product and is the rate of change of the total cost when the output of one product changes while the output of all other products remains constant.

Bailey & Friedlaender (1982) calculate the marginal cost of one product (in a multi-output environment) as follows:

$$MC_i = \frac{\partial C(Y_i, Y_j)}{\partial Y_i} = \frac{\partial \ln C(Y_i, Y_j)}{\partial \ln Y_i} * \frac{C(Y_i, Y_j)}{Y_i}$$

However, no meaningful definition can be found of a multi-output firm's average cost because there is no uniquely correct way of aggregating the output. A multi-output firm, can be thought of as producing a composite output, of which one unit is a bundle of different outputs produced in a given proportion.

The average cost of a multi-output firm is calculated using the concept of ray average cost (Baumol, Panzar, & Willig, 1988):

$$RAC = \frac{C(tY)}{t}$$

where: t = the scale of production of the composite unit Y

$C(tY)$ = the total cost of producing tY

Ray economies of scale are calculated as the inverse of the sum of cost elasticities with respect to each output. (Baumol et al., 1988; Clark & Speaker, 1994; Glass & McKillop, 1992; Goldberg et al., 1991; Iimi, 2004; Martín et al., 2011; Martín & Voltes-Dorta, 2008, 2011b; Segal, 2003; Weng & Wang, 2004):

$$Ray\ EOScale = \left[\frac{\partial \ln C(tY)}{\partial \ln t}\bigg|_{t=1}\right]^{-1} = \left[\sum_{i=1}^{m}\left(\frac{\partial \ln C(Y)}{\partial \ln Y_i}\right)\right]^{-1} = \frac{1}{\sum_{i=1}^{m} \epsilon_{CY_i}}$$

For a multi-output translog cost function, this comes down to:

$$Ray\ EOScale\ (Y_i) = \left[\sum_{i=1}^{m} \alpha_i + \sum_{i=1}^{m}\sum_{j=1}^{m} \alpha_{ij} \ln Y_j + \sum_{i=1}^{m}\sum_{j=1}^{n} \beta_{ij} \ln P_j\right]^{-1} \quad (18)$$

In this research, with a multi-output translog cost function based on two outputs (PAX and CARGO) and three inputs[40] (capital unit cost R, labor unit cost W and soft/other unit cost M), the inverse of the following equation should be taken:

$$\begin{aligned} &\alpha_{PAX} + \alpha_{CARGO} + \alpha_{PAXPAX} \ln PAX + \alpha_{CARGOCARGO} \ln CARGO \\ &+\alpha_{PAXCARGO} \ln CARGO + \alpha_{PAXCARGO} \ln PAX \\ &+\gamma_{PAXR}(\ln R) + \gamma_{PAXW}(\ln W) + \gamma_{PAXM}(\ln M) \\ &+\gamma_{CARGOR}(\ln R) + \gamma_{CARGOW}(\ln W) + \gamma_{CARGOM}(\ln M) \end{aligned} \quad (19)$$

Ray economies of scale, constant returns to scale or ray diseconomies of scale occur if this value is less, equal or greater than 1.

Product-specific economies of scale

Firms may also change their size through variation in the output of one product, holding the quantities of other products constant. To analyze whether this would be advantageous cost wise, the product-specific economies of scale need to be calculated.

A method, used by a.o. Clark (1988) showed[41] that the existence of product-specific economies of scale can be evaluated, based on declining marginal cost:

$$Product - specific\ EOScale =$$

$$\frac{\partial^2 TC}{\partial y_i^2} = \left(\frac{TC}{y_i^2}\right)\left[\frac{\partial^2 \ln TC}{\partial \ln y_i^2} + \left(\frac{\partial \ln TC}{\partial \ln y_i}\right) * \left(\frac{\partial \ln TC}{\partial \ln y_i} - 1\right)\right]$$

If this value is negative, the marginal costs of product i are declining, which implies product-specific economies of scale for product i. In case the value as explained above is positive,

[40] These three inputs are chosen because they grasp all inputs. The classification into capital, labor and soft/other, is commonly used in other literature.

[41] The equation of product-specific economies of scale as given by Clark (1988) contains a typographical error. The equation included with regards to product-specific economies of scale was: $\frac{\partial^2 TC}{\partial y_i^2} = \left(\frac{TC}{y_i^2}\right)\left[\frac{\partial \ln TC}{\partial \ln y_i^2} + \left(\frac{\partial \ln TC}{\partial \ln y_i}\right) * \left(\frac{\partial \ln TC}{\partial \ln y_i} - 1\right)\right]$. This equation does not contain the second derivative of TC to y_i. Why the equation included in this dissertation is the correct one, is mathematically explained in Appendix 1.

marginal costs are increasing and there are product-specific diseconomies of scale for product i.

For a multi-output translog cost function, this comes down to:

$$Product\ Specific\ EOScale = \left(\frac{TC}{y_i^2}\right)\left[\gamma_{ij} + \left(\epsilon_{CY_i}\right) * \left(\epsilon_{CY_i} - 1\right)\right]$$

where: $\epsilon_{CY_i} = \alpha_i + \sum_{j=1}^{m} \alpha_{ij} \ln Y_j + \sum_{j=1}^{n} \beta_{ij} \ln P_j$ (20)

In this research, with a multi-output translog cost function based on two outputs (PAX and CARGO) and three inputs (capital unit cost R, labor unit cost W and soft/other unit cost M) the existence of product-specific economies of scale can be evaluated using:

$$Product\ Specific\ EOScale_{PAX} =$$

$$\left(\frac{TC}{PAX^2}\right)\left[\alpha_{PAXPAX} + (\epsilon_{CPAX}) * (\epsilon_{CPAX} - 1)\right] \quad (21)$$

where: $\epsilon_{CPAX} = \alpha_{PAX} + \alpha_{PAXPAX} \ln PAX + \alpha_{PAXCARGO} \ln CARGO$
$+\gamma_{PAXR}(\ln R) + \gamma_{PAXW}(\ln W) + \gamma_{PAXM}(\ln M)$

$$Product\ Specific\ EOScale_{CARGO} =$$

$$\left(\frac{TC}{CARGO^2}\right)\left[\alpha_{CARGOCARGO} + (\epsilon_{CCARGO}) * (\epsilon_{CCARGO} - 1)\right] \quad (22)$$

where: $\epsilon_{CCARGO} = \alpha_{CARGO} + \alpha_{CARGOCARGO} \ln CARGO + \alpha_{PAXCARGO} \ln PAX$
$+\gamma_{CARGOR}(\ln R) + \gamma_{CARGOW}(\ln W) + \gamma_{CARGOM}(\ln M)$

To actually calculate the degree of product-specific economies of scale, the incremental cost of product i, being the addition to the firms total cost resulting from the given output of product i, is important. This can be calculated as (Baumol et al., 1988):

$$IC_i(Y) = C(Y) - C(Y_{N-i}) = C\left(Y_i, Y_j\right) - C(0, Y_j)$$

for a production set $N = \{1, \ldots, n\}$

Product-specific economies of scale exist when a given percentage increase in the output of product i would increase total cost by a smaller proportion (Moschandreas, 2000). To measure this, the average incremental cost needs to be calculated (Bailey & Friedlaender, 1982).

$$AIC_i = \frac{IC_i\,(Y)}{Y_i} = \frac{C\left(Y_i, Y_j\right) - C(0, Y_j)}{Y_i}$$

The product-specific economies of scale are then calculated by the ratio of AIC[42] and the marginal cost:

$$Product - specific\ EOScale = \frac{AIC_i}{MC_i} = \frac{IC_i(Y)/Y_i}{MC_i} = \frac{IC_i(Y)/C(Y_i,Y_j)}{\epsilon_{CY_i}}$$

It is important to mention that estimated product-specific economies of scale (and scope) are often unreliable and likely to have large standard errors (Iimi, 2004).

5.4 Economies of scope vs. cost complementarities

Firms producing multiple products, can however also expand their output while changing the composition of product mix. This can involve the introduction of new products or changing the proportions of the existing product range.

To assess whether diversification reduces costs, the costs of a diversified firm need to be compared to those of a single product firm (producing the same level of output). If the total cost of producing more (two) outputs by one firm is lower than the cost of producing the products separately, the production is characterized by economies of scope. (Moschandreas, 2000)

$$C(Y_1, Y_2) < C(Y_1, 0) + C(0, Y_2)$$

Bailey & Friedlaender (1982) state that, in general, economies of scope arise from the sharing or joint utilization of inputs. Also Panzar & Willig (1981) refer to the fact that the source of scope economies are joint and common costs which are created by production processes that share resources so that the use of a resource by one process leaves capacity for use by another process.

[42] The calculation of product-specific economies of scale based on AIC requires the calculation of the cost function at zero output levels. This should be treated with extra care for the translog cost function, since ln(0) is not defined (Cavallo & Rossi, 2001). However, if data transformation (as explained in section 6.1.4) would be carried out, this problem could be uplifted.

The proportion of total costs saved by joint production can be measured as follows, in case of two products (Panzar & Willig, 1981):

$$EOScope = \frac{C(Y_1, 0) + C(0, Y_2) - C(Y_1, Y_2)}{C(Y_1, Y_2)}$$

Economies of scope occur when this value is larger than zero. If $EOScope$ < 0, then diseconomies of scope exist.

Also for the calculation of economies of scope, the cost function at zero output levels needs to be calculated. The problem of ln(0) not being defined (Cavallo & Rossi, 2001) can again (see footnote 42) be solved through the data transformation, as explained in section 6.1.4.

Product-specific economies of scope

As for economies of scale, there is a difference between overall economies of scope and product-specific economies of scope (Iimi, 2004). Incremental analysis of the cost function , i.e. adding one product to analyze the change in costs, reveals the existence of product-specific cost economies.

$$Product - Specific\ EOScope = \frac{C(y_{N-i}) + C(Y_i) - C(Y)}{C(Y)}$$

for a production set $N = \{1, \ldots, n\}$

However, in case of two products, this comes down to the same analysis as for overall economies of scope.

Cost complementarities

Economies of scope are often mentioned together with cost complementarities. Weng & Wang (2004) refer to Baumol et al. (1988) when stating that interproduct cost complementarities are a sufficient (not a necessary) condition for economies of scope. Also Gilligan et al. (1984) state that cost complementarities give rise to economies of scope. In the paper of Keeler & Formby (1994), it is clearly mentioned that cost complementarities are a measure of economies of scope: if cost complementarities exist, then there are economies of scope.

Cost complementarities represent how an increase in the level of one output (Y_i) will affect the marginal cost of producing the second output (Y_j). The existence of cost complementarities can be analyzed by examining the derivative of the marginal cost of output j (Y_j) with respect to the level of output i (Y_i):

$$\frac{\partial}{\partial Y_i\left(\frac{\partial C}{\partial Y_j}\right)} = \frac{\partial^2 C}{\partial Y_i \partial Y_j}$$

If $\frac{\partial^2 C}{\partial Y_i \partial Y_j}$ <0, then the marginal cost of output j decreases if output i increases and thus cost complementarities exist. This measurement is a "local" concept because it describes how the cost function behaves in the neighborhood of a set of observations.

For a multi-output translog cost function where the data are normalized (as is explained in section 6.1.4), testing whether $\frac{\partial^2 C}{\partial Y_i \partial Y_j}$ <0 is equivalent to testing whether $\alpha_i \alpha_j + \alpha_{ij} < 0$ (D. W. Gillen et al., 1990; Iimi, 2004; Murray & White, 1983; Segal, 2003).

In this research, with a multi-output translog cost function based on two outputs (PAX and CARGO) this comes down to:

$$\alpha_{PAX}\alpha_{CARGO} + \alpha_{PAXCARGO} < 0. \quad (23)$$

5.5 Intermediate conclusion - Economies of scale vs. economies of scope

Regarding output related cost economies, different concepts where discussed in this chapter. An important issue is that all of these concepts are related to each other. The calculation of economies of scale and scope rely on elasticities and obviously overall and product-specific cost economies are linked, but there is also a link between economies of scale and economies of scope.

The cost function of a multi-output firm is sensitive to the composition of output as well as to the scale of output. Economies of scale and scope will thus influence each other, in fact the cost economies reinforce each other. In case of economies of scope, the overall economies of scale exceed above the weighted average of the product-specific economies of scale. This entails that, even in case of product-specific constant returns to scale, overall, there would be increasing returns to scale thanks to the existence of economies of scope.

Moschandreas (2000) states that the overall degree of economies of scale is equal to a weighted average of the product-specific scale economies pertinent to each product magnified by economies of scope by the factor $\frac{1}{1-EOScope}$. Thus economies of scope and decreasing AIC to each product can account for the existence of economies of scale. Strong economies of scope can compensate for constant or decreasing returns to scale to individual products, and thus confer overall economies of scale. The opposite is also true: diseconomies of scope can counterbalance any constant or increasing returns to scale, conferring overall diseconomies of scale.

6. Estimation of an airport multi-output translog cost function

In this chapter, the actual estimation of the aforementioned specification (section 4.3.4) is presented. First, the data used are described. This entails a description of the database, the limitations, the selected sample, the calculation of the unit costs, descriptive statistics and data transformation. Then, the model that is retained for the econometric analysis is explained, leading to the (description of the) estimation results and the calculation of the output related cost economies.

6.1 Data description

As stated before (see section 3.1), the data needed for this dissertation are the total capital cost, total labor cost and total soft cost plus some amount of resources with which the unit costs can be calculated. Next to these input variables, also the output variables (amount of passengers and cargo) need to be collected.

Moreover, in order to estimate the coefficients of the cost function, insight into the total costs is necessary.

6.1.1 ATRS Database

These necessary data can be collected from different data sources, but this holds the risk on incomparable data. A possible way to encounter this risk (partially), is to rely on a database because this gives more certainty that data are at least collected and reported in the same way, incorporating the same information.

The database used in this dissertation is the ATRS Database[43] (2015) which contains historic information on major airports and airport authorities in the regions of Europe, North America and Asia Pacific. The database consists of data from the financial years 2002 – 2012. Data are collected from annual reports as published by individual airports and airport groups, direct request of information from the airports, the Federal Aviation Administration (FAA) and the airport websites. Data for individual airports as well as airport groups are available[44].

[43] The ATRS Database (2015) was created and is maintained by the Air Transport Research Society headquartered at the Sauder School of Business at the University of British Columbia.

[44] For comparability reasons, only the data of the individual airports are taken into account in this dissertation. Data for airport groups stem from consolidated annual reports and might thus contain biases.

For each region, there is information regarding the airports itself, the aeronautical revenue, the non-aeronautical revenue, the operating expenses, the balance sheet and some traffic information. All monetary information included is given in local currency and in US dollars.

6.1.2 Data limitations

However, the use of a database does not guarantee that there are no data issues. Although, at first sight the database contains all the data needed for the empirical research carried out in this dissertation, there are some limitations.

The number of passengers and amount of cargo (output variables) are found in the traffic information sheet. The cost data (input variables) are found in the operating expense file. The total costs are then the sum of capital costs, labor costs and soft costs. In the database, labor costs are expressed as “personnel costs”. The soft/other costs are calculated by deducting the personnel costs from the total operating expenses (since they represent the sum of personnel, contractual services, airport security, and other expenses). Yet, for capital costs, the depreciation costs are selected. This is a proxy variable, not a perfect representation of the capital costs of airports. After all, there is more to capital costs than only depreciation. The database does not incorporate more information regarding capital costs and, furthermore, also in literature, depreciation is the variable used most often to reflect capital costs. Moreover, as stated before, if the capital costs are represented by analyzing depreciation data, then the capital costs are related to the level of production and a long term cost function can be estimated.

To calculate the unit costs, the amount of resources representing each cost need to be incorporated. For labor costs, the unit costs are calculated by dividing the total labor cost (personnel costs) by the number of full time equivalents.

However, for the calculation of the capital unit costs and soft unit costs, again proxy variables are needed. For the calculation of capital unit costs, terminal size (expressed in square meters) was chosen as a proxy variable. This because also in practice, capital costs are linked to square meters. The terminal size is often a proxy variable for turnover or (airport) activities.

Calculating soft unit costs is be done by dividing the soft cost by the number of gates[45]. This because of the high correlation between number of gates and the airport's overall demand for energy, utilities, etc.

Although those proxy variables are not perfect (e.g. they are more related to passenger traffic than to cargo traffic), they are the best proxies available. This is also confirmed by extensive literature review.

6.1.3 Data sample selected

The data sample selected from the ATRS Database (2015) includes cross-section observations from the year 2012. As can be deducted from the market evolution described in section 1.1, 2012 was a year in which the air transport sector was stable and recovered from the financial crisis a few years earlier. The data sample included only one outlier, being Sofia Airport (SOF). Therefore, the data (sample) of 2012 is likely to be robust.

Data for the year 2012 contains information regarding 201 airports (69 for Europe, 78 for North America and 54 for Asia Pacific), but not all data elements are available for all airports. Eliminating the airports for which data were incomplete from the dataset, resulted in a sample of 156 airports (43 for Europe, 75 for North America and 38 for Asia Pacific). Where possible, the information was however completed by direct contact with the airport[46], leading to 161 airports that can be included in the sample for this dissertation.

Four airports have no cargo activities, being Bristol International Airport (BRS), Dunedin International Airport (DUD), Townsville Airport (TSV) and Queenstown Airport (ZQN). None of the airports in the sample reports zero passengers. Those airports where omitted from the sample due to econometric reasons. However, this did not bias the results. The data set used for the analysis, can be found in Appendix 2.

[45] Different models were estimated (see section 6.3), where terminal size was chosen as a proxy for capital unit costs and for soft unit costs. In a second round of estimations the terminal size was replaced by number of gates as a proxy for soft unit costs and this yielded better results.

[46] Information was completed for Bradley International Airport (BDL) (terminal size), Bristol International Airport (BRS) (amount of cargo and terminal size), Gran Canaria Airport (LPA) (terminal size), Jeju International Airport (CJU) (capital costs) and St. John's International Airport (YYT) (terminal size).

Descriptive statistics for the key variables are included in Table 13. The key variables include Total Cost (TC), the output variables Passengers (PAX) and Freight & Mail (CARGO) and the input variables Labor Unit Cost (W), Capital Unit Cost (R) and Soft Unit Cost (M).

The data included in the estimations are normally distributed. See Appendix 3 for the histograms and (other) descriptive statistics.

Table 13: Descriptive statistics of key variables airport multi-output translog cost fuction

	Mean	Std. Dev.	Minimum	Maximum
Total Cost (TC)	2.57e+08	3.20e+08	5410805.	2.42e+09
Passengers (PAX)	18012200	17846470	853650.0	90476742
Cargo (CARGO)	348975.4	690414.8	1.000000	4040000.
Labor Unit Cost (W)	89637.69	67479.93	7286.632	517604.0
Capital Unit Cost (R)	415.8134	220.7213	0.111648	1177.693
Soft Unit Cost (M)	678.3555	574.2705	89.42914	4930.011
Nat. Log. Total Cost (LNTC)	18.77627	1.126810	15.50391	21.60861
Nat. Log. Passengers (LNPAX)	16.20778	1.066869	13.65728	18.32060
Nat. Log. Cargo (LNCARGO)	11.10098	2.512451	0.000000	15.21176
Nat. Log. Labor Unit Cost (LNW)	11.22180	0.611025	8.893797	13.15697
Nat. Log. Capital Unit Cost (LNR)	5.824474	0.901686	-2.192404	7.071313
Nat. Log. Soft Unit Cost (LNM)	6.275840	0.673245	4.493447	8.503097
Nat. Log. Total Cost (LNTC)	18.77627	1.126810	15.50391	21.60861

As can be deducted from these descriptive statistics, the sample selected holds a lot of airports of different sizes, with different traffic mixes, different types of equipment, etc. This broad scope allows the results to be interpreted as being applicable on an average airport.

As indicated earlier (section 4.3.2) the translog function is chosen because it is a flexible functional form, providing a second-order Taylor series approximation in logarithms to an arbitrary cost function around a certain point (Pels & Rietveld, 2000b). It is necessary to specify this approximation point and in this dissertation, analogously to most literature, it is assumed that this point is the mean.

6.1.4 Data transformation

In order to estimate the multi-output translog cost function using the data provided by ATRS Database (2015), the crude data should first be prepared for statistical analysis.

This can be achieved by normalizing the explanatory variables[47] around the mean, i.e. by dividing the observed values (variables) by their mean value. For (natural) logarithms, this comes down to: $\ln(x) \to \ln(x) - \ln(\bar{x})$ (see a.o. Martín & Voltes-Dorta, 2008; Pels & Rietveld, 2000; Van de Voorde, 1984).

The mean value was chosen given the approximation point of the translog (cost) function. However, Gillen et al. (1990) state that the elasticity estimates (cost or demand) at all data points are invariant to the point of data normalization if the translog parameter estimates converge globally.

Normalizing the data provides an easy calculation of output cost elasticities (Martín & Voltes-Dorta, 2008). Given the fact that the total cost and all regressors are in natural logarithms, the first-order coefficients of the translog cost function can this way be interpreted as cost elasticities evaluated at the sample means (D. W. Gillen et al., 1990). But, as stated by Gillen et al. (1990), data normalized at any data point other than the sample mean, would give the same results when estimating the translog cost function.

6.2 Model retained for econometric analysis

As described in section 4.3.4, the specification taken into account for estimations is a long-run[48] multi-output[49] translog cost function, with two outputs and three inputs. Estimations are made with the Eviews9-software, using the (Full Information) Maximum Likelihood (BFGS/Marquardt steps) estimation method.

[47] Only PAX, CARGO, R, W and M are normalized, TC are not.

[48] The estimation can be interpreted as long-run since it involves cross-section data and capital costs are reflected by depreciation (see section 4.3.1).

[49] The multi-product cost function is chosen. Taking into account multiple outputs is preferred over an aggregate output (index) since (a.o. Martín & Voltes-Dorta (2008) state that) single-product cost functions often overestimate cost economies.

The specification with which the estimations are made, is the following:

LNTC=C(1)+C(2)*LNPAX+C(3)*LNCARGO+C(4)*LNR+C(5)*LNW+(1-C(4)-C(5))*LNM
+0.5*C(7)*((LNPAX)^2)+0.5*C(8)*((LNCARGO)^2)+0.5*C(9)*((LNR)^2)+0.5*C(10)*((LNW)^2)
+0.5*(C(9)+C(10)+(2*C(19)))*((LNM)^2)+C(12)*LNPAX*LNCARGO+C(13)*LNPAX*LNR
+C(14)*LNPAX*LNW-(C(13)+C(14))*LNPAX*LNM+C(16)*LNCARGO*LNR
+C(17)*LNCARGO*LNW-(C(16)+C(17))*LNCARGO*LNM+C(19)*LNR*LNW-(C(9)
+C(19))*LNR*LNM-(C(19)+C(10))*LNW*LNM (24)

where: LNTC = nat. logarithm of total cost of producing passengers and cargo

LNPAX = normalized nat. logarithm of number of passengers handled

LNCARGO = normalized nat. logarithm of number of tons of freight and mail handled

LNR = normalized nat. logarithm of input price of capital (cost per unit of capital used)

LNW = normalized nat. logarithm of input price of labor (cost per unit of labor used)

LNM = normalized nat. logarithm of input price of other inputs (cost per unit of other inputs used)

C(1), …, C(19) = coefficients to be estimated

In order to be able to estimate returns to scale, the cost shares are estimated jointly with the specification (Berndt, 1996). These cost shares are written as:

SR=C(4)+C(9)*(LNR-LNM)+C(19)*(LNW-LNM)+C(13)*LNPAX+C(16)*LNCARGO (25)
SW=C(5)+C(10)*(LNW-LNM)+C(19)*(LNR-LNM)+C(14)*LNPAX+C(17)*LNCARGO (26)

where: SR = share of capital cost in total cost

SW = share of labor cost in total cost

6.3 Estimation results

Based on these specifications, different estimations were made. For the first estimations, the unit costs for capital and soft costs were calculated by dividing depreciation and other costs by terminal size (as a proxy for the units of capital and other resources). However, in a second round of estimations, capital costs were also calculated using depreciation and terminal size (as a proxy for capital units), but soft unit costs were calculated by dividing other costs by number of gates (as a proxy for other resources).

Both estimation rounds took into account different samples from the 157 airports in the database. In a first step, all 157 airports where included. Then, estimations were made with airports that handled more than 30,000 tons of freight and mail and finally, only airports that handled more than 50,000 tons of freight and mail were included. This in order to test the robustness of the model.

This thus resulted in 10 different estimation outputs. From all these different estimations, those involving all airports gave the best results. The estimations where terminal size was the only proxy, had a R^2-value of 0.85. However, the estimations based on terminal size as proxy for capital unit cost and number of gates as proxy for soft unit costs gave even better results. With a R^2-value of 0.90 and better scores on the Log likelihood, Akaike info criterion, Schwarz criterion and Hannan-Quinn criterion, this estimation turned out to be the best. These are the results that shall be presented here.

Table 14: Estimation results airport multi-output translog cost function

R-squared = 0.896220		Coefficient	Std. Error	z-Statistic	Prob.
C(1)	constant	19,4634	0,0412	472,3782	0,0000
C(2)	**Passengers (PAX)**	**0,6760**	**0,0444**	**15,2330**	**0,0000**
C(3)	**Cargo (CARGO)**	**0,0721**	**0,0284**	**2,5370**	**0,0112**
C(4)	**Capital Unit Cost (R)**	**0,3188**	**0,0088**	**36,3549**	**0,0000**
C(5)	**Labor Unit Cost (W)**	**0,2499**	**0,0111**	**22,4743**	**0,0000**
C(6)	**Soft Unit Cost (M)**	**0,4312**	**0,0087**	**49,6426**	**0,0000**
C(7)	0.5*PAX*PAX	0,0157	0,0696	0,2254	0,8217
C(8)	0.5*CARGO*CARGO	-0,0072	0,0144	-0,4985	0,6181
C(9)	0.5*R*R	0,0454	0,0066	6,8997	0,0000
C(10)	0.5*W*W	0,0306	0,0120	2,5585	0,0105
C(11)	0.5*M*M	0,1074	0,0170	6,3312	0,0000
C(12)	PAX*CARGO	-0,0001	0,0241	-0,0038	0,9970
C(13)	PAX*R	0,0093	0,0095	0,9814	0,3264
C(14)	PAX*W	-0,0282	0,0120	-2,3525	0,0186
C(15)	PAX*M	0,0189	0,0094	2,0056	0,0449
C(16)	CARGO*R	0,0120	0,0053	2,2513	0,0244
C(17)	CARGO*W	0,0017	0,0068	0,2570	0,7972
C(18)	CARGO*M	-0,0138	0,0053	-2,6054	0,0092
C(19)	R*W	0,0157	0,0081	1,9407	0,0523
C(20)	R*M	-0,0611	0,0061	-10,0298	0,0000
C(21)	W*M	-0,0463	0,0081	-5,7381	0,0000

As can be seen in the specification (section 4.3.4), some coefficients are not estimated directly, but indirectly because of the adding-up and linear homogeneity condition.

$$c_6 = 1 - c_4 - c_5 \tag{27}$$
$$c_{11} = c_9 + c_{10} + (2 * c_{19}) \tag{28}$$
$$c_{20} = -(c_9 + c_{19}) \tag{29}$$
$$c_{21} = -(c_{19} + c_{10}) \tag{30}$$
$$c_{15} = -(c_{13} + c_{14}) \tag{31}$$
$$c_{18} = -(c_{16} + c_{17}) \tag{32}$$

For these coefficients, the standard error, z-statistic and probability need to be calculated. This can be done according to the following method:

- Standard error of $c_6 =$

  $\sqrt{(variance\ of\ c_4) + (variance\ of\ c_5) + 2 * [covariance\ (c_4, c_5)]}$

  The standard errors of c_{15}, c_{18}, c_{20} and c_{21} are calculated in a similar way.

  The standard error of $c_{11} =$

  $$\sqrt{\begin{gathered}(variance\ of\ c_9) + (variance\ of\ c_{10}) + 2^2 * (variance\ of\ c_{19}) \\ +2 * [covariance\ (c_9, c_{10})] \\ +2 * [covariance\ (c_9, c_{19})] + 2 * [covariance\ (c_{10}, c_{19})]\end{gathered}}$$

- The z-statistic of each coefficient is the estimated/calculated value of the coefficient divided by its standard error.
- And the probability can be calculated based on the z-statistic, using basic statistical techniques.

As described above, the model performs very well and most of the relevant parameters are significantly different from zero. The first-order parameters have the expected sign. They are positive, which entails that an increase in output or inputs leads to an increase in total costs.

The coefficients for the input prices (c_4, c_5 and c_6) show that, at the sample mean, capital, labor and other costs account for respectively 32%, 25% and 43% of the total cost. Meaning that, in an average airport, most of the costs are incurred through energy, materials, general airport services, etc. Since soft/other costs represent contractual services, airport security, and other expenses (as described before), it holds some large expenditures, explaining the large share in total costs.

Labor represents the smallest expense. This can be explained by the fact that labor costs taken into account here only represent a fraction of all labor costs at an airport. As explained before, an airport holds a lot of employees, but not all are paid by the airport itself. An airport represents a lot of indirect (and also induced) employment. Moreover, a lot of services (such as ground handling, fueling, catering) are outsourced and thus a large amount of the actual labor costs at an airport are not borne by the airport itself. However, since the cost structure and cost function estimated here is that of the airport, only labor costs borne by the airport are taken into account – also for reasons of comparability.

Finally, capital expenses account for 32% of total costs. Here, it is important to bear in mind that capital costs are represented by depreciation. Therefore, the level of expenses is stable over different years. If investments were taken into account, the costs (or better "expenses") would show peaks in years when the investments were made.

Economies of scale

Due to the data normalization (as described in section 6.1.4) the output coefficients (c_2 and c_3) show the cost elasticities of the different outputs in the sample mean.

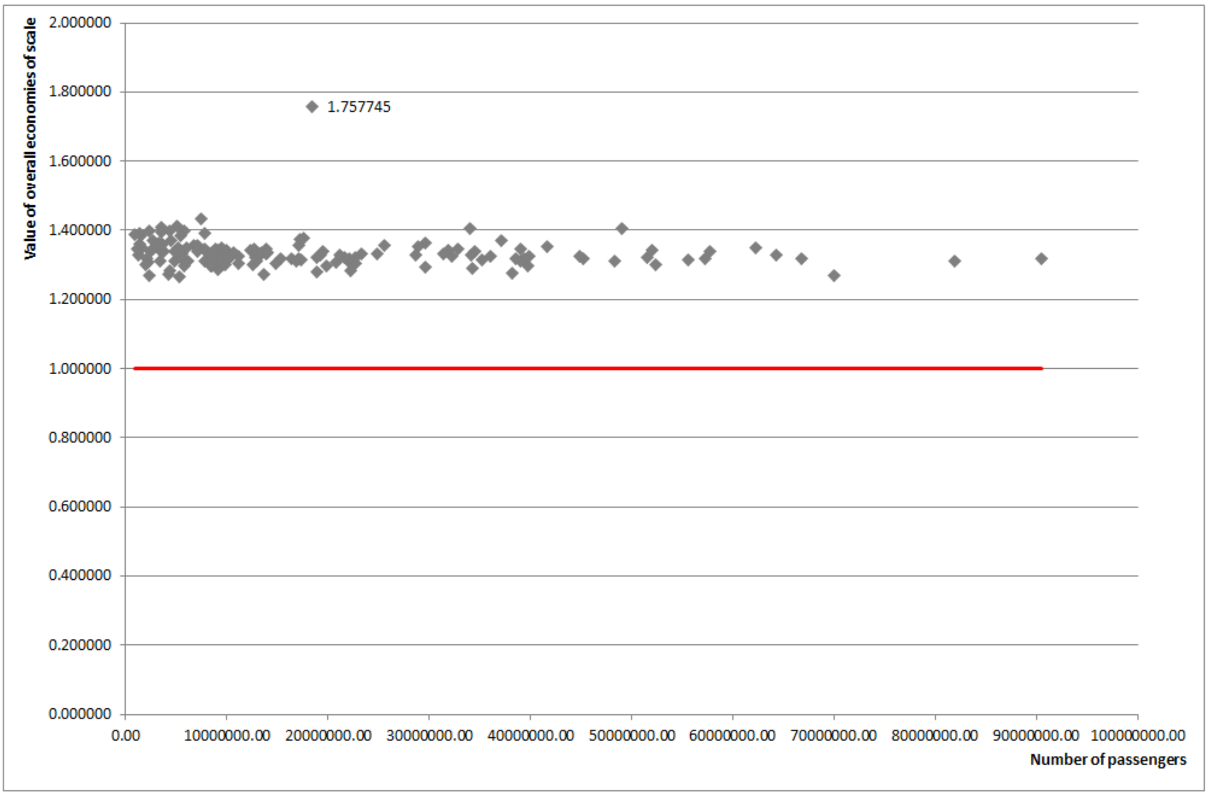
Based on this, the economies of scale in the sample mean can be calculated as:

$$EOScale = \frac{1}{\epsilon_{PAX} + \epsilon_{CARGO}} = \frac{1}{0.6760 + 0.0721} = 1.34$$

This indicates economies of scale for the average airport. A change of 1% in output only induces a cost increase of about 0.75%. However, to get a good view on economies of scale in the airport industry, the economies of scale need to be calculated not only in the sample mean, but also for all airports in the sample. The results, which can be found in Appendix 5, indicate that the values of $EOScale$ lie between 1.27 and 1.43. There is one outlier of 1.76 (i.e. Jeju International Airport), but this might be due to an error in the data[50].

[50] The capital costs of Jeju International Airport were given in Korean Won and converted to US Dollars by applying the same exchange rate as for the other variables (total operating expenses and personnel costs). However, this yielded a capital cost significantly lower than other comparable airports and could thus be an error in the database. Another possible explanation could be that there is state intervention at Jeju International Airport.

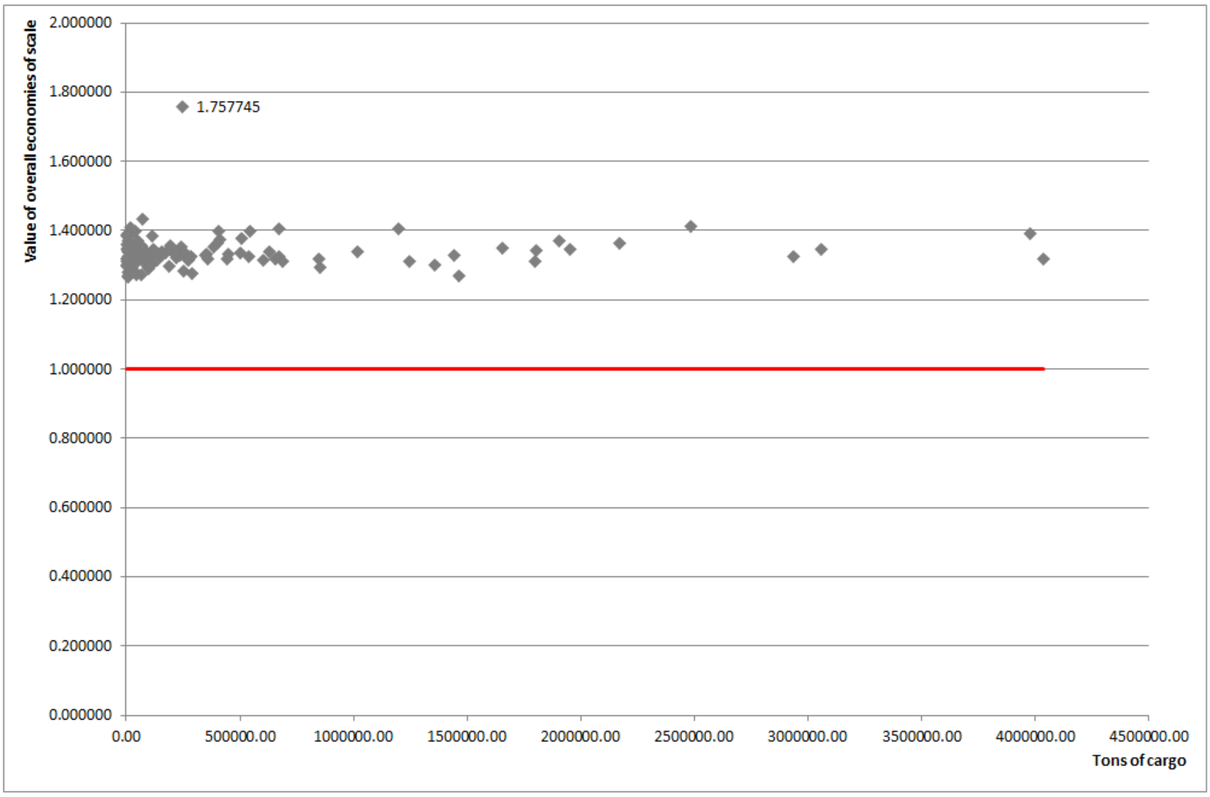
Figure 27: Value of overall economies of scale vs. number of passengers



As can be seen in Figure 27 and Figure 28, there is no real clear image regarding the evolution of economies of scale. However, remarkable is the fact that airports which represent smaller numbers of passengers indeed are more likely to experience higher economies of scale. This is in line with the findings from literature (Bottasso & Conti, 2010; Jeong, 2005; Main, Lever, & Crook, 2003; Martín et al., 2011; Martín & Voltes-Dorta, 2008, 2011b; Tolofari et al., 1990) that the increasing returns to scale seem to decrease as airports get bigger[51].

[51] Possibly due to the diversity in larger airports.

Figure 28: Value of overall economies of scale vs. tons of cargo



Regarding product-specific economies of scale, the method declining marginal costs, as used by Clark (1988), allows to evaluate the existence for each of the products in every airport in the sample. The results, which can be found in Appendix 6, indicate that indeed for each airport a negative value is found for both passengers and cargo. This entails that both passengers and cargo activities are characterized by declining marginal costs and thus, there are product-specific economies of scale.

In order to calculate the degree of product-specific economies of scale, the method including the average incremental cost needs to be used (as explained in section 5.3.1). This requires the calculation of the cost function at zero output levels. In theory, for the translog cost function it is impossible to calculate ln(0) since this is not defined (Cavallo & Rossi, 2001). However, as stated before, data transformation (as explained in section 6.1.4) can uplift this problem. For the calculation of product-specific economies of scale (and economies of scope), the costs for the separate production of passengers and cargo ($TC_{PAX=0}$ and $TC_{CARGO=0}$) need to be calculated. This involves setting the level of passengers at zero and the level of cargo at zero, which has implications for the translog cost function: If $PAX = 0$, then $\ln PAX =$

$\ln 0 = \infty$ so the equation would not be able to be calculated. But given the data transformation, $\ln PAX$ is replaced by "$\ln PAX - \ln \overline{PAX}$". If $PAX = 0$, then also $\overline{PAX} = 0$, and $\ln PAX - \ln \overline{PAX} = \ln 0 - \ln 0 = 0$. Therefore, in case the level of passengers is passengers zero, the expression "$\ln PAX - \ln \overline{PAX}$" can be omitted. The same goes for cargo of which the level is zero.

Nevertheless, taking this into account, the calculation of product-specific economies of scale is very difficult using an estimated translog cost function. When using the parameters found, the estimated $\ln TC$ can be calculated. Given the fact that no estimation is perfect, the estimated $\ln TC$ obviously differs somewhat from the lnTC that can be calculated using the total costs provided by the database. The difference of maximum 4% shows that the estimation is a very good approximation of reality.

However, in order to calculate product-specific economies of scale, the estimated values need to be converted from log to level ($\ln TC \rightarrow TC$). This can be done using e:

$y = e^x \Leftrightarrow x = \ln(y)$ or $TC = e^{\ln TC}$[52]. Given the difference between the estimated $\ln TC$ and the actual lnTC (as can be calculated from the TC in the database), the calculated TC will differ quite a lot from the total costs as can be found in the database. The same problem would thus appear for the total costs where PAX=0 or CARGO=0, and those are total costs that can only be calculated using the estimated $\ln TC$ converted to level using e. Since both $TC_{PAX=0}$ and $TC_{CARGO=0}$ are used in calculating product-specific economies of scale, the calculated value would be biased a lot. Therefore, although the calculation is possible in practice, it would lead to incorrect results.

For the calculation of product-specific economies of scale, another cost function will be estimated (i.e. the quadratic (cost) function). This specification and the estimation results will be explained in section 6.4.

[52] This is applicable in case the total cost is not estimated. For an estimated total cost, the following formula applies: $\widehat{TC} = e^{\ln \widehat{TC} + 1/2\, var\hat{u}^2} \Leftrightarrow u \sim N(0, \sigma^2)$

Economies of scope

A first indicator for economies of scope are the presence of cost complementarities (between passengers and cargo). Calculating cost complementarities gives a positive value of 0.0486, indicating that there are no cost complementarities and thus no economies of scope. A Wald Test shows that this equation is indeed significantly different from zero:

Table 15: Results Wald Test cost complementarities

Wald Test			
Test Statistic	**Value**	**df**	**Probability**
Chi-square	2.155220	1	0.1421
Null Hypothesis: C(2)*C(3)+C(12)=0			
Null Hypothesis Summary:			
Normalized Restriction (=0)		**Value**	**Std.Err.**
C(2)*C(3)+C(12)		0.048624	0.033121
Delta method computed using analytic derivatives			

Now, the degree of economies of scope needs to be calculated for each airport individually. However, since this also involves using $TC_{PAX=0}$ and $TC_{CARGO=0}$, also the calculation of economies of scope would be biased due to the imperfect estimation of the translog cost function. Therefore, also economies of scope will be calculated using the alternative cost function, as described in section 6.4.

6.4 Estimation of a quadratic (cost) function

Based on the translog cost function, using normalized data, it would be feasible to calculate the product-specific economies of scale and the economies of scope. However, as shown before, these results would be biased a lot by the imperfect estimation. One option is then to simply not calculate product-specific economies of scale and economies of scope and only analyze the existence of both cost economies using the estimated translog cost function relying on the methods of declining marginal costs and cost complementarities respectively. However, based on second-best cost functions, it would be possible to also calculate the product-specific economies of scale and economies of scope. That is what will be done in this dissertation. It is important to mention here that the calculation is indeed based on a second-best model which might cause biases in the results.

In order to calculate the product-specific economies of scale and the economies of scope for each airport individually, a cost function which does not involve logarithms needs to be estimated. As Pels & Rietveld (2000a) state, this other cost function is preferably also a flexible functional form since this allows a U-shaped average cost function. Possible alternatives for the translog cost function are then the quadratic cost function or the generalized Leontief cost function. The latter however imposes constant returns to scale and is thus not suitable for the analysis in this dissertation, being the calculation of output related cost economies for airports. Baumol et al. (1988), but also several other authors such as Cohn et al. (1989) and Mayo (1984), have recommended the use of a quadratic cost function for estimating scale and scope economies for most types of multi-product organizations. It is a second-order Taylor approximation around the mean and it has shown to comply most closely with the required features of a multi-product production function (Lewis & Dundar, 1995). Also various other authors (such as D. W. Caves et al., 1980; Kwoka, 2002; Pulley & Braunstein, 1992; Röller, 1990; Smet, 1998) have described or used a quadratic cost function for different sectors.

As stated before (section 4.3.2), in order for a flexible form to be attractive for empirical applications, it must be linear homogenous in input prices for all possible price and output levels, it must be parsimonious in parameters and contain the value zero in the permissible domain of output quantities (D. W. Caves et al., 1980). Although the quadratic cost function does not satisfy the homogeneity condition - nor can it be imposed by parametric restrictions without sacrificing the flexibility of the form - and entails more parameters than the translog cost function, it does allow zero output values, which makes it interesting for the calculation of product-specific economies of scale and economies of scope.

Baumol et al. (1988) writes the quadratic (cost[53]) function as follows:

$$C(y,w) = F + \sum_i a_i\, y_i + \frac{1}{2}\sum_i \sum_j a_{ij}\, y_i y_j \tag{33}$$

where: $C(y,w)$ = total cost of producing y using input with a price of w
F = fixed cost parameter
y_i & y_j = outputs i and j
w = price(s) of inputs

Baumol et al. (1988) assume that $F \geq 0$ and that $a_{ij} = a_{ji}$. Furthermore, they ignore the role of input prices w_i and take F, a_i and a_{ij} to be unspecified functions of the vector w in order to deal more clearly with the effects of changes in outputs.

However, as Caves et al. (1980) show, Lau (1974) suggests that the quadratic cost function can also be written taken into account the different inputs:

$$C = \alpha_0 + \sum_i^m \alpha_i\, Y_i + \sum_i^n \beta_i\, W_i + \frac{1}{2}\sum_i^m \sum_j^m \delta_{ij}\, Y_i Y_j + \frac{1}{2}\sum_i^n \sum_j^n \gamma_{ij}\, W_i W_j$$
$$+ \sum_i^m \sum_j^n \rho_{ij}\, Y_i W_j \tag{34}$$

where: C = total cost of producing $Y_i, \ldots, Y_m$
Y_i & Y_j = outputs i and j (m outputs)
W_i & W_j = prices of inputs i and j (n inputs)

Using the Least Squares (OLS) method[54], both types of equations where estimated using the same data as described in section 6.1. The estimation by the model of Baumol et al. (1988) yielded results with a R^2-value of 0.57, while R^2-value of the estimations according to the model of Lau (1974) was 0.92 (see Appendix 7 for the estimation results). The latter however showed to have almost no significant parameters, while for the first estimation all of the relevant parameters are significantly different from zero and have the expected sign. Given the cross-section data, a R^2-value of 0.57 is also satisfactory. Therefore, these estimation results (as shown in Table 16) will be used to calculate the product-specific economies of scale and economies of scope.

---

[53] Given the fact that input (prices) are not included here, this model is not to be considered as being a cost model.

[54] The Eviews9-software was used to obtain the OLS estimation results for the quadratic (cost) function.

Table 16: Estimation results airport quadratic (cost) function

R-squared = 0.572339		Coefficient	Std. Error	t-Statistic	Prob.
C(1)	constant	-12549864	33076728	-0.379417	0.7049
C(2)	**Passengers (PAX)**	15.10997	2.901036	5.208475	0.0000
C(3)	**Cargo (CARGO)**	234.0229	87.96118	2.660525	0.0086
C(4)	0.5*PAX*CARGO	0.000002580	0.00000133	1.938118	0.0545
C(5)	0.5*PAX*PAX	-0.000000226	0.0000000865	-2.612273	0.0099
C(6)	0.5*CARGO*CARGO	-0.000148	0.0000507	-2.922594	0.0040

The low t-Statistic and high probability of the constant parameter shows that it is likely that this parameter is zero. Therefore, the calculations of the product-specific economies of scale and economies of scope are made with a model assuming the constant to be zero (model A), and with the parameters set at the levels given in Table 16 (model B).

Model A:

$$TC = 0 + 15.10997 * PAX + 234.0229 * CARGO + \frac{1}{2} * 0.000002580 * PAX * CARGO - \frac{1}{2} * 0.000000226 * PAX * PAX - \frac{1}{2} * 0.000148 * CARGO * CARGO$$

Model B:

$$TC = -12549864 + 15.10997 * PAX + 234.0229 * CARGO + \frac{1}{2} * 0.000002580 * PAX * CARGO - \frac{1}{2} * 0.000000226 * PAX * PAX - \frac{1}{2} * 0.000148 * CARGO * CARGO$$

The results for all the individual airports can be found in Appendix 8 for product-specific economies of scale and Appendix 9 for economies of scope.

The results achieved in model A (where the constant is assumed to be zero) show to be the most plausible, therefore, only these results will be discussed below.

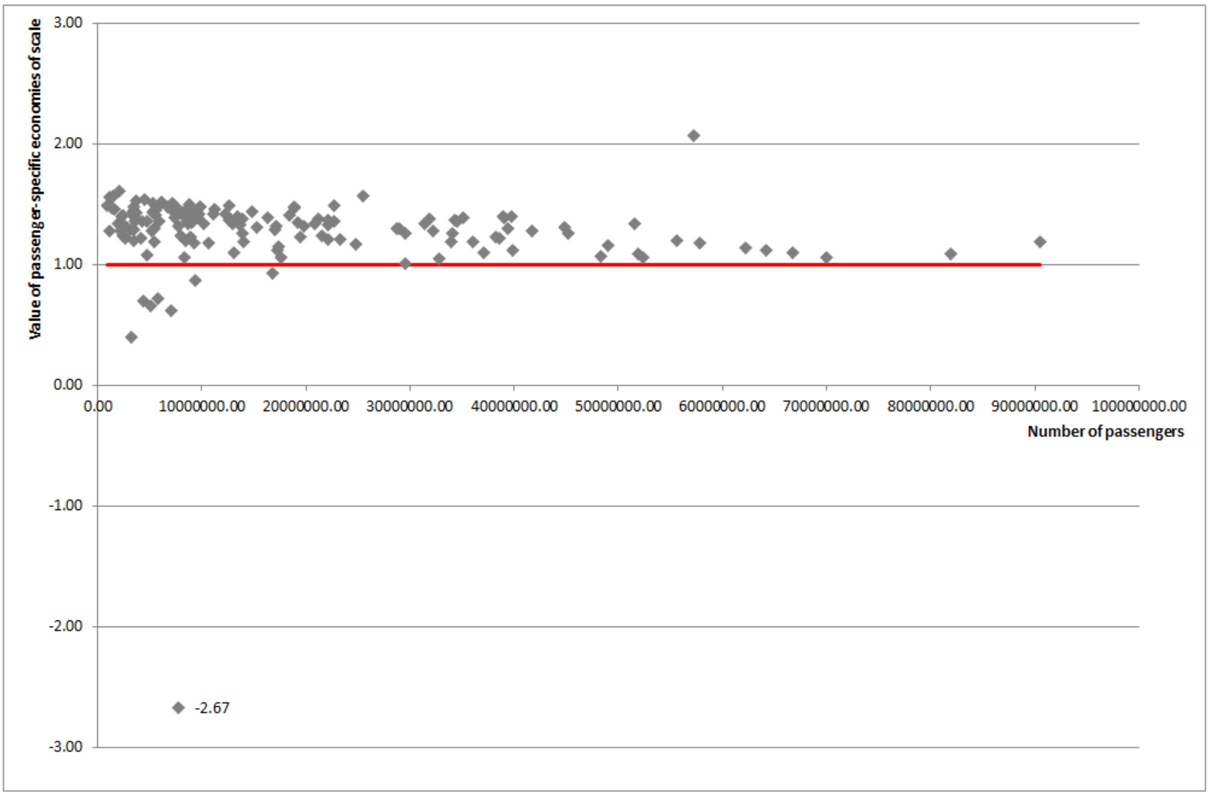
Given the fact that these results are yielded by a second-best model, the results might deviate somewhat from the results achieved by the translog model. It must be noted here, that although the quadratic model is a second best approach – as evidenced by the frequent use in previous literature – the results of the translog model are to be trusted more than those of the quadratic model.

Product-specific economies of scale

Regarding product-specific economies of scale, a difference can be made between economies of scale for passengers and economies of scale for cargo.

With respect to passengers, almost all airports show the existence of economies of scale, which is in line with the results generated by the translog model (see section 6.3). Only 7 of the 157 show the existence of diseconomies of scale. Furthermore, there is one outlier[55] (Memphis International Airport) with a very low value (-2.67). The other values range between 0.40 and 2.06.

Figure 29: Value of passenger-specific economies of scale vs. number of passengers

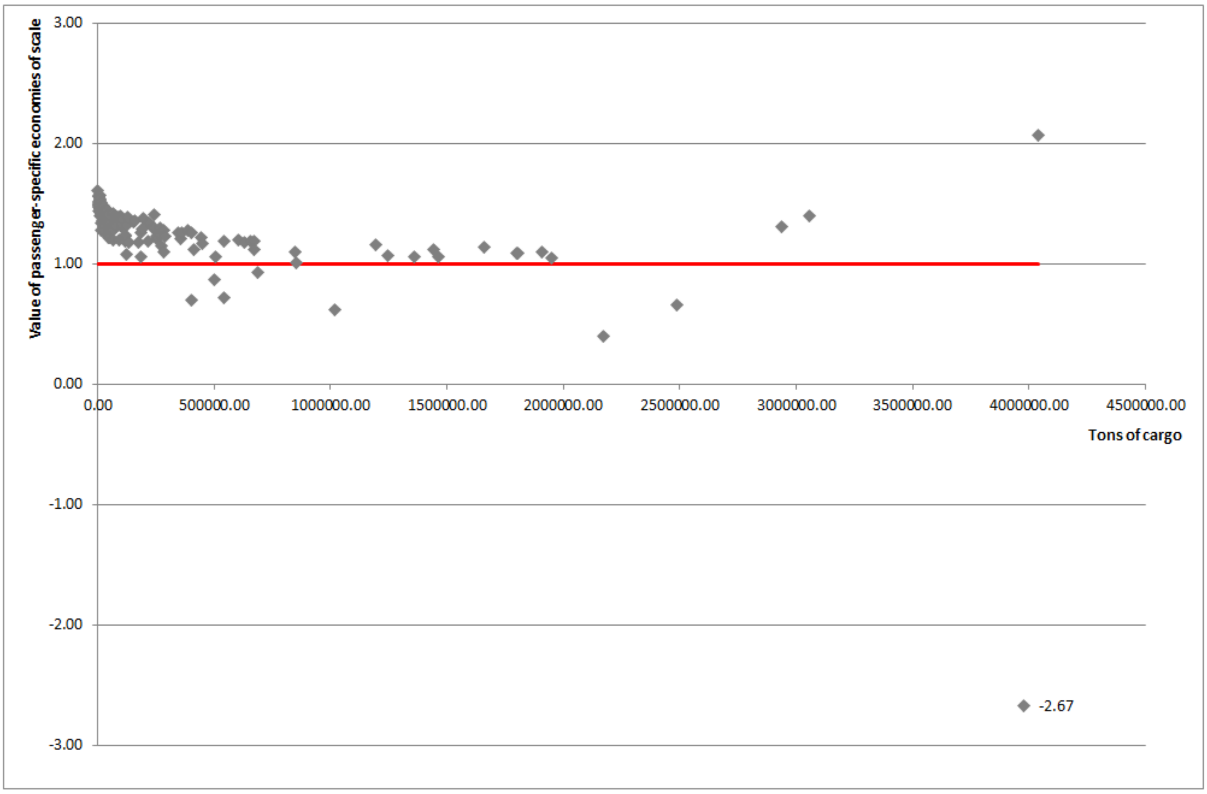


As can be seen in Figure 29 and Figure 30, the airports with the values below 1 (so diseconomies of scale) all have a rather small amount of passengers handled, but differing amount of cargo handled. The largest airports in terms of passengers show values above 1. So (some) airports that handle small numbers of passengers, are not inclined to increase the scale of their passenger operations, while large passenger airports would be willing to grow even

[55] This airport also shows deviating results regarding the cargo-specific economies of scale and the economies of scope, probably indicating a data error rather than an extraordinary airport.

more in terms of passenger handling. The higher values regarding passenger-specific economies of scale are present at the airports with low cargo numbers. So for them it is interesting to increase the scale of their passenger operations.

Figure 30: Value of passenger-specific economies of scale vs. tons of cargo



In contrast to what was found in the translog model, the quadratic model shows that only 99 airports experience economies of scale with respect to cargo. Nevertheless, also using this second best approach, the overall view indicates that airports experience cargo-specific economies of scale. The values range between 0.02 and 11.02 where 56 airports experience diseconomies of scale and, also here, Memphis International Airport is an outlier with a value of 27.48, while Jeju International Airport[56] has an unusual value of -12.69.

[56] As indicated before (section 6.3), the deviating results of Jeju International Airport can be due to an error in the database since the capital costs given needed to be converted from Korean Won to US Dollars using the exchange rates used to convert the other monetary values.

Figure 31: Value of cargo-specific economies of scale vs. number of passengers

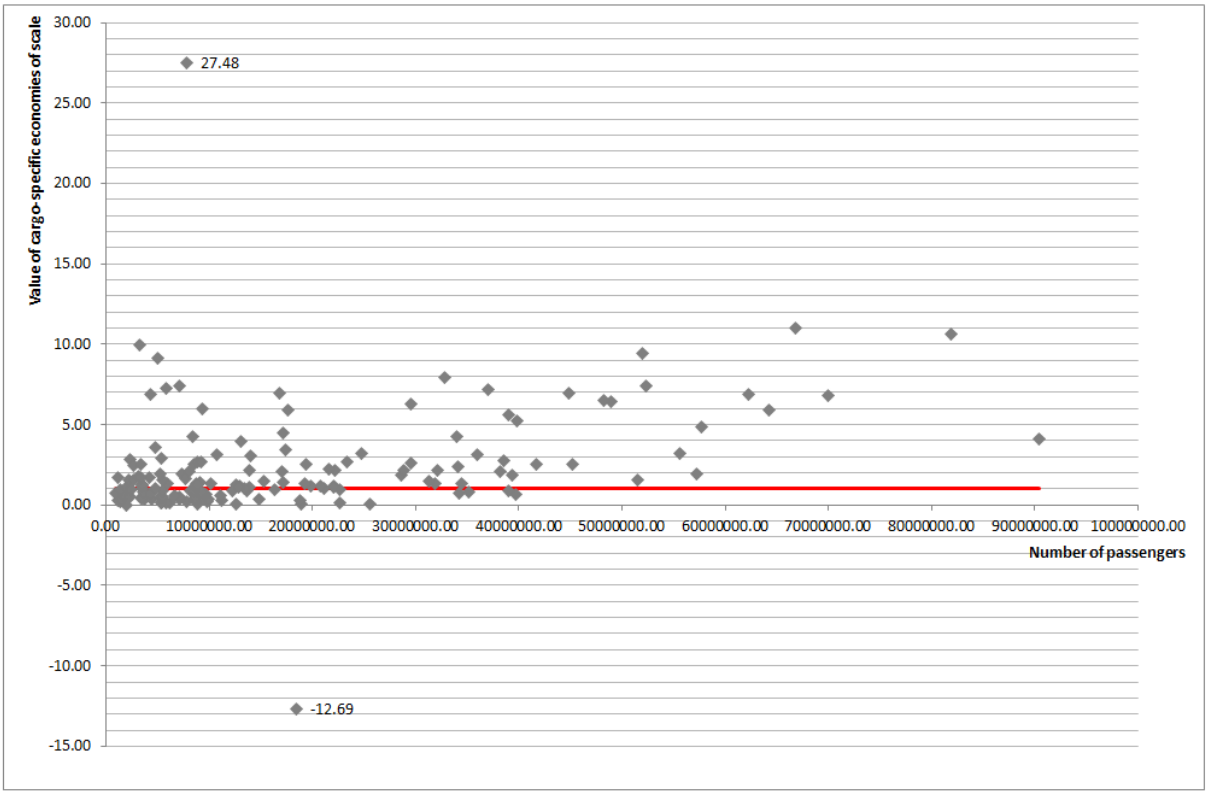
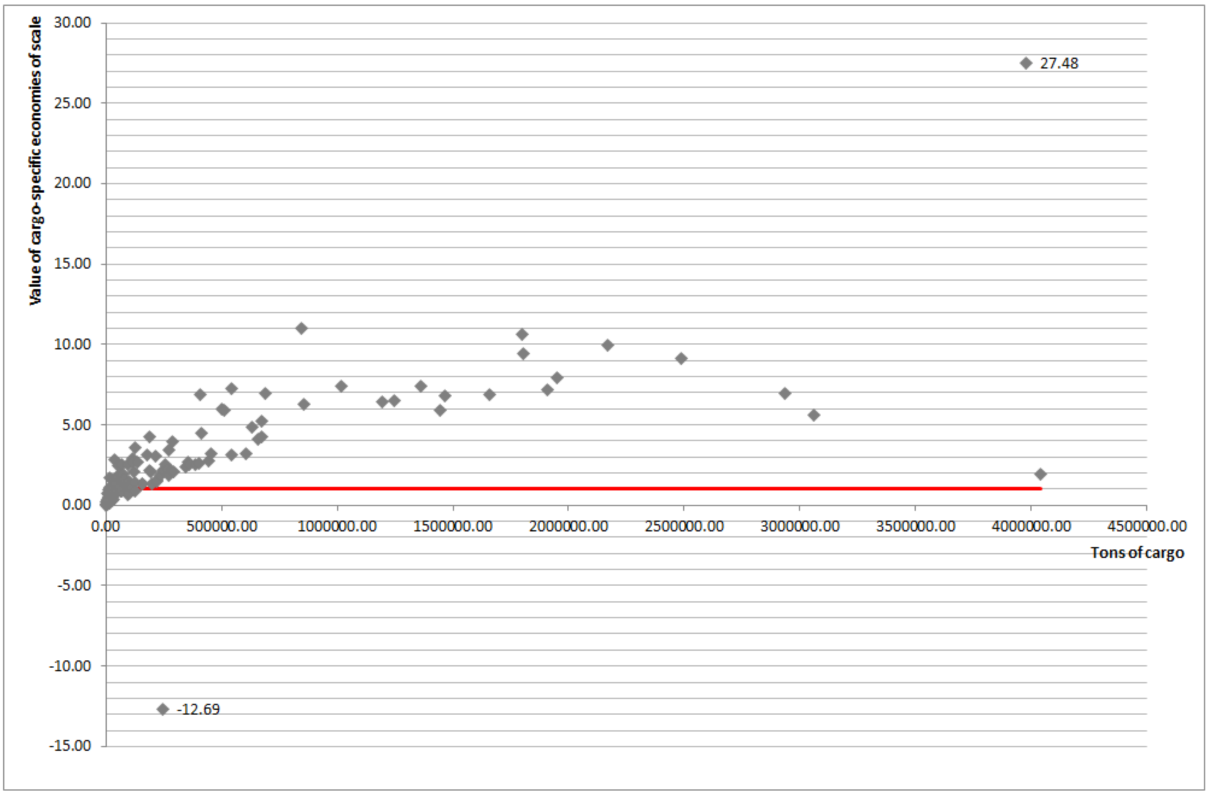


Figure 31 and Figure 32 show that, as opposed to the findings of economies of scale with respect to passengers, the airports showing diseconomies of scale all handle rather little cargo. Thus, airports which handle small amounts of cargo are not inclined to increase the scale of their cargo operations. The large airports, in terms of passengers and in terms of cargo show economies of scale for cargo operations. For those large airports, it is thus interesting to increase the scale of their cargo operations.

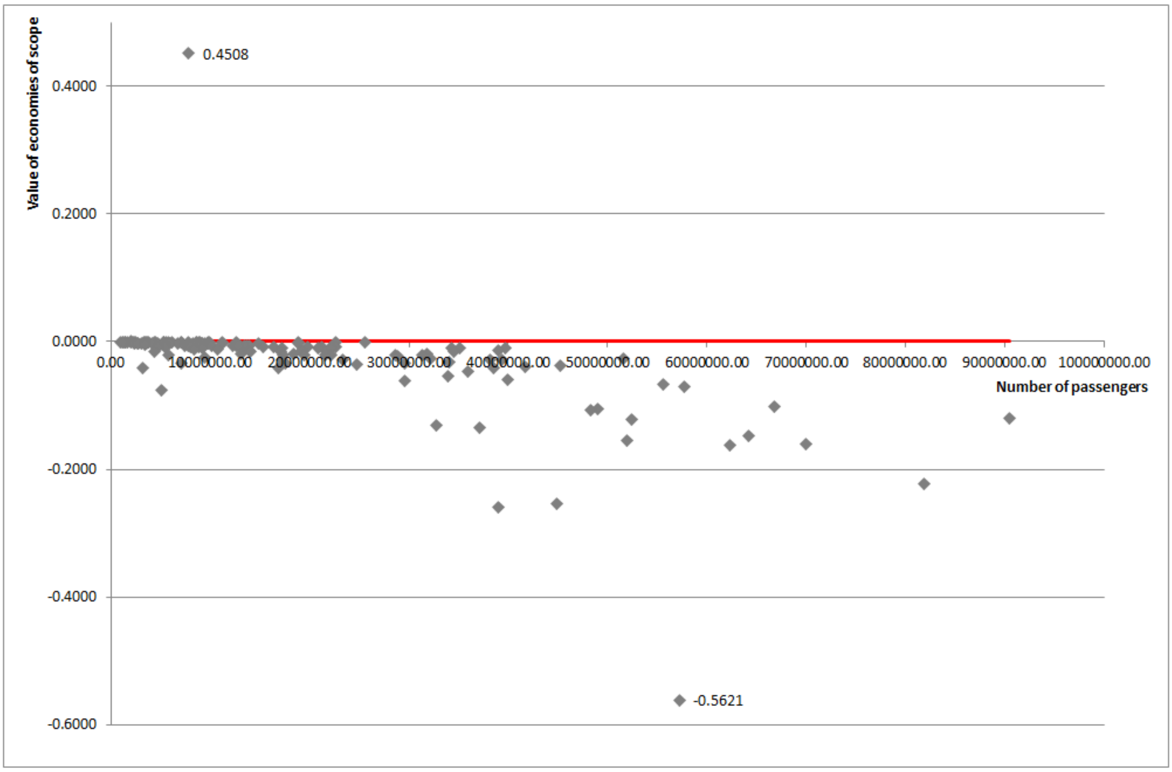
Figure 32: Value of cargo-specific economies of scale vs. tons of cargo



Economies of scope

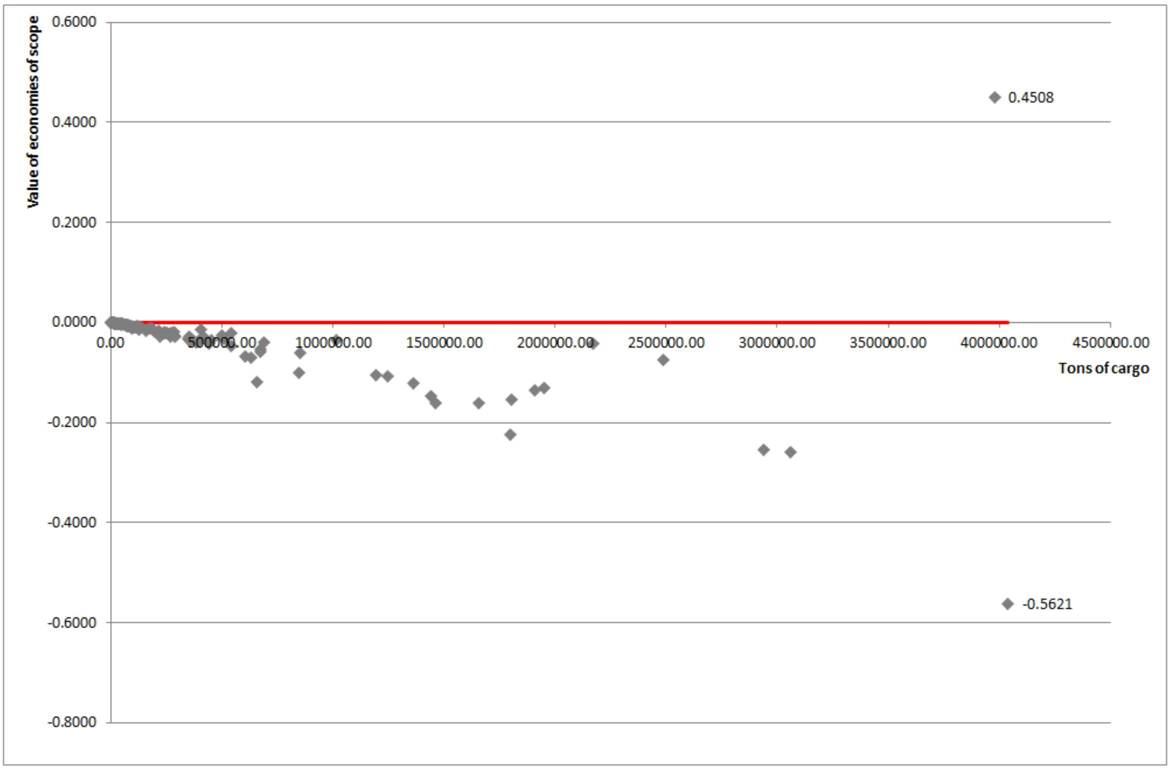
Analyzing the calculated values for the economies of scope, is becomes clear that Memphis International Airport is an outlier. It is the only airport that has a positive value and would thus experience economies of scope. All the other airport in the sample do not experience economies of scope. This finding is in line with what was indicated by the cost complementarities using the translog model.

Figure 33: Value of economies of scope vs. number of passengers



The values for the economies of scope range between -0.56 and -0.00003. The majority of the airports show a value very close to zero, indicating that the difference (cost wise) between offering the product separately or jointly is very small. Setting these values out against the number of passengers and the tons of cargo indicates that for larger airports, cost wise, it is less interesting to combine passenger and cargo activities.

Figure 34: Value of economies of scope vs. tons of cargo



6.5 Intermediate conclusion

The econometric analysis and accompanying calculations revealed that all airports in the sample experience ray (overall) economies of scale. Similar to earlier literature, also this analysis indicates that airports which handle rather small numbers of passengers are likely to achieve higher economies of scale. Regarding product-specific economies of scale, the translog model showed that they exist for both passengers and cargo. The results of the quadratic model deviate somewhat, but also here, the overall trend is that there are product-specific economies of scale for passengers and cargo and that mostly smaller airports (in terms of passengers and cargo) are less likely to increase the scale of their passenger- or cargo activities.

The translog model revealed that there are no cost complementarities and thus no economies of scope. These findings are reinforced by the quadratic model, showing also that larger airports are, based on cost data, less likely to combine both activities.

Conclusions, recommendations and further research

Within this last part of this dissertation, the conclusions of the research are formulated. Furthermore, some recommendations for the sector are listed and some directions for further research are presented.

7. Conclusions, recommendations and further research

Air transport is a booming business. Market developments show that both passenger and cargo traffic have grown in the past and will still grow in the future. Since 1977, every 15 years, air traffic has doubled. The air transport market is thus a market with a lot of opportunities.

Literature has shown that for airlines it is interesting to combine both commodities. Since they experience economies of scope, combining passengers and cargo results in lower costs. Moreover, the airline sector is characterized by increasing returns to density, which entails that if they want to decrease their cost by increasing the scale of operations, it is better to increase their traffic density on their existing network rather than to expand their network.

The question remains whether combining passengers and cargo is also interesting for airports. In practice, a lot of airports combine both commodities. However, literature explaining this phenomenon is rather scarce. Some previous research refers to the existence of economies of scale, but only up until a certain level. The larger the airport, the less advantageous (cost wise) it is to increase the scale of operations. However, other sources find constant returns to scale. Only one paper investigated whether for airports it is interesting to combine passengers and cargo cost wise. The authors found that there are strong economies of scope. The few sources available analyzing cost economies thus are not unanimous due to differences in method, partial views on airport operations or lack of data comparability.

This dissertation provides an answer to this research gap. The research focuses on the existence of output related cost economies that might influence the airport's strategic decision regarding passenger and/or cargo activities, by answering the following research question:

Do airports experience output related cost economies (economies of scale and/or economies of scope) which explain why airports combine passenger and cargo activities?

However, also other influencing factors were analyzed. In order to get a view on these factors and answer the research question, six sub research questions are formulated. In section 7.1 these questions are answered, based on the research carried out in this dissertation. Section 7.2 provides recommendations for the sector and in section 7.3 some directions for further research are listed.

7.1 Conclusions

To get insight into the existence of output related cost economies for airports and other factors influencing the airports' strategic decision concerning passenger and/or cargo handling, the six sub research questions will be answered, based on the extensive research in the previous chapters of this dissertation.

How are airports positioned in the air transport sector and what is their role?

Chapter 1 showed that the air transport sector is characterized by a lot of developments and trends. Traffic has grown the last decades - despite the external shocks such as oil crises, 9/11 and the financial crisis of 2009 - and will continue to grow in the future. Yet, the composition of traffic slightly changes. The share of domestic traffic decreases while the share of international traffic rises. Also on the cargo market, the scenery changed: over the years, more and more cargo (freight and mail) is transported by all cargo aircraft. However, given the fact that the all cargo is a volatile market – much more volatile than the combi market – the last years, in times of crisis, airlines were more inclined to first fill up their free belly capacity, before using all cargo aircraft. Moreover, emerging markets in the eastern and southern countries are more and more competing with the developed markets such as Europe and North America. These evolutions are challenging for airports, but are also opportunities.

Within the complex air transport sector, which involves a lot of stakeholders, the airport is the platform on which airlines and their customers meet. The market which an airport faces is an (imperfect) two-sided market, entailing that the airport can have an impact on both sides of the market by applying the correct pricing strategy.

What other stakeholders affect the airport and its strategy concerning passenger and/or cargo handling?

Given the fact that the airport is part of a two-sided market entails that especially the other stakeholders of that two-sided market influence the airport's strategy. On the one hand, there are passengers and/or cargo. The different types of passengers and cargo can impact the airport (operations), mainly on which resources need to be provided and the price and performance of the activities offered. Airlines on the other hand, have a larger influence on the airport's strategy (concerning passenger and/or cargo handling). Given fact that they are often joint in alliances, enhances the power they have over the airport. Taking this into account, they can indeed force some of their strategies on the airport. For example, given the economies of scope they experience, they will bring both passengers and cargo into the airports they serve. Given the increasing returns to density, they will bring in both commodities in large numbers to their existing network, rather than to increase their network. This is something the airport will need to and want to respond to by offering as much capacity as possible.

How is the airport's strategy concerning passenger and/or cargo handling influenced by the organizational structure of the airport?

Chapter 2 discussed the potential determinants of airport capacity and how this is related with airport activities and resources. The chapter revealed that the lay-out of the airport site (e.g. a separate cargo site), as well as the available infrastructure (e.g. number of runways or terminals and their dimensions) affects the how many customers the airport can receive. Moreover, the chapter also revealed that the type of airport ownership has some consequences for the management style and the importance of commercial activities on top of the core activity of aviation. This also impacts what and how many customers the airport will try to attract

This all determines which activities the airport needs or wants to offer and what extra resources they will need to provide - on top of the indispensable resources - to keep their customers satisfied.

What does the airport's cost structure look like?

Regarding those resources, Chapter 3 showed that the airport is responsible for the provision and maintenance of almost all infrastructure, while a lot of the operational tasks are outsourced to service providers. This results in the fact that the airport has to bear most of the capital costs, but that also labor costs and soft costs (related to the maintenance of the infrastructure) need to be borne by the airport. The labor costs related to the operational tasks are borne by third parties, but the large share of soft costs and capital costs with which the airport is confronted with forms a source for economies of scale.

Do airports experience economies of scale?

The empirical research, as explained in Chapter 6, indeed indicated that airports experience economies of scale. The average value is calculated to be 1.34 and the values for the individual airports range between 1.27 and 1.43. All the airports within the data sample, which included the largest airports worldwide, experienced increasing returns to scale. This is in line with earlier research, and confirms the findings of Martín & Voltes-Dorta (2011b) which showed that returns to scale are exhausted at some point, but that point lies beyond the scale of operations of the world's largest airports.

When analyzing the existence of product-specific economies of scale, the method based on the declining marginal costs (based on the translog cost function), reveals passengers and cargo activities are characterized by product-specific economies of scale. Increasing the scale of operations is thus interesting for both activities, (partly) explaining why airports perform both type of activities and that way combine passengers and cargo. The quadratic model confirms that indeed the majority of all airports in the sample experience product specific economies of scale for passengers and for cargo, with values ranging between 0.4 and 2.06 and 0.02 and 11.02 respectively. The analysis revealed that airports which handle small amounts of passengers are not inclined to increase the scale of their passenger or cargo operations. Also for airports with small cargo operations it does not seem interesting (cost wise) to increase the scale of their cargo handling activities. However, in this model some airports show to experience product-specific diseconomies of scale – as opposed to what the translog model revealed. This is due to the fact that the quadratic model is a second best model.

Do airports experience economies of scope?

Empirical research, based on cost complementarities calculated using the translog cost function, indicated that airports do not experience economies of scope. This contradicts earlier research (by Chow & Fung (2009)). Also the values calculated using the quadratic model show that, apart from one outlier, all airports indeed do not experience economies of scope. Although Chapter 3 indicated that there might be some joint costs, these results show that there are not enough joint costs to result in cost saving by combining both passengers and cargo. However, the values (which range between -0.56 and 0.00003) do indicate that for the majority of airports in the sample, the difference between offering both activities separately or jointly is very small.

7.2 Sector recommendations

The results of this research can give airport managers and other industry stakeholders, but also policymakers or other institutions insight into the airport cost structure and how airport strategies concerning passenger and/or cargo handling are influenced by the complexity of the air transport sector.

In general, the dissertation highlights that the whole air transport sector is characterized by the existence of output related cost economies, being economies of scale and scope. However, these are captured by the airlines, as also other studies reveal.

For airports, it is also important to handle both passengers and cargo, however, not from a cost side point of view. Although the difference in costs between offering passenger and cargo activities separately or jointly is rather small, still there are not enough joint costs to experience economies of scope.

Based on the results of this dissertation, airport managers can conclude that the business strategy of the airport should be set on responding to the market created by the economies of scope and returns to density which their most important customers (i.e. airlines) encounter. By stressing in their marketing that the airport handles both passengers and cargo, airports can enlarge their market share and be more competitive. This way, airports can also respond to the changing air transport environment, seizing the opportunities of the growing markets and the emerging markets.

Moreover, this dissertation showed that economies of scale do exist in the airport sector due to the large capital costs. Airports will thus have to attract as many customers as possible to make use of the free capacity they have. Given the existence of product-specific economies of scale, it is interesting to attract both passengers and cargo. And since airports are part of a two-sided market, they can attract the much wanted (or needed) traffic by offering the right resources for the right price.

As shown in this dissertation, the aeronautical exploitation is nowadays more and more combined with commercial activities. Given the trend for private ownership, the strive for commercialization continues even further. This is another incentive to attract as much traffic as possible, which thus lowers the risk of potential (pricing) power abuse. Policy makers, regulators and other institutions should take this into account and look at regulation more as a monitoring tool than as a controlling mechanism.

7.3 Further research

Directions for further research consist of directions to deepen the analysis carried out here as well as directions to complement this research.

In order to deepen the analysis, further research could overcome the data issues that this dissertation was limited by. More specifically, the input prices of capital and other resources (unit costs) can be calculated using other (proxy) variables. This might provide a more accurate view on airport costs. The use of more and/or different outputs such as a division between cargo carried in the belly of an aircraft and the cargo carried by a full freighter aircraft can also add to the refinement of empirical results, since the handling of both airplanes is different. The difference in handling of aircraft can also be taken into account by incorporating variables to reflect the fleet characteristics.

By using panel data (i.e. data for multiple airports for multiple years), an insight in the evolution of cost economies can be gained. The research can also be carried out by using another method or model (e.g. variable cost function, a dynamic specification of the translog cost function or generalized translog cost function). Furthermore, the research carried out here can be complemented by a calculation of Allen substitution elasticities or Hicks price elasticities. Oher possibilities are the analysis of the revenue structure of airports or analysis of the cost economies for airlines.

References

ACI Europe. (2004). *The social and economic impact of airports in Europe*.

Adams, R., Bauer, P., & Sickles, R. (2002). *Scope and Scale Economies in Federal Reserve Payment Processing* (Working Paper No. 02–13). Federal Reserve Bank of Cleveland. Retrieved from https://www.clevelandfed.org:443/newsroom and events/publications/working papers/working papers archives/2002 working papers/wp 0213 scope and scale economies

Airbus. (2015). Global Market Forecast 2015-2034 | Airbus, a leading aircraft manufacturer. Retrieved August 17, 2015, from http://www.airbus.com/company/market/forecast/

Airbus. (2016). *Global Market Forecast 2016-2035 "Mapping Demand."*

Allaz, C. (2005). *History of Air Cargo and Airmail from the 18th Century*. Paris: Cristopher Foyle Publishing.

Antoniou, A. (1991). Economies of Scale in the Airline Industry: The Evidence Revisited. *Logistics and Transportation Review*, (27), 159–184.

Appold, S. J., & Kasarda, J. D. (2011). Seeding growth at airports and airport cities: Insights from the two-sided market literature. *Research in Transportation Business & Management*, *1*(1), 91–100. https://doi.org/10.1016/j.rtbm.2011.06.011

ATRS. (2015). ATRS Data Set. Europe, North America and Asia-Pacific airport data for 2012.

Bailey, E. E., & Friedlaender, A. F. (1982). Market Structure and Multiproduct Industries. *Journal of Economic Literature*, *20*(3), 1024–1048.

Baltagi, B. H., Griffin, J. M., & Rich, D. P. (1995). Airline Deregulation: The Cost Pieces of the Puzzle. *International Economic Review*, *36*(1), 245–258. https://doi.org/10.2307/2527435

Basso, L. J., & Jara-Díaz, S. R. (2005). Calculation of Economies of Spatial Scope from Transport Cost Functions with Aggregate Output with an Application to the Airline Industry. *Journal of Transport Economics and Policy*, *39*(1), 25–52.

Basso, L. J., & Jara-Díaz, S. R. (2006). Is Returns to Scale with Variable Network Size Adequate for Transport Industry Structure Analysis? *Transportation Science*, *No. 3*(Vol. 40), 259–268.

Baumol, W. J., Panzar, J. C., & Willig, R. D. (1988). *Contestable markets and the theory of industry structure - Revised edition*. Harcourt Brace Jovanovich.

Berndt, E. R. (1996). *The Practice of Econometrics: Classic and Contemporary* (Har/Dskt edition). Reading, Mass.: Addison Wesley.

Besanko, D., & Braeutigam, R. R. (2010). *Microeconomics*. John Wiley & Sons.

Bhadra, D. (2010). Choice of Aircraft Fleets in the U.S. Domestic Scheduled Air Transportation System: Findings from a Multinomial Logit Analysis. *Journal of the Transportation Research Forum*, *44*(3). https://doi.org/10.5399/osu/jtrf.44.3.586

Boeing. (2016). *Long-Term Market. Current Market Outlook 2016 - 2035.*

Boos, F. (2015, December). *Challenges and opportunities in air freight*. Presentation presented at the Air Transport Colloquium 2015, Antwerp.

Borenstein, S. (1992). The Evolution of U.S. Airline Competition. *Journal of Economic Perspectives*, *6*(2), 45–73. https://doi.org/10.1257/jep.6.2.45

Bottasso, A., & Conti, M. (2010). *An Assessment on the Cost Structure of the UK Airport Industry: Ownership Outcomes and Long Run Cost Economies* (SSRN Scholarly Paper No. ID 1618318). Rochester, NY: Social Science Research Network. Retrieved from http://papers.ssrn.com/abstract=1618318

Bottasso, A., & Conti, M. (2012). The Cost Structure of the UK Airport Industry. *Journal of Transport Economics and Policy*, *46*(3), 313–332.

Braeutigam, R. R. (1999). Learning about transport costs. In *Essays in Transportation Economics and Policy: A Handbook in Honor of John R. Meyer* (pp. 57–97). Brookings Institution Press.

Brueckner, J. K., & Spiller, P. T. (1994). Economies of Traffic Density in the Deregulated Airline Industry. *The Journal of Law & Economics*, *37*(2), 379–415.

Castro, M. (2002). *Acquisitions Mergers and Strategic Alliances - Current Trends and Directions in the Parcel Courier and Post* (p. 92). Universal Postal Union.

Cavallo, L., & Rossi, S. P. S. (2001). Scale and scope economies in the European banking systems. *Journal of Multinational Financial Management*, *11*(4–5), 515–531. https://doi.org/10.1016/S1042-444X(01)00033-0

Caves, D. W., Christensen, L. R., & Tretheway, M. W. (1984). Economies of Density versus Economies of Scale: Why Trunk and Local Service Airline Costs Differ. *RAND Journal of Economics*, *15*(4), 471–489.

Caves, D. W., Christensen, L. R., & Tretheway, M. W. . (1980). Flexible Cost Functions for Multiproduct Firms. *The Review of Economics and Statistics*, *62*(3), 477–481. https://doi.org/10.2307/1927120

Caves, R. E. (1962). *Air transport and its regulators: an industry study*. Harvard University Press.

Chow, C. K. W., & Fung, M. K. Y. (2009). Efficiencies and scope economies of Chinese airports in moving passengers and cargo. *Journal of Air Transport Management*, *15*(6), 324–329. https://doi.org/10.1016/j.jairtraman.2009.05.002

Christensen, L. R., Jorgensen, D. W., & Lau, L. J. (1971). Conjugate Duality and the Transcendental Production Function. *Econometrica*, *July 1971*, 255–256.

CIA. (2016). *The World Factbook 2016-17.* Washington D.C.: Central Intelligence Agency.

Civil Aviation Authority. (2008). *Connecting passengers at UK airports* (p. 31).

Clark, J. A. (1988). Economies of scale and scope at depository financial institutions: a review of the literature. *Economic Review*, (Sep), 16–33.

Clark, J. A., & Speaker, P. J. (1994). Economies of scale and scope in banking: evidence from a generalized translog cost function. *Quarterly Journal of Business and Economics*, 3–25.

Cohn, E., Rhine, S. L. W., & Santos, M. C. (1989). Institutions of Higher Education as Multi-Product Firms: Economies of Scale and Scope. *The Review of Economics and Statistics*, *71*(2), 284–290. https://doi.org/10.2307/1926974

Cook, G. N., & Goodwin, J. (2008). Airline Networks: A Comparison of Hub-andSpoke and Point-to-Point Systems. *Journal of Aviation/Aerospace Education & Research*, *2*(17).

Czinkota, M. R., & Ronkainen, I. A. (2004). *International Marketing*. Australia: Thomson.

De Wever, S., Martens, R., & Vandenbempt, K. (2005). The impact of trust on strategic resource acquisition through interorganizational networks:Towards a conceptual model. *Human Relations*, *58*(12), 1523–1543. https://doi.org/10.1177/0018726705061316

Decuyper, J. (2015, December). *Air Traffic Control: Current challenges and opportunities*. Presented at the Air Transport Colloquium 2015, Antwerp.

Denny, M. (1974). The Relationship between Functional Forms for the Production System. *The Canadian Journal of Economics / Revue Canadienne d'Economique*, *7*(1), 21–31. https://doi.org/10.2307/134212

Dewulf, W. (2014). *The strategy of Air Cargo Operators - About Carpet Sellers and Cargo Stars*. Universiteit Antwerpen, Antwerpen.

Dewulf, W., Van de Voorde, E., & Vanelslander, T. (2009). Assessing the features, key drivers and current trends in the air freight industry and their impact on the regional supply chain. Presented at the METRANS NATIONAL URBAN FREIGHT CONFERENCE.

DG MOVE, European Commission. (2016). *Study on airport ownership and management and the ground handling market in selected non-EU countries*.

Diewert, W. E. (1971). An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function. *Journal of Political Economy*, *79*(3), 481–507.

Diewert, W. E. (1992). The Measurement of Productivity*. *Bulletin of Economic Research*, *44*(3), 163–198. https://doi.org/10.1111/j.1467-8586.1992.tb00542.x

Doganis, R. S., & Thompson, G. F. (1973). *The Economics of British airports : report of an investigation*. London: Transport Studies Group, Dept. of Civil Engineering, Polytechnic of Central London.

Doganis, R. S., & Thompson, G. F. (1974). ESTABLISHING AIRPORT COST AND REVENUE FUNCTIONS. *Aeronautical Journal*, *78*(763), 285–304.

Douglas, G. W., & Miller, J. C. I. (1974). *Economic Regulation of Domestic Air Transport: Theory and Policy*. Brookings Institution.

Eurocontrol. (2015a). In *ATM Lexicon*.

Eurocontrol. (2015b, December 17). Single European Sky. Retrieved from http://www.eurocontrol.int/dossiers/single-european-sky

European Commission. (2015). Single European Sky II - Single European Sky 2+. Retrieved from http://ec.europa.eu/transport/modes/air/single_european_sky/ses_2_en.htm

Evans, D. S. (2003). Some Empirical Aspects of Multi-sided Platform Industries. *Review of Network Economics*, *2*(3), 1–19.

Formby, J. P., Thistle, P. D., & Keeler, J. P. (1990). Costs under Regulation and Deregulation: The Case of US Passenger Airlines*. *Economic Record*, *66*(4), 308–321. https://doi.org/10.1111/j.1475-4932.1990.tb01736.x

Gardiner, J., Ison, S., & Humphreys, I. (2005). Factors influencing cargo airlines' choice of airport: An international survey. *Journal of Air Transport Management*, *11*(6), 393–399. https://doi.org/10.1016/j.jairtraman.2005.05.004

Georgia Institute of Technology. (2001, December). Georgia DOT Research Project 10-20 – Final Report: Airport Costs and Production Technology: A Translog Cost Function Analysis with Implications for Economic Development.

Gillen, D., & Morrison, W. G. (2005). Regulation, competition and network evolution in aviation. *Journal of Air Transport Management*, *11*(3), 161–174.

Gillen, D. W., Oum, T. H., & Tretheway, M. W. (1990). Airline Cost Structure and Policy Implications: A Multi-Product Approach for Canadian Airlines. *Journal of Transport Economics and Policy*, *24*(1), 9–34.

Gilligan, T., Smirlock, M., & Marshall, W. (1984). Scale and scope economies in the multi-product banking firm. *Journal of Monetary Economics*, *13*(3), 393–405. https://doi.org/10.1016/0304-3932(84)90041-2

Gimeno, J., & Woo, C. (1999). Multimarket contact, economies of scope, and firm performance. *Academy of Managemenit Journal*, *43*(3).

Glass, J. C., & McKillop, D. G. (1992). An empirical analysis of scale and scope economies and technical change in an Irish multiproduct banking firm. *Journal of Banking & Finance*, *16*(2), 423–437. https://doi.org/10.1016/0378-4266(92)90023-S

Goldberg, L. G., Hanweck, G. A., Keenan, M., & Young, A. (1991). Economies of scale and scope in the securities industry. *Journal of Banking & Finance*, *15*(1), 91–107. https://doi.org/10.1016/0378-4266(91)90039-O

Gomez-Ibanez, J. A., Oster, C. V., & Pickrell, D. H. (1983). Airline deregulation: What's behind the recent losses? *Journal of Policy Analysis and Management*, *3*(1), 74–89. https://doi.org/10.2307/3324006

Graham, A. (2001). *Managing Airports 4th Edition: An international perspective*. London: Butterworth-Heinemann.

Graham, A. (2010). Airport strategies to gain competitive advantage. In *Airport Competition: The European Experience* (pp. 89–102). Farnham: Ashgate Publishing, Ltd.

Grandjot, H. H., Roland, A., & Roessler, I. (2007). *Air Cargo Guide: An introduction to the air cargo industry* (1st ed.). München: Huss-Verlag.

Hall, R. (1973). The Specification of Technology with Several Kinds of Output. *Journal of Political Economy*, *81*(4), 878–92.

Hall, R. W. (2002). Alternative Access and Locations for Air Cargo. Presented at the Metrans Conference, Long Beach.

Harimaya, K. (2008). Impact of nontraditional activities on scale and scope economies: A case study of Japanese regional banks. *Japan and the World Economy*, *20*(2), 175–193. https://doi.org/10.1016/j.japwor.2006.11.003

IATA. (2015). *Worldwide Slot Guidelines* (No. 7th Edition).

ICAO. (2000). *Financial Situation of Airports and Air Navigation Services* (ANSConf Working Paper No. 3). International Civil Aviation Organization (ICAO).

ICAO. (2008). *Ownership, Organization and Regulatory Practices of Airports and Air Navigation Services Providers, 2007*.

ICAO. (2012). ICAO's Policies on Charges for Airports and Air Navigation Services - Ninth Edition.

ICAO. (2013). *Annex 14 to the Convention on International Civil Aviation - Aerodromes - Volume 1 - Aerodrome Design and Operations* (No. Sixth edition).

ICAO. (2014). Annual Report 2014 - The World of Air Transport in 2014.

ICAO. (2015). Annual Report 2015- The World of Air Transport in 2015.

Iimi, A. (2004). Banking sector reforms in Pakistan: economies of scale and scope, and cost complementarities. *Journal of Asian Economics*, *15*(3), 507–528. https://doi.org/10.1016/j.asieco.2004.03.004

International Air Transport Association (IATA). (1981). *World Air Transport Statistics 1980 (WATS)* (No. 25). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1982). *World Air Transport Statistics 1981 (WATS)* (No. 26). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1983). *World Air Transport Statistics 1982 (WATS)* (No. 27). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1984). *World Air Transport Statistics 1983 (WATS)* (No. 28). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1985). *World Air Transport Statistics 1984 (WATS)* (No. 29). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1986). *World Air Transport Statistics 1985 (WATS)* (No. 30). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1987). *World Air Transport Statistics 1986 (WATS)* (No. 31). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1988). *World Air Transport Statistics 1987 (WATS)* (No. 32). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1989). *World Air Transport Statistics 1988 (WATS)* (No. 33). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1990). *World Air Transport Statistics 1989 (WATS)* (No. 34). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1991). *World Air Transport Statistics 1990 (WATS)* (No. 35). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1992). *World Air Transport Statistics 1991 (WATS)* (No. 36). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1993). *World Air Transport Statistics 1992 (WATS)* (No. 37). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1994). *World Air Transport Statistics 1993 (WATS)* (No. 38). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1995). *World Air Transport Statistics 1994 (WATS)* (No. 39). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1996). *World Air Transport Statistics 1995 (WATS)* (No. 40). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1997). *World Air Transport Statistics 1996 (WATS)* (No. 41). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1998). *World Air Transport Statistics 1997 (WATS)* (No. 42). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (1999). *World Air Transport Statistics 1998 (WATS)* (No. 43). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2000). *World Air Transport Statistics 1999 (WATS)* (No. 44). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2001). *World Air Transport Statistics 2000 (WATS)* (No. 45). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2002). *World Air Transport Statistics 2001 (WATS)* (No. 46). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2003). *World Air Transport Statistics 2002 (WATS)* (No. 47). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2004). *World Air Transport Statistics 2003 (WATS)* (No. 48). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2005). *World Air Transport Statistics 2004 (WATS)* (No. 49). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2006). *World Air Transport Statistics 2005 (WATS)* (No. 50). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2007). *World Air Transport Statistics 2006 (WATS)* (No. 51). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2008). *World Air Transport Statistics 2007 (WATS)* (No. 52). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2009). *World Air Transport Statistics 2008 (WATS)* (No. 53). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2010). *World Air Transport Statistics 2009 (WATS)* (No. 54). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2011). *World Air Transport Statistics 2010 (WATS)* (No. 55). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2012). *World Air Transport Statistics 2011 (WATS)* (No. 56). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2013). *World Air Transport Statistics 2012 (WATS)* (No. 57). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2014). *World Air Transport Statistics 2013 (WATS)* (No. 58). Montreal-Geneva: IATA.

International Air Transport Association (IATA). (2015). *World Air Transport Statistics 2014 (WATS)* (No. 59). Montreal-Geneva: IATA.

Jeong, J. (2005). *An Investigation of Operating Cost of Airports: Focus on the Effect of Output Scale*. University of British Columbia.

Kadar, M., & Larew, J. (2004). Securing the future of Air cargo. *Mercer on Travel and Transport*, (fall 2003/winter2004).

Kasarda, J. D., & Green, J. D. (2005). Air cargo as an economic development engine: A note on opportunities and constraints. *Journal of Air Transport Management*, *11*(6), 459–462.

Keeler, J. P., & Formby, J. P. (1994). Cost economies and consolidation in the U.S. airline industry. *International Journal of Transport Economics / Rivista Internazionale Di Economia Dei Trasporti*, *21*(1), 21–45.

Keeler, T. (1970). Airport Costs and Congestion. *The American Economist*, *14*(1), 47–53. https://doi.org/10.1177/056943457001400108

Keeler, T. E. (1978). *Domestic Trunk Airline Regulation: An Economic Evaluation* (Study on Federal Regulation). Washington D.C.: US Government Printing Office.

Kim, H. Y. (1987a). Economics of scale and scope in multiproduct firms: evidence from US railroads. *Applied Economics*, *19*(6), 733–741. https://doi.org/10.1080/00036848700000105

Kim, H. Y. (1987b). Economies of Scale in Multi-Product Firms: An Empirical Analysis. *Economica*, *54*(214), 185–206. https://doi.org/10.2307/2554390

Kirby, M. G. (1986). Airline Economics of "Scale" and Australian Domestic Air Transport Policy. *Journal of Transport Economics and Policy*, *20*(3), 339–352.

Kumbhakar, S. C. (1990). A Reexamination of Returns to Scale, Density and Technical Progress in U. S. Airlines. *Southern Economic Journal*, *57*(2), 428–442. https://doi.org/10.2307/1060621

Kupfer, F. (2012). *The airport choice for scheduled freighter operations in Europe*. Antwerpen: Universiteit Antwerpen, Faculteit Toegepaste Economische Wetenschappen.

Kupfer, F., & Lagneaux, F. (2009). Assessing the economic importance of airports and the air transport cluster in Belgium. *Aerlines*, *44*.

Kupfer, F., Meersman, H., Onghena, E., & Van de Voorde, E. (2011). World air cargo and merchandise trade. In *Critical issues in air transport economics and business / Macário, Rosário [edit.]; et al.* (pp. 98–111). London: Routledge.

Kupfer, F., Meersman, H., Pauwels, T., Struyf, E., Van de Voorde, E., & Vanelslander, T. (2011). Economische regulering van luchthavens: de gevalstudie Brussels Airport Company. *TPEdigitaal*, *5*(3), 40–59.

Kupfer, F., Meersman, H., Pauwels, T., Struyf, E., Van de Voorde, E., & Vanelslander, T. (2013). Economic regulation of airports: The case of Brussels Airport Company. *Case Studies on Transport Policy*, *1*(1–2), 27–34. https://doi.org/10.1016/j.cstp.2013.08.002

Kwoka, J. E. (2002). Vertical economies in electric power: evidence on integration and its alternatives. *International Journal of Industrial Organization*, *20*(5), 653–671.

Lang, G., & Welzel, P. (1996). Efficiency and technical progress in banking Empirical results for a panel of German cooperative banks. *Journal of Banking & Finance*, *20*(6), 1003–1023. https://doi.org/10.1016/0378-4266(95)00040-2

Lau, L. J. (1974). Application of Duality Theory: A Comment. In *M.D. Intriligator and D.A. Kendrick, eds., Frontiers in Quantitative Economics* (pp. 176–199). Amsterdam: North-Holland Publishing Company.

Leggette, J. A., & Killingsworth, B. (1983). An empirical study of economies of scope: the case of air carriers. *Studies in Economics and Finance*, *7*(2), 27–33. https://doi.org/10.1108/eb028637

Lewis, D. R., & Dundar, H. (1995). Economies of Scale and Scope in Turkish Universities - Education Economics - Volume 3, Issue 2. *Education Economics*, *3*(2), 133–157.

Lipczynski, J., Wilson, J. O. S., & Goddard, J. A. (2009). *Industrial Organization: Competition, Strategy, Policy* (Third edition). Harlow: Pearson Education.

Macário, R., & Van de Voorde, E. (2010). *Critical Issues in Air Transport Economics and Business*. Abingdon, Oxon: Routledge.

Macário, R., & Van de Voorde, E. (2012). *Physical and financial flows*. Presented at the AirDev Conference, Lisbon.

Main, B. G. M., Lever, B., & Crook, J. (2003). *Central Scotland airport study*. The David Hume Institute.

Marques, A. C. ., & Galves, M. L. (2008). Airport city: an evolutionary approach. Presented at the 12th Air Transport Research Society (ATRS) World Conference, Athens.

Martín, J. C., Román, C., & Voltes-Dorta, A. (2011). Scale economies and marginal costs in Spanish airports. *Transportation Research Part E: Logistics and Transportation Review*, *47*(2), 238–248. https://doi.org/10.1016/j.tre.2010.09.007

Martín, J. C., & Voltes-Dorta, A. (2008). International Airports: Economies of Scale and Marginal Costs. *Journal of the Transportation Research Forum*, *47*(1). https://doi.org/10.5399/osu/jtrf.47.1.1056

Martín, J. C., & Voltes-Dorta, A. (2011a). The dilemma between capacity expansions and multi-airport systems: Empirical evidence from the industry's cost function. *Transportation Research Part E: Logistics and Transportation Review*, *47*(3), 382–389. https://doi.org/10.1016/j.tre.2010.11.009

Martín, J. C., & Voltes-Dorta, A. (2011b). The econometric estimation of airports' cost function. *Transportation Research Part B: Methodological*, *45*(1), 112–127. https://doi.org/10.1016/j.trb.2010.05.001

Martini, G. (2015, December). *Aviation contribution to trade*. Presented at the Air Transport Colloquium 2015, Antwerp.

Martín, J. C., & Roman, C. (2001). An application of DEA to measure the efficiency of Spanish airports prior to privatization. *Journal of Air Transport Management*, *7*(3), 149–157.

Matthews, B., & Menaz, B. (2003). *Airport Capacity: The Problem of Slot Allocation*. University of Leeds: Institute for Transport Studies.

Mayer, C., & Sinai, T. (2003). Network Effects, Congestion Externalities, and Air Traffic Delays: Or Why Not All Delays Are Evil. *American Economic Review*, *93*(4), 1194–1215. https://doi.org/10.1257/000282803769206269

Mayo, J. W. (1984). Multiproduct Monopoly, Regulation, and Firm Costs. *Southern Economic Journal*, *51*(1), 208–218. https://doi.org/10.2307/1058333

Meincke, P. (2002). Competiton of Airports in Europa - Parameters and Types of Competive Situations among Airports. Presented at the 6th Air Transport Research Society (ATRS) World Conference, Seattle.

Morrell, P. S. (2011). *Moving Boxes by Air: The Economics of International Air Cargo*. Ashgate Publishing, Ltd.

Morrison, S., & Winston, C. (1986). *The Evolution of the Airline Industry*. Brookings Institution Press.

Moschandreas, M. (2000). *Business Economics*. Cengage Learning EMEA.

Murray, J. D., & White, R. W. (1983). Economies of Scale and Economies of Scope in Multiproduct Financial Institutions: A Study of British Columbia Credit Unions. *The Journal of Finance*, *38*(3), 887–902. https://doi.org/10.2307/2328088

Niemeier, H. M. (2009). *Regulation of large airports: status quo and options for reform* (No. 2009–10). OECD/International Transport Forum.

O'Connell, J. F. (2011). The Rise of the Arabian Gulf Carriers: An Insight into the Business Model of Emirates Airlines. *Journal of Air Transport Management - J AIR TRANSP MANAG*, *17*(6), 339–346. https://doi.org/10.1016/j.jairtraman.2011.02.003

Onghena, E. (2013). *From Cost Structure to Strategy - The Impact of the Cost Structure on the Strategic Behavior of Integrators*. Universiteit Antwerpen, Antwerpen.

Oum, T. H., & Waters, W. G. (1996). A Survey of Recent Developments in Transportation Cost Function Research. *LOGISTICS AND TRANSPORTATION REVIEW*, *32*(4).

Oum, T. H., & Waters II, W. G. (2000). Transport Demand Elasticities. In *Handbook of Transport Modelling* (Vol. 1, pp. 197–210). Kidlington (Oxford): Elsevier Science Ltd.

Oum, T. H., Yu, C., & Fu, X. (2003). A comparative analysis of productivity performance of the world's major airports: summary report of the ATRS global airport benchmarking research report—2002. *Journal of Air Transport Management*, *9*(5), 285–297. https://doi.org/10.1016/S0969-6997(03)00037-1

Oxley, D., & Jain, C. (2015). *Global Air Passenger Markets: Riding out periods of turbulence* (Growth through Shocks No. The Travel & Tourism Competitiveness Report 2015).

Page, P. (2003). Selling Cargo. *Air Cargo World*, *93*(1), 44–49.

Pagliari, R. (2001). Selling Grandfather: an analysis of the latest EU proposals on slot trading. *Air and Space Europe*, *No 1/2*(Vol. 3).

Pai, V. (2010). On the factors that affect airline flight frequency and aircraft size. *Journal of Air Transport Management*, *16*(4), 169–177. https://doi.org/10.1016/j.jairtraman.2009.08.001

Panzar, J. C., & Willig, R. D. (1981). Economies of Scope. *The American Economic Review*, *71*(2), 268–272.

Pels, E., Nijkamp, P., & Rietveld, P. (2003). Inefficiencies and scale economies of European airport operations. *Transportation Research Part E: Logistics and Transportation Review*, *39*(5), 341–361. https://doi.org/10.1016/S1366-5545(03)00016-4

Pels, E., & Rietveld, P. (2000a). Cost Functions in Transport. In *Handbook of Transport Modelling* (pp. 321–333). Kidlington, Oxford OX5 AGB, UK: Elsevier Science.

Pels, E., & Rietveld, P. (2000b). *Cost Functions in Transport. In: Handbook of Transport Modelling*.

Pollack, M. (1977). Some elements of the airline fleet planning problem. *Transportation Research*, *11*(5), 301–310. https://doi.org/10.1016/0041-1647(77)90040-5

Pulley, L. B., & Braunstein, Y. M. (1992). A Composite Cost Function for Multiproduct Firms With An Application to Economies of Scope in Banking. *The Review of Economics and Statistics*, *74*(2), 221–230. https://doi.org/10.2307/2109653

Rochet, J.-C., & Tirole, J. (2003). Platform Competition in Two-sided Markets. *Journal of the European Economic Association*, *1*(4), 990–1029.

Rochet, J.-C., & Tirole, J. (2006). Two-Sided Markets: A Progress Report. *The RAND Journal of Economics*, *37*(3), 645–667.

Röller, L.-H. (1990). Proper Quadratic Cost Functions with an Application to the Bell System. *The Review of Economics and Statistics*, *72*(2), 202–210. https://doi.org/10.2307/2109709

Roy, R., & Cofsky, D. (1985). *An empirical investigation of production technology of Canadian air services*. Ottawa-Hull: Canadian Transport Commission, Research Branch, Economic and Social Research Directorate.

Salazar de la Cruz, F. (1999). A DEA Approach the the Airport Production Function. *International Journal of Transport Economics / Rivista Internazionale Di Economia Dei Trasporti*, *26*(2), 255–270.

Sandhu, R., & Klabjan, D. (2006). Fleeting with Passenger and Cargo Origin-Destination Booking Control. *Transportation Science*, *40*(4), 517–528. https://doi.org/10.1287/trsc.1060.0157

Schaar, D., & Sherry, L. (2010). Analysis of airport stakeholders. *Integrated Communications Navigation and Surveillance Conference*, J4-1-J4-17. https://doi.org/doi.org/10.1109/ICNSURV.2010.5503233

Segal, D. (2003). A Multi-Product Cost Study of the US Life Insurance Industry. *Review of Quantitative Finance and Accounting*, 169–186. https://doi.org/10.1023/A:1023098109619

Shaw, S. (2011). *Airline Marketing and Management*. Ashgate Publishing, Ltd.

Sickles, R. C., Good, D., & Johnsons, R. L. (1986). Allocative distortions and the regulatory transition of the U.S. airline industry. *Journal of Econometrics*, *33*(1), 143–163.

Sinha, D. (2001). *Deregulation and Liberalisation of the Airline Industry: Asia, Europe, North America and Oceania*. Ashgate.

Smet, M. (1998). *Multi-product cost functions: An application to the production characteristics of secondary education in Flanders* (Discussion Papers (REL - Recherches Economiques de Louvain) No. 1998043). Université catholique de Louvain, Institut de Recherches Economiques et Sociales (IRES).

Starkie, D. N. M., & Thompson, D. (1985). *Privatising London's airports* (No. Report Series no. 16). Oxford: Institute for Fiscal Studies.

Struyf, E., Meersman, H., Pauwels, T., Van de Voorde, E., & Vanelslander, T. (2011). How efficient operations can make an airport more competitive. In *Proceedings of the Bivec-Gibet Transport Research Days 2011 / Cornelis, E. [edit.]* (pp. 581–588). Namur.

Tolofari, S. R., Ashford, N. J., & Caves, R. E. (1990). *The Cost of Air Service Fragmentation*. Department of Transport Technology, University of Technology, Loughborough.

Van Cayseele, P., & Wuyts, C. (2007). Cost efficiency in the European securities settlement and depository industry. *Journal of Banking & Finance*, *31*(10), 3058–3079. https://doi.org/10.1016/j.jbankfin.2007.01.007

Van de Voorde, E. (1984). *De kostenstructuur van de Belgische spoorwegen* (SESO Working Paper). University of Antwerp, Faculty of Applied Economics.

Van de Voorde, E., & de Wit, J. (2013). Luchtvaartlogistiek: Grote bewegingen in market en onderzoek. *Tijdschrift Vervoerswetenschap*, *2*(49).

Van Scyoc, L. J. (1989). Effects of airline deregulation on profitability. *LOGISTICS AND TRANSPORTATION REVIEW*, *25*(1).

Walters, A. (1978). *Airports - an economic survey* (No. REP80) (pp. 1–37). The World Bank. Retrieved from http://documents.worldbank.org/curated/en/1978/05/1555575/airports-economic-survey

Wei, W., & Hansen, M. (2007). Airlines' competition in aircraft size and service frequency in duopoly markets. *Transportation Research Part E: Logistics and Transportation Review*, *43*(4), 409–424. https://doi.org/10.1016/j.tre.2006.01.002

Weng, C.-C., & Wang, K.-L. (2004). Scale and scope economies of international tourist hotels in Taiwan. *Tourism Management*, *25*(6), 761–769. https://doi.org/10.1016/j.tourman.2004.06.005

Wensveen, J. G. (2011). *Air Transportation: A Management Perspective*. Ashgate Publishing, Ltd.

White, L. J. (1978). Economies of Scale and the Question of Natural Monopoly in the Airline Industry. *Journal of Air Law and Commerce*, *44*, 545.

Zardkoohi, A., & Kolari, J. (1994). Branch office economies of scale and scope: evidence from savings banks in Finland. *Journal of Banking & Finance*, *18*(3), 421–432. https://doi.org/10.1016/0378-4266(94)90001-9

Zhang, A., Van Hui, Y., & Leung, L. (2004). Air cargo alliances and competition in passenger markets. *Transportation Research Part E: Logistics and Transportation Review*, *40*(2), 83–100.

Zondag, W.-J. (2006). *Competing for Air Cargo. A Qualitative Analysis of Competitive Rivalry in the Air Cargo Industry*. Vrije Universiteit Amsterdam.

Zuidberg, J. (2014). Identifying airline cost economies: An econometric analysis of the factors affecting aircraft operating costs. *Journal of Air Transport Management*, *40*, 86–95. https://doi.org/10.1016/j.jairtraman.2014.06.007

Appendices

Appendix 1 – Product-specific economies of scale, based upon declining marginal cost

To calculate the product-specific economies of scale, based on the declining marginal cost, the second derivative of TC to product y_i needs to be found.

$$\frac{\partial TC}{\partial y_i} = \frac{\partial TC}{\partial x_j} * \frac{\partial x_j}{\partial y_i}$$

where: $j = 1,2$

$$x_1 = \ln y_i \rightarrow \frac{\partial x_1}{\partial y_i} = \frac{1}{y_i} \text{ and } \frac{\partial x_1}{\partial y_j} = 0$$

$$x_2 = \ln y_j \rightarrow \frac{\partial x_2}{\partial y_i} = 0 \text{ and } \frac{\partial x_2}{\partial y_j} = \frac{1}{y_j}$$

The first derivative of TC to product y_i is the following:

$$\frac{\partial TC}{\partial y_i} = \left(\frac{\partial TC}{\partial x_1} * \frac{\partial x_1}{\partial y_i}\right) + \left(\frac{\partial TC}{\partial x_2} * \frac{\partial x_2}{\partial y_i}\right) = \frac{\partial TC}{\partial x_1} * \frac{1}{y_i}$$

The second derivative of TC to product y_i is then:

$$\frac{\partial^2 TC}{\partial y_i^2} = \left(\frac{\partial^2 TC}{\partial x_1 \partial x_1} * \frac{\partial x_1}{\partial y_i} * \frac{1}{y_i}\right) + \left(\frac{\partial^2 TC}{\partial x_1 \partial x_2} * \frac{\partial x_2}{\partial y_i} * \frac{1}{y_i}\right) + \left(\frac{\partial TC}{\partial x_1} * \left(\frac{-1}{y_i^2}\right)\right)$$

$$= \left(\frac{\partial^2 TC}{\partial x_1^2} - \frac{\partial TC}{\partial x_1}\right) * \frac{1}{y_i^2}$$

where:

$$\frac{\partial \ln TC}{\partial x_1} = \frac{1}{TC} * \frac{\partial TC}{\partial x_1}$$

$$\rightarrow \frac{\partial TC}{\partial x_1} = TC * \frac{\partial \ln TC}{\partial x_1}$$

$$\frac{\partial^2 \ln TC}{\partial x_1^2} = \left(\frac{-1}{TC^2}\right) * \left(\frac{\partial TC}{\partial x_1}\right)^2 + \left(\frac{1}{TC}\right) * \left(\frac{\partial^2 TC}{\partial x_1^2}\right)$$

$$\rightarrow \frac{\partial^2 TC}{\partial x_1^2} = TC * \left(\frac{\partial^2 \ln TC}{\partial x_1^2} + \frac{1}{TC^2} * \left(\frac{\partial TC}{\partial x_1}\right)^2\right)$$

$$= TC * \left(\frac{\partial^2 \ln TC}{\partial x_1^2} + \frac{1}{TC^2} * TC^2 \left(\frac{\partial \ln TC}{\partial x_1}\right)^2\right)$$

$$= TC * \left(\frac{\partial^2 \ln TC}{\partial x_1^2} + \left(\frac{\partial \ln TC}{\partial x_1}\right)^2\right)$$

$$= \left[TC * \left(\frac{\partial^2 \ln TC}{\partial x_1^2} + \left(\frac{\partial \ln TC}{\partial x_1}\right)^2\right) - \left(TC * \frac{\partial \ln TC}{\partial x_1}\right)\right] * \frac{1}{y_i^2}$$

$$= \frac{TC}{y_i^2}\left[\left(\frac{\partial^2 \ln TC}{\partial x_1^2} + \left(\frac{\partial \ln TC}{\partial x_1}\right)^2\right) - \left(\frac{\partial \ln TC}{\partial x_1}\right)\right]$$

$$= \left(\frac{TC}{y_i^2}\right)\left[\frac{\partial^2 \ln TC}{\partial x_1^2} + \left(\frac{\partial \ln TC}{\partial x_1}\right) * \left(\frac{\partial \ln TC}{\partial x_1} - 1\right)\right]$$

$$= \left(\frac{TC}{y_i^2}\right)\left[\frac{\partial^2 \ln TC}{\partial \ln {y_i}^2} + \left(\frac{\partial \ln TC}{\partial \ln y_i}\right) * \left(\frac{\partial \ln TC}{\partial \ln y_i} - 1\right)\right]$$

Appendix 2 – Data set used

Airport code	Total Costs	Number of passengers	Tons of cargo (freight & mail)	Capital Unit Cost (R)	Labor Unit Cost (W)	Soft Unit Cost (M)
European airports – sorted by number of passengers						
LHR	2423820082	69984868.00	1464550.00	1177.69	87411.09	7000498.80
MAD	894169021.3	45195014.00	359362.00	338.07	88316.41	1995242.20
MUC	1247933470	38217181.00	290301.00	643.78	56261.60	2510954.44
BCN	512753660.4	35145176.00	96520.00	270.72	78952.56	1551549.97
LGW	669147925.2	34241200.00	99736.00	679.55	99595.91	2240707.33
ZRH	827969732.5	24802400.00	451687.00	1165.62	228524.18	2694827.46
CPH	374029469.6	23336187.00	354181.13	448.36	86169.49	916691.91
PMI	193244284.6	22666682.00	13712.00	163.14	78747.32	1186594.34
VIE	672288723.3	22165794.00	252276.00	990.44	71655.33	2146217.30
OSL	478890415.7	22080000.00	104543.00	752.18	146601.91	6198004.57
DUS	474203254.6	20830000.00	101588.00	352.16	70572.35	2664776.17
MAN	360943934.1	19841236.00	98696.00	376.66	55806.72	2768186.34
MXP	332897361.4	17230649.00	414317.00	153.71	73785.10	1185224.09
LIS	223849920.5	15314746.00	100643.00	298.85	62943.33	2686595.81
SAW	85788823.53	14872910.00	29357.00	172.12	29261.75	569935.74
GVA	318705690.1	13859466.00	74739.00	678.24	170890.90	3306480.87
HAM	260536832.8	13697690.00	64641.00	1078.93	72746.73	3375607.83
TLV	407588459.4	13134070.00	285812.00	654.71	104291.17	4422396.19
ATH	248198393.3	12944041.00	76425.00	496.92	80269.15	2350147.61
AGP	217878243	12582191.00	2711.00	227.91	78564.57	1859641.24
NCE	220100179.8	11189896.00	17705.00	633.70	109347.05	2100638.36
LED	202016950.6	11154560.00	31110.00	189.49	52288.46	1586968.90
LPA	100834831.7	9892288.00	20603.00	212.10	80098.28	1262387.28
STR	251908553.8	9735087.00	31612.00	309.03	73156.29	2095757.95
LTN	147961672.5	9617697.00	29635.00	410.81	64584.70	3590799.44
EDI	124581881.5	9195061.00	42938.00	594.26	73054.95	1654568.33
BHX	128070953.4	8922539.00	19091.00	348.42	62356.61	1584252.93
BGY	106123390.7	8890604.00	117005.00	236.01	68091.36	3020223.76
ALC	140919599.3	8855441.00	2526.00	165.48	77146.06	2188345.95
LIN	166245972.8	8604832.41	19808.00	350.04	73785.10	2621228.63
BUD	202084952	8504020.00	93123.00	312.08	34152.82	5650045.89
BLQ	90848959.67	5958648.00	40645.00	232.55	73460.09	2726303.62
NAP	75307873.11	5801836.00	5281.00	538.43	79797.22	2435476.24
HAJ	149743476.8	5288327.00	15870.00	383.93	82835.38	3029294.27
RIX	40836732.69	4767764.00	32953.00	214.17	19653.28	483343.05
MLA	40048385.56	3658972.00	16488.00	80.34	30895.94	995372.89
TRN	66428104.29	3521847.00	10543.00	338.45	74880.11	1417578.93
SOF	45396283.41	3467455.00	16248.00	12.60	15142.28	537361.50
BEG	47941074.91	3363919.00	8218.00	169.28	26743.56	1933427.79
KEF	99101481.13	2380214.00	38986.00	154.72	79311.72	2509359.95

Airport code	Total Costs	Number of passengers	Tons of cargo (freight & mail)	Capital Unit Cost (R)	Labor Unit Cost (W)	Soft Unit Cost (M)
ZAG	51378790.76	2342309.00	9494.00	1013.14	29343.21	1064603.37
TLL	44433598.77	2206791.00	23921.00	470.57	28715.73	1349216.54
SZG	60060476.3	1666487.00	8135.60	472.80	82994.49	1398361.50
LJU	31663606.47	1198911.00	17031.00	524.63	36576.77	771522.16
North American airports – sorted by number of passengers						
ATL	384615000	90476742.00	658234.00	260.51	72730.17	677574.88
ORD	688542734	64222204.00	1443281.40	426.39	107009.58	1806574.13
LAX	704101292	62273218.00	1658705.00	246.67	105254.61	1730998.60
DFW	637806948	55629321.00	605219.10	476.98	95563.91	1323202.06
DEN	566738292	51570726.00	221528.00	349.22	117743.58	1705968.86
JFK	916953894	49009778.00	1196426.00	389.53	517604.03	4444754.45
SFO	543063079	41664866.00	385113.00	344.36	163998.70	1547185.84
LAS	350975643	39752130.00	96173.00	415.45	75520.93	987946.11
PHX	316031718	39359155.00	271109.44	376.80	84542.37	1142722.48
CLT	117284997	38998303.00	127230.00	258.98	59623.85	620617.25
IAH	363474023	38556641.00	442147.00	402.49	77059.86	1208969.78
MIA	596666714	37071794.00	1906504.00	263.33	120899.48	1842366.16
MCO	322833274	34511222.00	158219.00	193.80	88839.35	1518070.34
YYZ	550982342	34089901.00	345825.50	429.05	103155.44	1419070.75
EWR	569272525	33952143.00	672475.00	441.04	466775.20	2581952.22
SEA	339165161	32179403.00	283500.00	422.56	105041.09	1600504.28
MSP	256793901	31857466.00	198684.00	388.34	120824.99	551996.16
DTW	318776793	31357866.00	217374.00	460.72	117087.88	782571.37
PHL	302044170	29595214.00	402682.98	343.19	145786.21	717159.78
BOS	433312198	28681855.00	237019.96	607.59	151190.87	1762942.39
LGA	297569779	25534678.00	7426.00	441.71	510140.68	1929575.32
FLL	175822409	22651605.00	96579.60	397.23	64020.13	1554843.93
BWI	219951520	22116301.00	109712.03	417.58	87873.48	1422459.88
IAD	456576326	21603118.00	267875.00	686.85	111093.02	1369926.28
SLC	134362211	19265779.00	155974.00	486.28	84033.89	502497.27
DCA	220553562	18915370.00	5965.00	621.32	113125.13	2211682.27
MDW	169416118	18866502.00	25320.00	593.29	177020.38	1937651.00
HNL	191851825	17588000.00	508865.00	147.64	79607.80	2133935.81
SAN	163701280	17154638.00	124929.00	579.02	103722.87	1998358.54
YVR	226023102.5	17077359.00	193352.70	329.52	112569.28	961755.81
TPA	181588246	16359566.00	85517.00	479.60	80995.42	863443.61
PDX	167668703	13902632.00	187771.00	490.75	108505.46	973622.95
YUL	259420544.6	13431023.00	78555.40	489.00	106780.01	894367.13
YYC	183321666.2	12842992.00	81828.40	703.81	110625.89	1259946.71
STL	129685966	12320723.00	68935.92	328.50	79030.55	473232.93
MCI	133328198	10143893.00	86351.34	560.16	66539.75	729680.76
HOU	79644336	9834776.00	11039.00	456.76	72851.43	1150327.00
BNA	96315109	9478367.00	42849.00	378.99	109684.07	755345.28
OAK	152301862	9403042.00	500942.47	879.07	107331.95	2790352.59

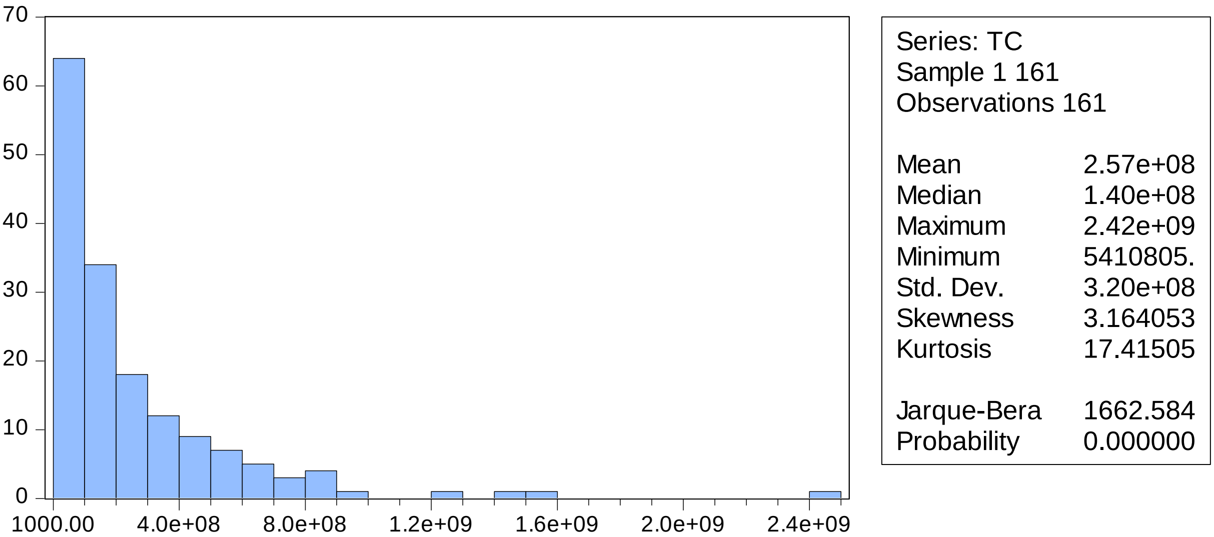
Airport code	Total Costs	Number of passengers	Tons of cargo (freight & mail)	Capital Unit Cost (R)	Labor Unit Cost (W)	Soft Unit Cost (M)
AUS	89599280	9059823.00	70204.00	322.60	82679.02	1620464.88
RDU	98097838	8891514.00	77390.00	436.92	80392.59	441829.83
SMF	139577088	8721854.00	66741.00	513.74	90664.82	1832742.78
CLE	119395837	8598655.00	70354.00	581.84	70545.93	600739.41
SNA	98798094	8569397.00	16211.00	309.21	104943.03	2956674.90
MSY	79884723	8544901.00	46784.00	333.58	71783.07	936648.66
SJC	130932063	8234365.00	41883.00	594.56	123825.84	1907790.39
SAT	75444754	8040468.00	119528.91	462.52	65871.07	747719.13
MEM	111713000	7812249.00	3978315.00	603.41	80694.81	366455.70
DAL	54550152	7778426.00	9759.00	204.28	45088.34	1516883.05
PIT	147366883	7746218.00	79474.00	376.64	79827.77	988937.80
MKE	61929341	7392890.00	72805.00	58.96	94579.25	732250.15
RSW	76361545	7138350.00	15058.00	264.07	89152.15	838160.80
IND	156021687	7093753.00	1016974.00	855.15	58906.41	786705.75
YEG	112229556	6671769.00	25557.70	394.00	135251.08	1206940.92
CMH	83653281	6184760.00	4810.00	356.73	68434.56	812283.03
CVG	113403221	5817610.00	544111.00	287.93	85326.81	719478.18
PBI	67465548	5513734.00	19055.00	517.69	69337.99	1078601.07
ABQ	62482964	5465226.00	62806.00	595.50	58300.95	710454.70
BDL	57287553	5391535.00	116251.00	413.05	138902.13	1125715.00
JAX	70790100	5212117.00	67959.00	410.02	78213.48	1159663.29
ANC	107161721	5044689.00	2486056.00	448.62	100719.70	749836.12
YOW	68243948.67	4482644.00	10570.30	287.74	136713.22	1052243.86
ONT	84683058	4354049.00	405720.00	442.02	119886.62	904107.49
BUR	50540163	4187235.00	47164.00	695.93	24817.61	2328144.79
PVD	43993074	3756912.00	10499.83	582.86	100048.19	477790.95
OKC	45785397	3549158.00	31739.00	557.98	74832.30	968527.53
YHZ	56153752.86	3506016.00	30070.10	245.12	115145.19	736988.56
TUS	42609863	3470061.00	31262.00	366.40	72640.46	467193.61
RNO	63184210	3434259.00	51286.00	740.51	84035.07	455208.65
YWG	65197914.88	3423256.00	68607.70	600.71	99071.93	1085688.08
SDF	56825924	3232610.00	2172242.00	802.57	48131.64	790940.83
RIC	40346058	3124547.00	45959.00	401.90	58544.61	466030.82
TUL	33880736	2694423.00	51039.00	243.99	52772.84	593548.38
ALB	38235043	2436925.00	18242.00	501.97	60654.86	563754.33
YYJ	15815548.1	1470061.00	4188.70	264.38	102894.67	693727.80
YYT	21921849.49	1412778.00	10514.50	397.27	133830.28	929150.24
YQB	27116755.19	1410625.00	2219.90	225.52	69647.88	981991.31
Asia Pacific airports – sorted by number of passengers						
PEK	713016250.8	81929359.00	1799864.00	173.71	43839.99	3331062.49
HND	1482878791	66795178.00	846764.00	294.68	122921.26	24072313.44
CGK	124828309.7	57772864.00	629706.00	36.56	18036.09	628411.87
HKG	796054726.2	57200000.00	4040000.00	373.17	71153.50	7193061.58
BKK	480092730.4	52368712.00	1360879.00	202.18	31587.38	2373346.02

Airport code	Total Costs	Number of passengers	Tons of cargo (freight & mail)	Capital Unit Cost (R)	Labor Unit Cost (W)	Soft Unit Cost (M)
SIN	803328950.1	51940972.00	1806225.00	222.72	84489.72	4493210.13
CAN	507848294.4	48309410.00	1248763.78	293.56	49968.45	2517781.54
PVG	498061906.1	44880164.00	2938156.94	187.53	33590.67	1753826.25
KUL	262150572.1	39887866.00	673170.00	82.82	23872.26	1204016.42
ICN	674023573.3	38970684.00	3059332.70	338.46	79339.24	1999416.73
SYD	434449519.2	35986799.00	540642.00	612.18	115474.30	1428091.56
NRT	1538282734	32793596.00	1952207.00	712.21	180667.37	6077193.05
SZX	242453078.9	29569725.00	854901.36	208.51	21842.36	2031101.08
MEL	234083347.8	28917592.00	243493.00	330.11	154072.37	2254459.72
BNE	205059966	21182134.00	89156.00	369.58	120598.05	2731729.71
GMP	175202128.3	19429224.00	254563.30	324.41	81412.82	1288288.37
CJU (JEJU)	57101090.14	18443047.00	244646.70	0.11	103043.23	1051581.54
XMN	89486802.24	17354076.00	271465.84	96.25	14962.46	869221.41
KIX	886285142.5	16799000.00	687426.00	890.62	104072.36	9005576.16
AKL	139295526.7	14006122.00	214320.00	375.42	85270.08	2822740.59
PER	150371717.3	12632800.00	73670.03	424.54	152987.58	3915078.57
HAK	37516421.92	10696700.00	175365.00	86.68	18796.85	733060.70
NGO	484452418.8	9210765.00	135169.00	773.70	96248.32	5059455.44
HKT	81174519.46	9161005.00	31731.00	296.86	30061.85	2314809.04
CMB	56716038.73	8376663.00	186616.00	88.02	7286.63	975888.21
ADL	82935750.56	7099483.00	17181.00	201.27	109743.03	3758094.84
CHC	62162148.21	5551600.00	27748.00	304.30	61708.00	1492253.95
WLG	56078744.65	5374000.00	5500.00	288.24	73684.64	1313246.53
OOL	39910688.01	5326570.00	5444.00	592.05	36066.76	1708525.35
PEN	31334978.66	4767815.00	123246.00	185.10	23846.97	700217.24
CNX	38408419.32	4334608.00	21480.00	552.91	30061.85	1470632.29
GUM	60573905	2714343.00	30379.00	498.48	73636.15	1249058.65
DRW	26960106.3	2044622.00	316.00	599.98	137694.88	1004760.10
HDY	17839094.41	2013243.00	16201.00	582.82	30061.85	1188379.45
NTL	15934540.88	1184423.00	3000.00	585.52	82691.03	621592.27
CEI	8208032.24	926323.00	4893.00	84.76	30061.85	513323.26

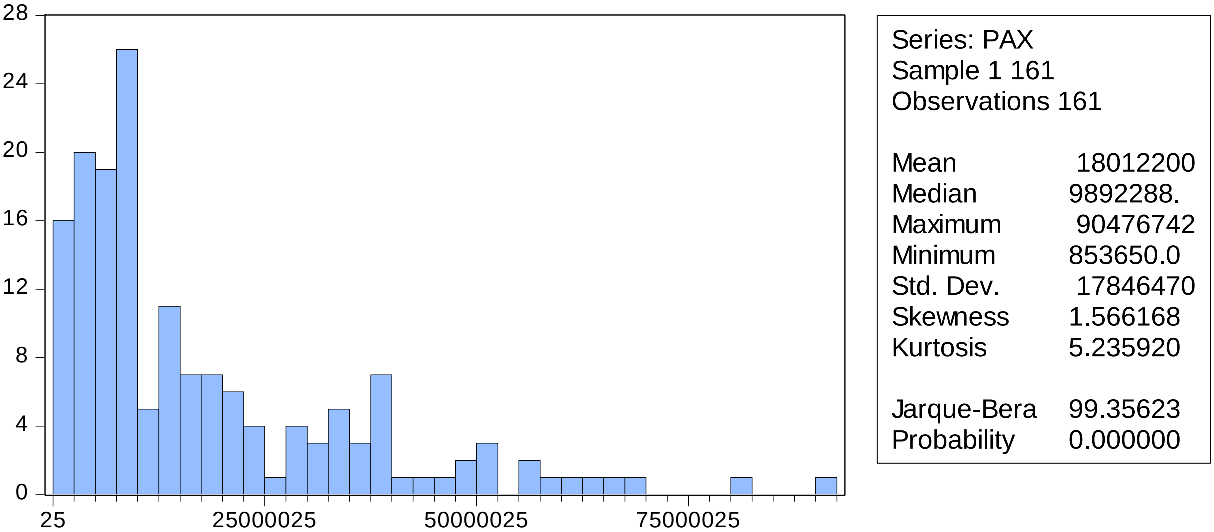
Appendix 3 – Histograms and descriptive statistics of key variables

	Mean	Std. Dev.	Minimum	Maximum
Total Cost (TC)	2.57e+08	3.20e+08	5410805.	2.42e+09
Passengers (PAX)	18012200	17846470	853650.0	90476742
Cargo (CARGO)	348975.4	690414.8	1.000000	4040000.
Labor Unit Cost (W)	89637.69	67479.93	7286.632	517604.0
Capital Unit Cost (R)	415.8134	220.7213	0.111648	1177.693
Soft Unit Cost (M)	678.3555	574.2705	89.42914	4930.011

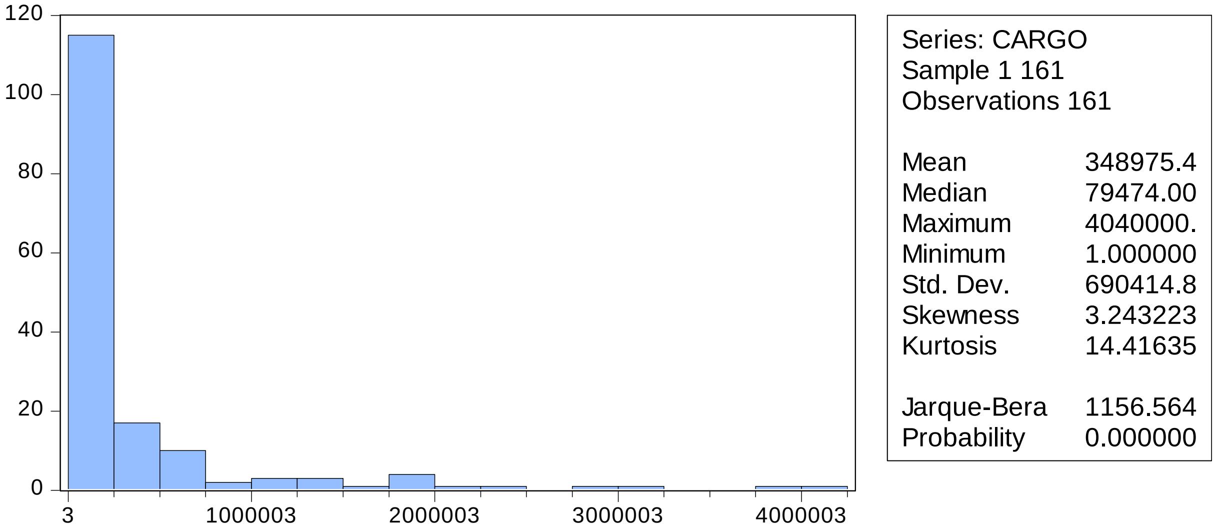
Total Cost (TC)



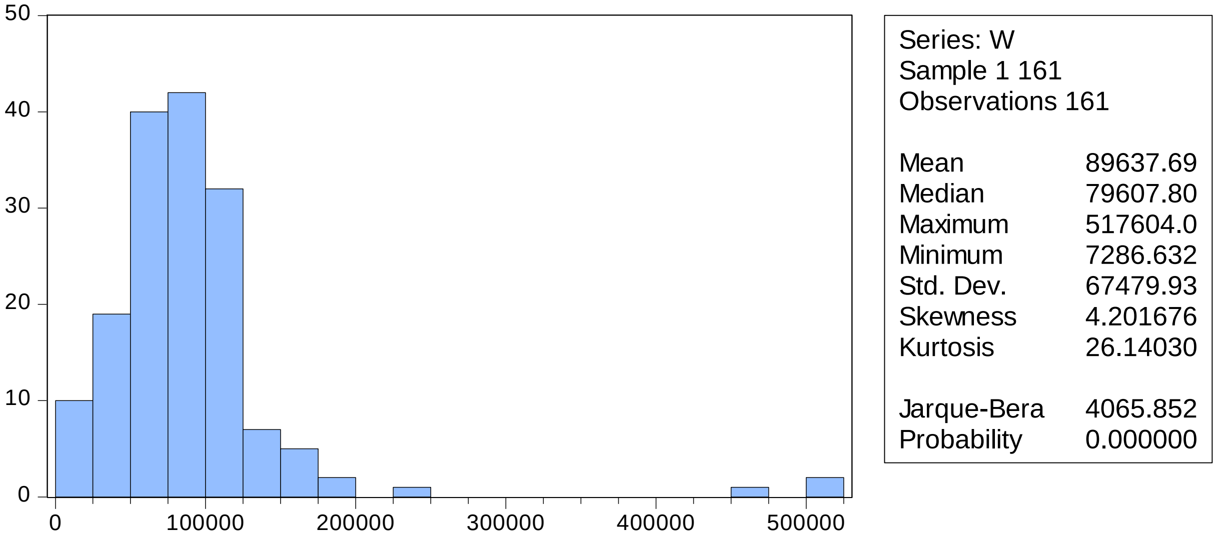
Passengers (PAX)



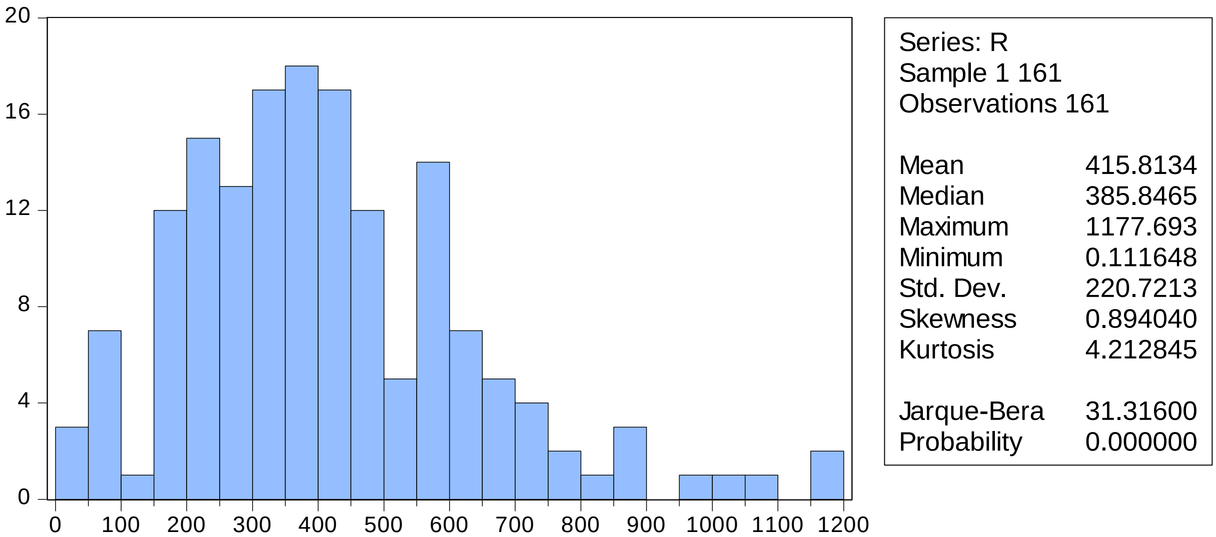
Cargo (CARGO)



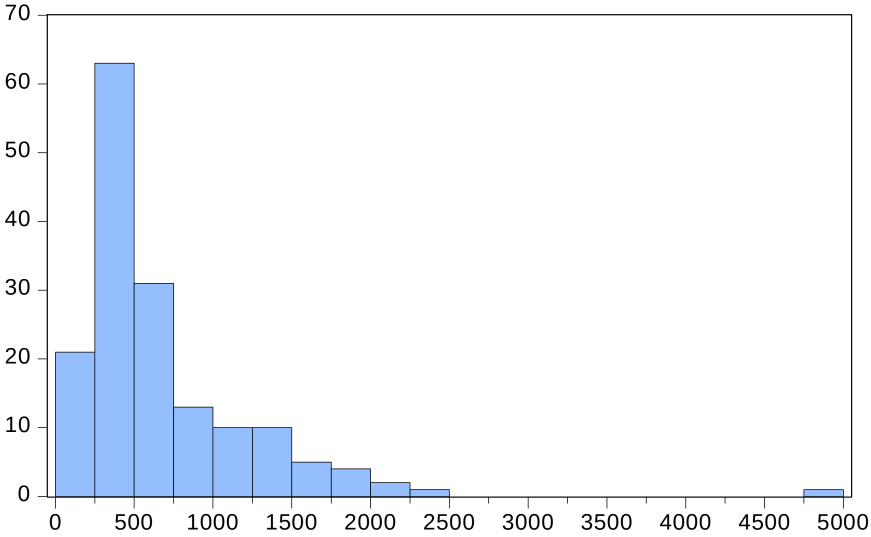
Labor Unit Cost (W)



Capital Unit Cost (R)



Soft Unit Cost (M)

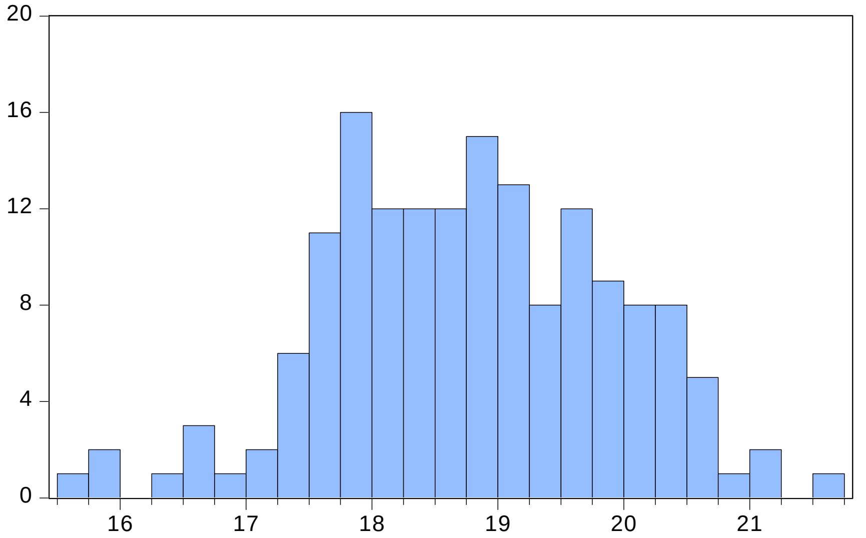


Series: M
Sample 1 161
Observations 161

Mean	678.3555
Median	478.8677
Maximum	4930.011
Minimum	89.42914
Std. Dev.	574.2705
Skewness	3.228934
Kurtosis	20.73931
Jarque-Bera	2390.764
Probability	0.000000

	Mean	Std. Dev.	Minimum	Maximum
Nat. Log. Total Cost (LNTC)	18.77627	1.126810	15.50391	21.60861
Nat. Log. Passengers (LNPAX)	16.20778	1.066869	13.65728	18.32060
Nat. Log. Cargo (LNCARGO)	11.10098	2.512451	0.000000	15.21176
Nat. Log. Labor Unit Cost (LNW)	11.22180	0.611025	8.893797	13.15697
Nat. Log. Capital Unit Cost (LNR)	5.824474	0.901686	-2.192404	7.071313
Nat. Log. Soft Unit Cost (LNM)	6.275840	0.673245	4.493447	8.503097

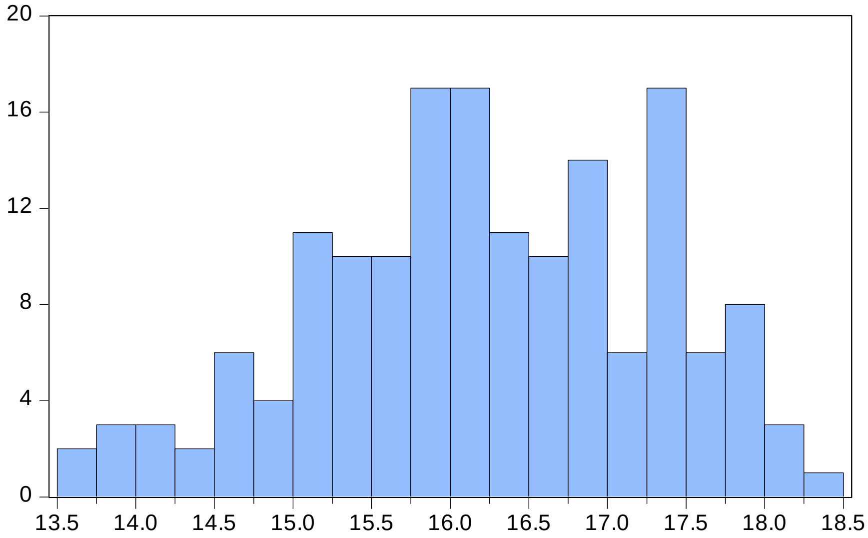
Nat. Log. Total Cost (LNTC)



Series: LNTC
Sample 1 161
Observations 161

Mean	18.77627
Median	18.75413
Maximum	21.60861
Minimum	15.50391
Std. Dev.	1.126810
Skewness	-0.141195
Kurtosis	2.898085
Jarque-Bera	0.604624
Probability	0.739107

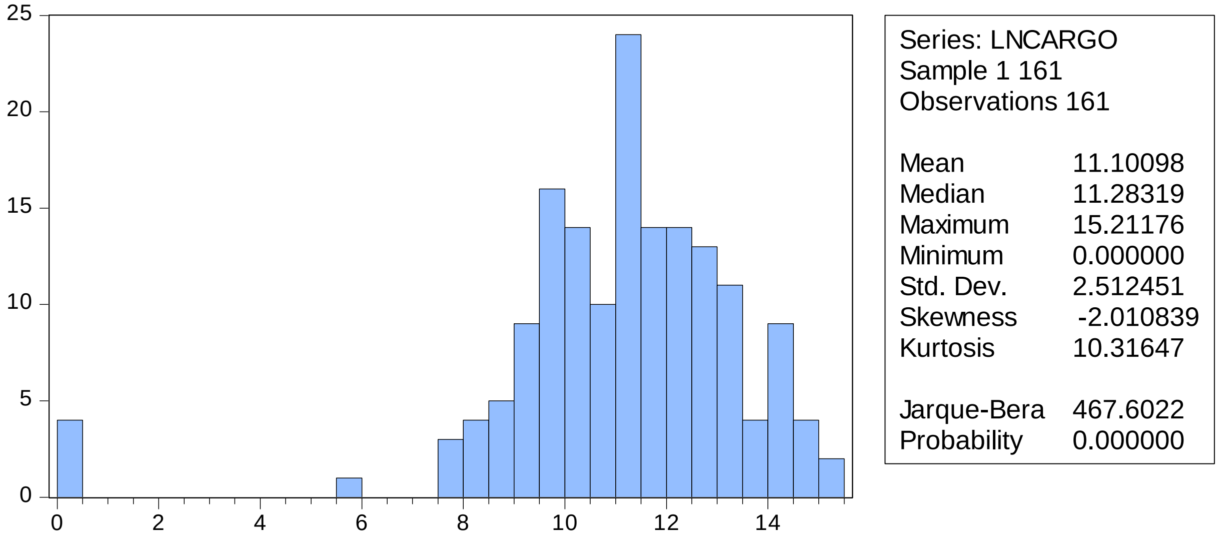
Nat. Log. Passengers (LNPAX)



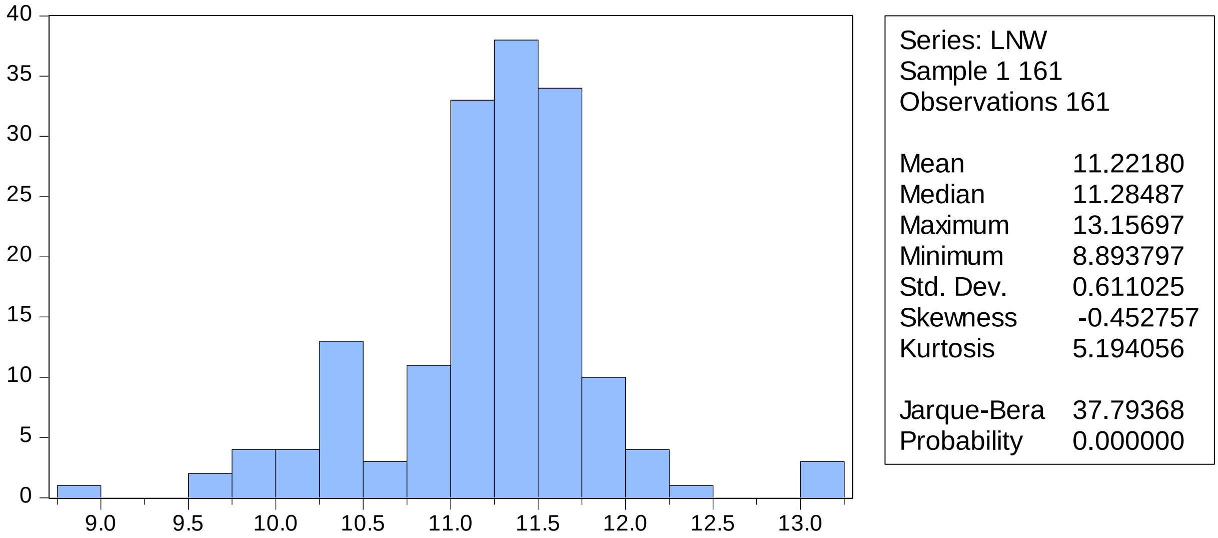
Series: LNPAX
Sample 1 161
Observations 161

Mean	16.20778
Median	16.10727
Maximum	18.32060
Minimum	13.65728
Std. Dev.	1.066869
Skewness	-0.216226
Kurtosis	2.390944
Jarque-Bera	3.743006
Probability	0.153892

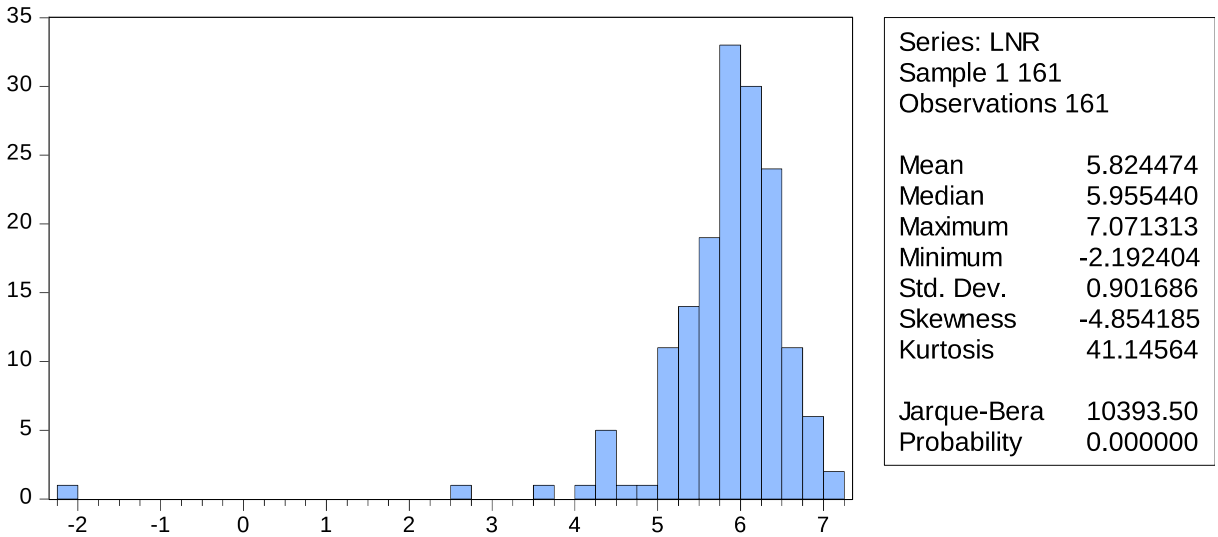
Nat. Log. Cargo (LNCARGO)



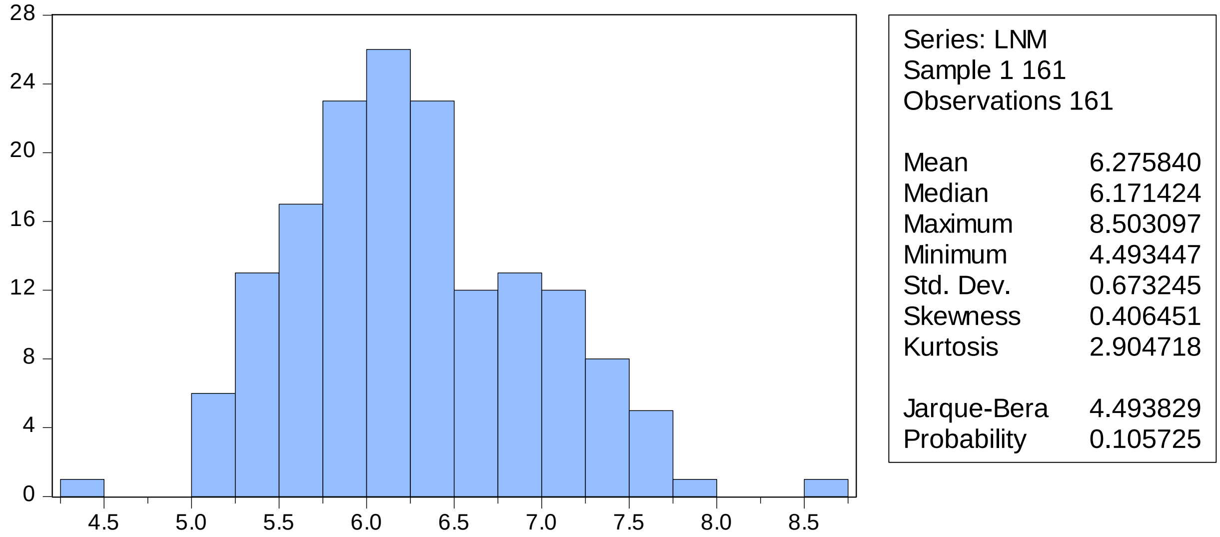
Labor Unit Cost (LNW)



Nat. Log. Capital Unit Cost (LNR)



Nat. Log. Soft Unit Cost (LNM)


28
24
20
16
12
8
4
0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
Series: LNM
Sample 1 161
Observations 161
Mean 6.275840
Median 6.171424
Maximum 8.503097
Minimum 4.493447
Std. Dev. 0.673245
Skewness 0.406451
Kurtosis 2.904718
Jarque-Bera 4.493829
Probability 0.105725

Appendix 4 – Airports in the data sample

Airport code (IATA)	Airport	City	Country
ABQ	Albuquerque International Sunport	Albuquerque (Bernalillo County, New Mexico)	US
ADL	Adelaide International	Adelaide (South Australia)	Australia
AGP	Málaga - Costa del Sol	Málaga	Spain
AKL	Auckland International	Auckland	New Zealand
ALB	Albany International Airport	New York	US
ALC	Alicante - Elche International	Alicante	Spain
ANC	Ted Stevens Anchorage International	Anchorage	US
ATH	Athens International - Eleftherios Venizelos	Athens	Greece
ATL	Hartsfield - Jackson Atlanta International	Atlanta	US
AUS	Austin - Bergstrom International	Austin (Texas)	US
BCN	Barcelona - El Prat	Barcelona	Spain
BDL	Bradley International	Windsor Locks (Hartford County, Conneticut)	US
BEG	Belgrade Nikola Tesla	Belgrade	Serbia
BGY	Bergamo - Orio Al Serio International	Bergamo	Italy
BHX	Birmingham	Birmingham	UK
BKK	Suvarnabhumi	Bangkok	Thailand
BLQ	Bologna Guglielmo Marconi	Bologna	Italy
BNA	Nashville International	Nashville (Tennessee)	US
BNE	Brisbane	Brisbane (Queensland)	Australia
BOS	General Edward Lawrence Logan International	Boston (Massachusetts)	US
BRS	Bristol International	Bristol	UK
BUD	Budapest Liszt Ferenc International	Budapest	Hungary
BUR	Bob Hope	Burbank (California)	US
BWI	Baltimore Washington International Thurgood Marshall	Baltimore (Washington DC)	US
CAN	Guangzhou Baiyun International	Guangdong	China
CEI	Chiang Rai International	Chiang Rai	Thailand
CGK	Soekarno - Hatta International	Jakarta Cengkareng (Bantam)	Indonesia
CHC	Christchurch International	Christchurch	New Zealand
CJU (JEJU)	Jeju International	Jeju	South-Korea
CLE	Cleveland Hopkins International	Cleveland (Cuyahoga County, Ohio)	US
CLT	Charlotte Douglas International	Charlotte (North Carolina)	US
CMB	Bandaranaike International	Katunayake (Colombo)	Sri Lanka
CMH	Port Columbus International	Columbus (Ohio)	US
CNX	Chiang Mai International	Chiang Mai	Thailand
CPH	Copenhagen Kastrup	Copenhagen	Denmark
CVG	Cincinnati/Northern Kentucky International	Hebon (Kentucky)	US
DAL	Dallas Love Field	Dallas (Texas)	US
DCA	Ronald Reagan Washington National	Washington DC (Virginia)	US
DEN	Denver International	Denver (Colorado)	US
DFW	Dallas Fort Worth International	Dallas (Texas)	US
DRW	Darwin International	Darwin (Northern Territory)	Australia

Airport code (IATA)	Airport	City	Country
DTW	Detroit Metropolitan Wayne County	Romulus (Michigan)	US
DUD	Dunedin International	Dunedin	New Zealand
DUS	Düsseldorf	Düsseldorf (North Rhine-Westphalia)	Germany
EDI	Edinburgh	Edinburgh (Schotland)	UK
EWR	Newark Liberty International	Newark (New Jersey)	US
FLL	Fort Lauderdale - Hollywood International	Fort Lauderdale (Florida)	US
GMP	Gimpo International	Seoul	South-Korea
GUM	Antonio B. Won Pat International	Tamuning Barrigada	Guam
GVA	Geneva Cointrin International	Geneva	Switserland
HAJ	Hannover - Langenhagen	Langenhagen (Lower Saxony)	Germany
HAK	Haikou Meilan International	Haikou (Hainan)	China
HAM	Hamburg	Hamburg	Germany
HDY	Hat Yai International	Hat Yai	Thailand
HKG	Hong Kong International	Hong Kong	
HKT	Phuket International	Thalang (Phuket)	Thailand
HND	Tokyo Haneda International	Tokyo	Japan
HNL	Honolulu International	Honolulu (Hawaï)	US
HOU	Houston William P. Hobby	Houston (Texas)	US
IAD	Washington Dulles International	Washington DC (Virginia)	US
IAH	Houston George Bush Intercontinental	Houston (Texas)	US
ICN	Incheon International	Seoul	South-Korea
IND	Indianapolis International	Indianapolis (Marion County, Indiana)	US
JAX	Jacksonville International	Jacksonville (Duval County, Florida)	US
JFK	John F. Kennedy International	New York	US
KEF	Keflavík International	Reykjavik	Iceland
KIX	Kansai International	Osaka	Japan
KUL	Kuala Lumpur International	Kuala Lumpur	Malaysia
LAS	McCarran International	Las Vegas (Clarck County, Nevada)	US
LAX	Los Angeles International	Los Angeles (California)	US
LED	Pulkovo - Leningrad	Saint Petersburg	Russia
LGA	LaGuardia	New York	US
LGW	London Gatwick	London	UK
LHR	London Heathrow	London	UK
LIN	Milan - Linate	Milan	Italy
LIS	Lisbon Portela	Lisbon	Portugal
LJU	Ljubljana Jože Pučnik	Ljubljana	Slovenia
LPA	Gran Canaria - Las Palmas	Las Palmas (Gran Canaria)	Spain
LTN	London Luton	London	UK
MAD	Adolfo Suárez Madrid - Barajas International	Madrid	Spain
MAN	Manchester	Manchester	UK
MCI	Kansas City International	Kansas City (Missouri)	US
MCO	Orlando International	Orlando (Florida)	US
MDW	Chicago Midway International	Chicago (Illinois)	US
MEL	Melbourne - Tullamarine	Melbourne (Victoria)	Australia

Airport code (IATA)	Airport	City	Country
MEM	Memphis International	Memphis (Tennessee)	US
MIA	Miami International	Miami (Florida)	US
MKE	General Mitchell International	Milwaukee (Wisconsin)	US
MLA	Malta International	Luqa	Malta
MSP	Minneapolis - Saint Paul	Minneapolis (Hennepin County, Minnesota)	US
MSY	Louis Armstrong New Orleans International	New Orleans (Louisiana)	US
MUC	Munich International	Munich (Bavaria)	Germany
MXP	Milan - Malpensa International	Milan	Italy
NAP	Naples International	Naples	Italy
NCE	Nice - Côte d'Azur	Nice	France
NGO	Chūbu Centrair International	Tokoname	Japan
NRT	Narita International	Narita (Tokyo)	Japan
NTL	Newcastle	Williamtown (New South Wales)	Australia
OAK	Oakland International	Oakland (Alameda County, California)	US
OKC	Will Rogers World	Oklahoma City (Oklahoma)	US
ONT	Ontario International	Ontario (San Bernardino County, California)	US
OOL	Gold Coast	Gold Coast - Bilinga (Queensland)	Australia
ORD	Chicago O'Hare International	Chicago (Illinois)	US
OSL	Oslo Gardermoen	Oslo	Norway
PBI	Palm Beach International	West Palm Beach (Florida)	US
PDX	Portland International	Portland (Oregon)	US
PEK	Beijing Capital International	Beijing	China
PEN	Penang International	Penang	Malaysia
PER	Perth	Perth (Western Australia)	Australia
PHL	Philadelphia International	Philadelphia (Pennsylvania)	US
PHX	Phoenix Sky Harbor International	Phoenix (Arizona)	US
PIT	Pittsburgh International	Pittsburgh (Pennsylvania)	US
PMI	Palma de Mallorca	Palma de Mallorca (Islas de Baleares)	Spain
PVD	T.F. Green	Warwick (Kent County, Rhode Island)	US
PVG	Shanghai Pudong International	Shanghai	China
RDU	Raleigh - Durham International	Morrisville (Wake County, North Carolina)	US
RIC	Richmond International	Richmond (Virginia)	US
RIX	Riga International	Riga	Latvia
RNO	Reno - Tahou International	Reno (Washoe County, Nevada)	US
RSW	Southwest Florida International	Fort Myers (Florida)	US
SAN	San Diego International	San Diego (California)	US
SAT	San Antonio International	San Antonio (Texas)	US
SAW	Sabiha Gökçen International	Istanbul	Turkey
SDF	Louisville International Standiford Field	Louisville (Jefferson County, Kentucky)	US

Airport code (IATA)	Airport	City	Country
SEA	Seattle - Tacoma International	Seattle (Washington)	US
SFO	San Francisco International	San Francisco (California)	US
SIN	Singapore Changi International	Changi	Singapore
SJC	San Jose International	San Jose (Santa Clara County, California)	US
SLC	Salt Lake City International	Salt Lake City (Utah)	US
SMF	Sacramento International	Sacramento (Sacramento County, California)	US
SNA	John Wayne - Orange County	Santa Ana (Orange County, California)	US
SOF	Sofia Airport	Sofia	Bulgaria
STL	Lambert - St. Louis International	St. Louis (St. Louis County, Missouri)	US
STR	Stuttgart	Stuttgart (Baden-Württemberg)	Germany
SYD	Sydney Kingsford Smith International	Mascot (New South Wales)	Australia
SZG	Salzburg W.A. Mozart	Salzburg	Austria
SZX	Shenzhen Bao'an	Shenzhen	China
TLL	Tallinn	Tallinn	Estonia
TLV	Ben Gurion International	Tel Aviv	Israel
TPA	Tampa International	Tampa (Hillsborough County, Florida)	US
TRN	Turino - Caselle International	Caselle Torinese	Italy
TSV	Townsville	Townsville (Queensland)	Australia
TUL	Tulsa International	Tulsa (Tulsa County, Oklahoma)	US
TUS	Tucson International	Tucson (Pima County, Arizona)	US
VIE	Vienna International	Vienna	Austria
WLG	Wellington International	Wellington	New Zealand
XMN	Xiamen Gaoqi International	Xiamen	China
YEG	Edmonton International	Edmonton (Alberta)	Canada
YHZ	Halifax - Stanfield International	Halifax (Nova Scotia)	Canada
YOW	Ottawa Macdonald - Cartier International	Ottawa (Ontario)	Canada
YQB	Quebec City Jean Lesage International	Quebec City (Quebec)	Canada
YUL	Montréal - Pierre Elliott Trudeau International	Montréal (Quebec)	Canada
YVR	Vancouver International	Richmond (British Columbia)	Canada
YWG	Winnipeg James Armstrong Richardson International	Winnipeg (Manitoba)	Canada
YYC	Calgary International	Calgary (Alberta)	Canada
YYJ	Victoria International	Sidney (British Columbia)	Canada
YYT	St. John's International	St. John's (Newfoundland and Labrador)	Canada
YYZ	Lester B. Pearson International	Toronto (Ontario)	Canada
ZAG	Zagreb	Zagreb	Croatia
ZQN	Queenstown	Queenstown	New Zealand
ZRH	Zürich	Zürich	Switserland

Appendix 5 – Values of overall economies of scale for every airport in the data sample

Airport Code	Cost elasticity for output PAX	Cost elasticity for output CARGO	Sum of cost elasticities	Value of overall economies of scale
European airports – sorted by number of passengers				
LHR	0.731855	0.056458	0.788313	1.268531
MAD	0.689501	0.068896	0.758397	1.318571
MUC	0.709949	0.074236	0.784185	1.275209
BCN	0.682018	0.078972	0.760990	1.314078
LGW	0.690570	0.085143	0.775713	1.289137
ZRH	0.670461	0.079696	0.750157	1.333054
CPH	0.667767	0.083107	0.750875	1.331780
PMI	0.665609	0.090651	0.756260	1.322297
VIE	0.695644	0.083051	0.778695	1.284199
OSL	0.692944	0.072744	0.765688	1.306014
DUS	0.689639	0.074176	0.763815	1.309217
MAN	0.696845	0.074264	0.771109	1.296833
MXP	0.662254	0.065344	0.727598	1.374385
LIS	0.686667	0.071989	0.758656	1.318121
SAW	0.673497	0.094219	0.767716	1.302566
GVA	0.668514	0.082868	0.751382	1.330881
HAM	0.697145	0.087717	0.784862	1.274110
TLV	0.686640	0.067939	0.754579	1.325243
ATH	0.679406	0.082356	0.761762	1.312746
AGP	0.668192	0.100199	0.768391	1.301421
NCE	0.668682	0.097894	0.766576	1.304503
LED	0.672847	0.081909	0.754756	1.324932
LPA	0.655701	0.090129	0.745829	1.340789
STR	0.671047	0.084442	0.755489	1.323646
LTN	0.687200	0.080704	0.767904	1.302246
EDI	0.671788	0.093347	0.765135	1.306959
BHX	0.670064	0.093089	0.763153	1.310354
BGY	0.675919	0.066647	0.742565	1.346683
ALC	0.663296	0.094624	0.757920	1.319400
LIN	0.674300	0.086250	0.760550	1.314838
BUD	0.709136	0.061832	0.770968	1.297071
BLQ	0.665528	0.075653	0.741181	1.349199
NAP	0.668652	0.102117	0.770769	1.297406
HAJ	0.667015	0.087211	0.754226	1.325862
RIX	0.665791	0.097691	0.763482	1.309789
MLA	0.653457	0.081771	0.735229	1.360121
TRN	0.648006	0.098945	0.746951	1.338776
SOF	0.643832	0.066868	0.710700	1.407063
BEG	0.675756	0.086357	0.762113	1.312141

Airport Code	Cost elasticity for output PAX	Cost elasticity for output CARGO	Sum of cost elasticities	Value of overall economies of scale
KEF	0.643615	0.072416	0.716031	1.396588
ZAG	0.672843	0.115213	0.788056	1.268945
TLL	0.669765	0.096063	0.765828	1.305776
SZG	0.636247	0.105261	0.741508	1.348603
LJU	0.643858	0.107978	0.751836	1.330077
North American airports – sorted by number of passengers				
ATL	0.682981	0.075864	0.758844	1.317793
ORD	0.689755	0.063350	0.753105	1.327836
LAX	0.683820	0.056337	0.740157	1.351064
DFW	0.685935	0.075048	0.760983	1.314090
DEN	0.680848	0.075410	0.756258	1.322301
JFK	0.657239	0.054002	0.711241	1.405993
SFO	0.666131	0.073204	0.739334	1.352568
LAS	0.680666	0.090262	0.770928	1.297138
PHX	0.679072	0.079829	0.758901	1.317695
CLT	0.673823	0.088556	0.762379	1.311684
IAH	0.682996	0.076168	0.759164	1.317238
MIA	0.673550	0.055552	0.729102	1.371549
MCO	0.674834	0.071909	0.746743	1.339149
YYZ	0.676484	0.077018	0.753502	1.327136
EWR	0.645346	0.066963	0.712309	1.403884
SEA	0.677218	0.076647	0.753865	1.326498
MSP	0.652250	0.093076	0.745326	1.341694
DTW	0.661065	0.089628	0.750693	1.332102
PHL	0.649526	0.083243	0.732770	1.364685
BOS	0.670366	0.081613	0.751979	1.329824
LGA	0.633299	0.103584	0.736883	1.357067
FLL	0.684652	0.083219	0.767871	1.302301
BWI	0.674118	0.084680	0.758797	1.317875
IAD	0.670979	0.085164	0.756143	1.322501
SLC	0.654945	0.098225	0.753170	1.327722
DCA	0.676848	0.104786	0.781633	1.279372
MDW	0.661117	0.096430	0.757547	1.320049
HNL	0.671146	0.055423	0.726570	1.376330
SAN	0.674910	0.083308	0.758218	1.318882
YVR	0.653426	0.083597	0.737023	1.356810
TPA	0.663570	0.094888	0.758458	1.318465
PDX	0.655181	0.088378	0.743559	1.344883
YUL	0.653535	0.095747	0.749282	1.334610
YYC	0.661696	0.095180	0.756876	1.321220
STL	0.644952	0.100147	0.745099	1.342103

Airport Code	Cost elasticity for output PAX	Cost elasticity for output CARGO	Sum of cost elasticities	Value of overall economies of scale
MCI	0.659884	0.098699	0.758584	1.318246
HOU	0.663730	0.104946	0.768676	1.300938
BNA	0.641802	0.099449	0.741251	1.349071
OAK	0.674582	0.073856	0.748438	1.336116
AUS	0.661937	0.082975	0.744912	1.342440
RDU	0.640703	0.103745	0.744448	1.343277
SMF	0.665404	0.087399	0.752803	1.328368
CLE	0.652343	0.103421	0.755764	1.323165
SNA	0.665438	0.085160	0.750598	1.332271
MSY	0.655000	0.093596	0.748595	1.335835
SJC	0.657873	0.092503	0.750375	1.332666
SAT	0.655172	0.093728	0.748899	1.335293
MEM	0.637679	0.081871	0.719550	1.389757
DAL	0.671324	0.091548	0.762872	1.310835
PIT	0.652573	0.090689	0.743262	1.345421
MKE	0.624117	0.073476	0.697593	1.433500
RSW	0.641897	0.100866	0.742763	1.346324
IND	0.662846	0.084825	0.747671	1.337487
YEG	0.639647	0.097584	0.737231	1.356427
CMH	0.649420	0.112673	0.762093	1.312176
CVG	0.637516	0.078141	0.715657	1.397317
PBI	0.655947	0.103376	0.759323	1.316963
ABQ	0.654006	0.101919	0.755925	1.322883
BDL	0.634539	0.088278	0.722817	1.383476
JAX	0.650748	0.090645	0.741393	1.348812
ANC	0.635374	0.072272	0.707646	1.413137
YOW	0.627670	0.102102	0.729772	1.370292
ONT	0.631714	0.082879	0.714593	1.399399
BUR	0.697813	0.088063	0.785876	1.272465
PVD	0.625368	0.120961	0.746328	1.339893
OKC	0.645505	0.102259	0.747764	1.337320
YHZ	0.620342	0.097277	0.717618	1.393498
TUS	0.628303	0.107293	0.735596	1.359442
RNO	0.630048	0.112796	0.742844	1.346177
YWG	0.639798	0.096522	0.736319	1.358106
SDF	0.655656	0.078250	0.733906	1.362572
RIC	0.633521	0.105300	0.738821	1.353507
TUL	0.634036	0.095057	0.729093	1.371567
ALB	0.634375	0.112085	0.746460	1.339657
YYJ	0.609625	0.113082	0.722706	1.383688
YYT	0.610815	0.107795	0.718610	1.391576

Airport Code	Cost elasticity for output PAX	Cost elasticity for output CARGO	Sum of cost elasticities	Value of overall economies of scale
YQB	0.625125	0.110284	0.735410	1.359787
Asia Pacific airports – sorted by number of passengers				
PEK	0.721915	0.040983	0.762898	1.310791
HND	0.731984	0.027368	0.759353	1.316911
CGK	0.695561	0.051242	0.746804	1.339040
HKG	0.724210	0.034640	0.758850	1.317784
BKK	0.719176	0.048950	0.768126	1.301869
SIN	0.704231	0.041012	0.745243	1.341845
CAN	0.709573	0.054042	0.763615	1.309561
PVG	0.708536	0.046792	0.755328	1.323929
KUL	0.701737	0.052164	0.753901	1.326434
ICN	0.690053	0.053301	0.743354	1.345253
SYD	0.677541	0.078178	0.755719	1.323243
NRT	0.692106	0.051629	0.743735	1.344564
SZX	0.718004	0.054217	0.772221	1.294967
MEL	0.668923	0.070741	0.739664	1.351965
BNE	0.675721	0.076286	0.752007	1.329775
GMP	0.669939	0.076834	0.746773	1.339095
CJU (JEJU)	0.584372	-0.015462	0.568911	1.757745
XMN	0.697188	0.064247	0.761435	1.313310
KIX	0.706778	0.055514	0.762292	1.311834
AKL	0.679693	0.069148	0.748841	1.335397
PER	0.669011	0.074836	0.743847	1.344363
HAK	0.679010	0.068918	0.747928	1.337026
NGO	0.687504	0.073374	0.760878	1.314272
HKT	0.696679	0.081021	0.777700	1.285843
CMB	0.707444	0.063091	0.770535	1.297800
ADL	0.661751	0.076380	0.738131	1.354772
CHC	0.660490	0.089621	0.750111	1.333136
WLG	0.652208	0.102682	0.754890	1.324696
OOL	0.683893	0.106539	0.790432	1.265131
PEN	0.665858	0.081688	0.747545	1.337712
CNX	0.682202	0.097607	0.779808	1.282366
GUM	0.645512	0.097718	0.743230	1.345479
DRW	0.621450	0.136900	0.758350	1.318652
HDY	0.666664	0.103270	0.769935	1.298811
NTL	0.617763	0.126183	0.743946	1.344183
CEI	0.620784	0.100341	0.721125	1.386722

Appendix 6 – Evaluation of existence of product-specific economies of scale for every airport in the data sample – based on declining marginal costs

Airport Code	Value for PAX	Value for CARGO
European airports – sorted by number of passengers		
LHR	-0.0000000894	-0.0000683271
MAD	-0.0000000869	-0.0004939799
MUC	-0.0000001625	-0.0011242070
BCN	-0.0000000835	-0.0043992650
LGW	-0.0000001130	-0.0057238118
ZRH	-0.0000002763	-0.0003268475
CPH	-0.0000001416	-0.0002486520
PMI	-0.0000000778	-0.0921183040
VIE	-0.0000002682	-0.0008804355
OSL	-0.0000001936	-0.0032708090
DUS	-0.0000002168	-0.0034861019
MAN	-0.0000001793	-0.0028140246
MXP	-0.0000002332	-0.0001323928
LIS	-0.0000001904	-0.0016353949
SAW	-0.0000000792	-0.0092111791
GVA	-0.0000003417	-0.0047466840
HAM	-0.0000002714	-0.0054381676
TLV	-0.0000004713	-0.0003518492
ATH	-0.0000002994	-0.0035171326
AGP	-0.0000002835	-2.8860587686
NCE	-0.0000003619	-0.0670582004
LED	-0.0000003319	-0.0171982164
LPA	-0.0000002165	-0.0211891224
STR	-0.0000005451	-0.0213021302
LTN	-0.0000003188	-0.0137114297
EDI	-0.0000003018	-0.0062050161
BHX	-0.0000003304	-0.0321937200
BGY	-0.0000002730	-0.0005379654
ALC	-0.0000003731	-2.0509507189
LIN	-0.0000004579	-0.0364414032
BUD	-0.0000005325	-0.0015194569
BLQ	-0.0000005294	-0.0042412392
NAP	-0.0000004606	-0.2670109600
HAJ	-0.0000011053	-0.0516072954
RIX	-0.0000003716	-0.0035854350
MLA	-0.0000006305	-0.0121209385
TRN	-0.0000011376	-0.0575798485
SOF	-0.0000008066	-0.0119666899
BEG	-0.0000008618	-0.0611149018

Airport Code	Value for PAX	Value for CARGO
KEF	-0.0000037379	-0.0048488266
ZAG	-0.0000019145	-0.0622074344
TLL	-0.0000018750	-0.0073015342
SZG	-0.0000046659	-0.0919900837
LJU	-0.0000047057	-0.0112998975
North American airports – sorted by number of passengers		
ATL	-0.0000000094	-0.0000686212
ORD	-0.0000000331	-0.0000219915
LAX	-0.0000000364	-0.0000154464
DFW	-0.0000000412	-0.0001333980
DEN	-0.0000000430	-0.0008882745
JFK	-0.0000000800	-0.0000373330
SFO	-0.0000000647	-0.0002747640
LAS	-0.0000000448	-0.0033889372
PHX	-0.0000000413	-0.0003467739
CLT	-0.0000000157	-0.0006369296
IAH	-0.0000000491	-0.0001442045
MIA	-0.0000000887	-0.0000097936
MCO	-0.0000000552	-0.0009534376
YYZ	-0.0000000963	-0.0003606430
EWR	-0.0000001053	-0.0000877066
SEA	-0.0000000665	-0.0003290118
MSP	-0.0000000534	-0.0005959207
DTW	-0.0000000676	-0.0005990066
PHL	-0.0000000731	-0.0001555507
BOS	-0.0000001081	-0.0006336061
LGA	-0.0000000988	-0.5398697338
FLL	-0.0000000686	-0.0015737161
BWI	-0.0000000917	-0.0015478102
IAD	-0.0000002006	-0.0005415076
SLC	-0.0000000761	-0.0005289394
DCA	-0.0000001252	-0.6260553780
MDW	-0.0000000992	-0.0249262365
HNL	-0.0000001272	-0.0000441175
SAN	-0.0000001133	-0.0008764654
YVR	-0.0000001634	-0.0005066501
TPA	-0.0000001408	-0.0023111567
PDX	-0.0000001824	-0.0004173479
YUL	-0.0000003031	-0.0039421494
YYC	-0.0000002314	-0.0025547900
STL	-0.0000001822	-0.0026556176
MCI	-0.0000002705	-0.0017192598
HOU	-0.0000001709	-0.0660937260

Airport Code	Value for PAX	Value for CARGO
BNA	-0.0000002296	-0.0050754668
OAK	-0.0000003511	-0.0000458803
AUS	-0.0000002272	-0.0015140650
RDU	-0.0000002662	-0.0016407883
SMF	-0.0000003797	-0.0027247193
CLE	-0.0000003409	-0.0024102381
SNA	-0.0000002784	-0.0319938874
MSY	-0.0000002301	-0.0033588922
SJC	-0.0000004043	-0.0068026652
SAT	-0.0000002453	-0.0004865375
MEM	-0.0000003942	-0.0000005813
DAL	-0.0000001848	-0.0517568315
PIT	-0.0000005183	-0.0020918988
MKE	-0.0000002480	-0.0008794356
RSW	-0.0000003210	-0.0329656994
IND	-0.0000006443	-0.0000127963
YEG	-0.0000005416	-0.0163663786
CMH	-0.0000004636	-0.3875010687
CVG	-0.0000007218	-0.0000303484
PBI	-0.0000004660	-0.0185590855
ABQ	-0.0000004406	-0.0015638228
BDL	-0.0000004261	-0.0003716740
JAX	-0.0000005514	-0.0013737168
ANC	-0.0000009095	-0.0000012873
YOW	-0.0000007404	-0.0603891532
ONT	-0.0000009692	-0.0000428042
BUR	-0.0000005626	-0.0019880753
PVD	-0.0000006813	-0.0453006359
OKC	-0.0000007747	-0.0044994580
YHZ	-0.0000010043	-0.0059002266
TUS	-0.0000007709	-0.0044896321
RNO	-0.0000011647	-0.0025767887
YWG	-0.0000011949	-0.0013075449
SDF	-0.0000011424	-0.0000009553
RIC	-0.0000008947	-0.0019369770
TUL	-0.0000010097	-0.0012123742
ALB	-0.0000013924	-0.0122615333
YYJ	-0.0000016269	-0.0968918198
YYT	-0.0000024387	-0.0204970462
YQB	-0.0000029798	-0.5795139091
Asia Pacific airports – sorted by number of passengers		
PEK	-0.0000000197	-0.0000102341
HND	-0.0000000600	-0.0000699311

Airport Code	Value for PAX	Value for CARGO
CGK	-0.0000000073	-0.0000175692
HKG	-0.0000000448	-0.0000019818
BKK	-0.0000000326	-0.0000139331
SIN	-0.0000000574	-0.0000114558
CAN	-0.0000000414	-0.0000189914
PVG	-0.0000000472	-0.0000029883
KUL	-0.0000000319	-0.0000327644
ICN	-0.0000000880	-0.0000041520
SYD	-0.0000000680	-0.0001178082
NRT	-0.0000002824	-0.0000226669
SZX	-0.0000000518	-0.0000193972
MEL	-0.0000000576	-0.0002879433
BNE	-0.0000000930	-0.0020034567
GMP	-0.0000000953	-0.0002112194
CJU (JEJU)	-0.0000000381	0.0000081156
XMN	-0.0000000581	-0.0000817389
KIX	-0.0000006016	-0.0001118304
AKL	-0.0000001435	-0.0002170132
PER	-0.0000001939	-0.0021176037
HAK	-0.0000000663	-0.0000870570
NGO	-0.0000011373	-0.0019935297
HKT	-0.0000001892	-0.0065828147
CMB	-0.0000001546	-0.0001079820
ADL	-0.0000003425	-0.0218419792
CHC	-0.0000004206	-0.0071678875
WLG	-0.0000004100	-0.1841466130
OOL	-0.0000002820	-0.1378726766
PEN	-0.0000002851	-0.0001695906
CNX	-0.0000004111	-0.0079310497
GUM	-0.0000017524	-0.0062592126
DRW	-0.0000014160	-33.8438994397
HDY	-0.0000009090	-0.0067829332
NTL	-0.0000025040	-0.2079544245
CEI	-0.0000021018	-0.0334151296

Appendix 7 – Estimation results Quadratic Cost Function (model of Lau (1974))

R-squared = 0.917482		**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**
C(1)	constant	-34215394	45536708	-0.751380	0.4537
C(2)	**Passengers (PAX)**	**8.266506**	**2.785581**	**2.967604**	**0.0035**
C(3)	**Cargo (CARGO)**	**-5.105395**	**105.0497**	**-0.048600**	**0.9613**
C(4)	0.5*PAX*CARGO	2.56E-06	3.07E-06	0.834203	0.4056
C(5)	0.5*PAX*PAX	-1.87E-07	5.65 E-08	-3.301226	0.0012
C(6)	0.5*CARGO*CARGO	-7.95E-05	2.71 E-05	-2.929399	0.0040
C(7)	**Capital Unit Cost (R)**	**-40698.66**	**129813.9**	**-0.313515**	**0.7544**
C(8)	**Labor Unit Cost (W)**	**162.0901**	**556.8147**	**0.291102**	**0.7714**
C(9)	**Soft Unit Cost (M)**	**18.89715**	**20.80040**	**0.908499**	**0.3652**
C(10)	0.5*R*W	0.112774	1.700173	0.066331	0.9472
C(11)	0.5*R*M	0.105381	0.058512	1.800995	0.0739
C(12)	0.5*W*M	-0.000169	0.000358	-0.471805	0.6378
C(13)	0.5*R*R	-218.1771	289.4140	-0.753858	0.4522
C(14)	0.5*W*W	0.001773	0.002059	0.861052	0.3907
C(15)	0.5*M*M	-4.40E-06	2.65 E-06	-1.663420	0.0985
C(16)	PAX*R	0.018914	0.003954	4.783509	0.0000
C(17)	PAX*W	-3.86E-05	2.06 E-05	-1.875391	0.0629
C(18)	PAX*M	1.21E-06	5.41 E-07	2.235062	0.0270
C(19)	CARGO*R	0.068310	0.116921	0.584245	0.5600
C(20)	CARGO*W	0.001536	0.000481	3.194701	0.0017
C(21)	CARGO*M	-7.58E-06	9.65 E-06	-0.785577	0.4335

Appendix 8 – Values of product-specific economies of scale for every airport in the data sample

	Model A (constant = 0)		Model B (constant ≠ 0)	
Airport Code	Product-specific economies of scale passengers	Product-specific economies of scale cargo	Product-specific economies of scale passengers	Product-specific economies of scale cargo
European airports – sorted by number of passengers				
LHR	1.06	6.83	1.08	6.93
MAD	1.25	2.53	1.28	2.59
MUC	1.23	2.10	1.26	2.15
BCN	1.39	0.80	1.43	0.82
LGW	1.37	0.77	1.41	0.79
ZRH	1.16	3.21	1.20	3.31
CPH	1.20	2.70	1.25	2.79
PMI	1.49	0.14	1.55	0.14
VIE	1.21	2.17	1.25	2.26
OSL	1.33	1.20	1.39	1.25
DUS	1.34	1.19	1.40	1.24
MAN	1.32	1.20	1.38	1.25
MXP	1.11	4.47	1.16	4.65
LIS	1.31	1.50	1.39	1.59
SAW	1.44	0.38	1.53	0.40
GVA	1.37	1.08	1.46	1.15
HAM	1.33	0.90	1.42	0.96
TLV	1.09	3.95	1.15	4.17
ATH	1.34	1.16	1.43	1.24
AGP	1.49	0.04	1.61	0.04
NCE	1.46	0.28	1.58	0.30
LED	1.42	0.58	1.54	0.62
LPA	1.47	0.39	1.62	0.43
STR	1.41	0.63	1.55	0.70
LTN	1.38	0.63	1.52	0.69
EDI	1.38	0.80	1.52	0.88
BHX	1.44	0.38	1.60	0.42
BGY	1.22	2.72	1.33	2.96
ALC	1.50	0.05	1.67	0.06
LIN	1.43	0.44	1.59	0.49
BUD	1.20	2.52	1.32	2.76
BLQ	1.36	1.34	1.56	1.54
NAP	1.47	0.15	1.73	0.17
HAJ	1.43	0.54	1.69	0.64
RIX	1.35	1.04	1.62	1.24
MLA	1.43	0.83	1.83	1.06

	Model A (constant = 0)		Model B (constant ≠ 0)	
Airport Code	Product-specific economies of scale passengers	Product-specific economies of scale cargo	Product-specific economies of scale passengers	Product-specific economies of scale cargo
TRN	1.47	0.47	1.92	0.61
SOF	1.45	1.05	1.87	1.36
BEG	1.42	0.44	1.88	0.58
KEF	1.24	2.84	1.73	3.95
ZAG	1.40	0.53	2.11	0.80
TLL	1.28	1.52	1.90	2.26
SZG	1.46	0.68	2.75	1.28
LJU	1.27	1.68	2.97	3.93
North American airports – sorted by number of passengers				
ATL	1.19	4.09	1.21	4.17
ORD	1.12	5.93	1.14	6.02
LAX	1.13	6.88	1.15	6.98
DFW	1.20	3.24	1.22	3.31
DEN	1.34	1.54	1.37	1.58
JFK	1.15	6.43	1.17	6.55
SFO	1.28	2.56	1.31	2.62
LAS	1.40	0.66	1.44	0.68
PHX	1.30	1.83	1.33	1.88
CLT	1.39	0.87	1.43	0.90
IAH	1.22	2.77	1.25	2.84
MIA	1.09	7.18	1.11	7.31
MCO	1.36	1.37	1.40	1.41
YYZ	1.25	2.41	1.29	2.47
EWR	1.19	4.27	1.22	4.37
SEA	1.27	2.13	1.31	2.20
MSP	1.37	1.33	1.42	1.37
DTW	1.34	1.50	1.38	1.54
PHL	1.26	2.63	1.29	2.71
BOS	1.30	1.84	1.34	1.90
LGA	1.57	0.06	1.64	0.06
FLL	1.36	0.96	1.41	1.00
BWI	1.36	1.07	1.42	1.12
IAD	1.24	2.25	1.29	2.34
SLC	1.34	1.36	1.40	1.43
DCA	1.47	0.06	1.55	0.06
MDW	1.48	0.27	1.55	0.28
HNL	1.05	5.88	1.10	6.10
SAN	1.32	1.44	1.39	1.52
YVR	1.29	2.06	1.35	2.16
TPA	1.38	0.94	1.46	0.99

	Model A (constant = 0)		Model B (constant ≠ 0)	
Airport Code	Product-specific economies of scale passengers	Product-specific economies of scale cargo	Product-specific economies of scale passengers	Product-specific economies of scale cargo
PDX	1.26	2.17	1.33	2.30
YUL	1.39	1.00	1.49	1.06
YYC	1.37	1.08	1.46	1.15
STL	1.42	0.91	1.52	0.97
MCI	1.33	1.30	1.44	1.41
HOU	1.48	0.18	1.62	0.20
BNA	1.45	0.73	1.59	0.80
OAK	0.86	5.99	0.91	6.32
AUS	1.34	1.41	1.47	1.54
RDU	1.37	1.24	1.50	1.36
SMF	1.34	1.32	1.47	1.45
CLE	1.35	1.18	1.49	1.30
SNA	1.46	0.37	1.62	0.41
MSY	1.40	0.91	1.55	1.01
SJC	1.40	0.86	1.56	0.96
SAT	1.24	2.11	1.36	2.31
MEM	-2.67	27.48	-2.34	24.08
DAL	1.46	0.23	1.64	0.26
PIT	1.32	1.62	1.46	1.79
MKE	1.39	1.92	1.54	2.14
RSW	1.51	0.34	1.71	0.39
IND	0.61	7.39	0.64	7.75
YEG	1.47	0.62	1.68	0.71
CMH	1.52	0.11	1.77	0.13
CVG	0.71	7.24	0.76	7.74
PBI	1.44	0.52	1.70	0.61
ABQ	1.29	1.55	1.49	1.79
BDL	1.18	2.91	1.34	3.30
JAX	1.28	1.93	1.48	2.23
ANC	0.66	9.09	0.70	9.66
YOW	1.54	0.36	1.88	0.45
ONT	0.70	6.90	0.77	7.54
BUR	1.22	1.74	1.47	2.11
PVD	1.53	0.36	1.96	0.46
OKC	1.36	1.23	1.72	1.56
YHZ	1.42	1.24	1.81	1.58
TUS	1.39	1.18	1.78	1.50
RNO	1.29	1.70	1.61	2.13
YWG	1.19	2.50	1.47	3.08
SDF	0.40	9.96	0.43	10.57

	Model A (constant = 0)		Model B (constant ≠ 0)	
Airport Code	**Product-specific economies of scale passengers**	**Product-specific economies of scale cargo**	**Product-specific economies of scale passengers**	**Product-specific economies of scale cargo**
RIC	1.28	1.80	1.65	2.31
TUL	1.22	2.42	1.61	3.20
ALB	1.41	0.95	2.05	1.38
YYJ	1.57	0.38	3.46	0.84
YYT	1.47	0.97	3.13	2.08
YQB	1.56	0.22	3.72	0.52
Asia Pacific airports – sorted by number of passengers				
PEK	1.09	10.66	1.11	10.82
HND	1.09	11.02	1.11	11.21
CGK	1.18	4.87	1.20	4.97
HKG	2.06	1.95	2.11	1.99
BKK	1.06	7.40	1.07	7.52
SIN	1.09	9.42	1.11	9.58
CAN	1.06	6.54	1.08	6.65
PVG	1.31	6.99	1.33	7.12
KUL	1.12	5.23	1.15	5.34
ICN	1.39	5.59	1.42	5.71
SYD	1.18	3.15	1.21	3.23
NRT	1.04	7.90	1.07	8.06
SZX	1.01	6.26	1.03	6.41
MEL	1.30	2.16	1.34	2.23
BNE	1.38	1.02	1.44	1.07
GMP	1.23	2.55	1.28	2.66
CJU (JEJU)	1.41	-12.69	1.47	-13.25
XMN	1.15	3.42	1.20	3.57
KIX	0.92	6.99	0.96	7.24
AKL	1.18	3.05	1.25	3.22
PER	1.36	1.26	1.46	1.35
HAK	1.17	3.15	1.26	3.37
NGO	1.18	2.69	1.28	2.92
HKT	1.36	0.70	1.50	0.77
CMB	1.05	4.22	1.14	4.58
ADL	1.45	0.51	1.65	0.58
CHC	1.40	0.85	1.64	0.99
WLG	1.51	0.16	1.79	0.19
OOL	1.44	0.16	1.71	0.19
PEN	1.08	3.56	1.24	4.08
CNX	1.36	0.76	1.66	0.94
GUM	1.32	1.55	1.79	2.10
DRW	1.61	0.02	2.73	0.03

	Model A (constant = 0)		Model B (constant ≠ 0)	
Airport Code	Product-specific economies of scale passengers	Product-specific economies of scale cargo	Product-specific economies of scale passengers	Product-specific economies of scale cargo
HDY	1.33	1.09	2.12	1.74
NTL	1.56	0.30	4.87	0.95
CEI	1.49	0.76	8.96	4.58

Appendix 9 – Values of (overall) economies of scope for every airport in the data sample

Airport Code	Economies of scope Model A (constant = 0)	Economies of scope Model B (constant ≠ 0)
European airports – sorted by number of passengers		
LHR	-0.1612	-0.1792
MAD	-0.0383	-0.0626
MUC	-0.0293	-0.0564
BCN	-0.0105	-0.0418
LGW	-0.0107	-0.0425
ZRH	-0.0352	-0.0679
CPH	-0.0284	-0.0640
PMI	-0.0014	-0.0470
VIE	-0.0212	-0.0602
OSL	-0.0098	-0.0531
DUS	-0.0094	-0.0548
MAN	-0.0090	-0.0563
MXP	-0.0288	-0.0707
LIS	-0.0087	-0.0670
SAW	-0.0027	-0.0674
GVA	-0.0065	-0.0717
HAM	-0.0057	-0.0724
TLV	-0.0198	-0.0749
ATH	-0.0065	-0.0756
AGP	-0.0003	-0.0785
NCE	-0.0016	-0.0873
LED	-0.0028	-0.0869
LPA	-0.0018	-0.0979
STR	-0.0028	-0.0984
LTN	-0.0026	-0.0997
EDI	-0.0036	-0.1026
BHX	-0.0017	-0.1083
BGY	-0.0088	-0.0988
ALC	-0.0002	-0.1113
LIN	-0.0017	-0.1121
BUD	-0.0072	-0.1044
BLQ	-0.0033	-0.1546
NAP	-0.0005	-0.1734
HAJ	-0.0013	-0.1861
RIX	-0.0026	-0.1969
MLA	-0.0013	-0.2797
TRN	-0.0009	-0.3016
SOF	-0.0013	-0.2981

Airport Code	Economies of scope Model A (constant = 0)	Economies of scope Model B (constant ≠ 0)
BEG	-0.0007	-0.3231
KEF	-0.0027	-0.3971
ZAG	-0.0008	-0.5141
TLL	-0.0018	-0.4878
SZG	-0.0007	-0.8829
LJU	-0.0012	-1.3388
North American airports – sorted by number of passengers		
ATL	-0.1199	-0.1422
ORD	-0.1481	-0.1662
LAX	-0.1624	-0.1804
DFW	-0.0669	-0.0880
DEN	-0.0272	-0.0516
JFK	-0.1052	-0.1249
SFO	-0.0388	-0.0639
LAS	-0.0110	-0.0401
PHX	-0.0280	-0.0550
CLT	-0.0141	-0.0431
IAH	-0.0418	-0.0673
MIA	-0.1354	-0.1570
MCO	-0.0164	-0.0470
YYZ	-0.0323	-0.0605
EWR	-0.0549	-0.0802
SEA	-0.0267	-0.0567
MSP	-0.0195	-0.0510
DTW	-0.0210	-0.0525
PHL	-0.0345	-0.0644
BOS	-0.0219	-0.0550
LGA	-0.0008	-0.0424
FLL	-0.0091	-0.0519
BWI	-0.0102	-0.0533
IAD	-0.0221	-0.0614
SLC	-0.0135	-0.0597
DCA	-0.0006	-0.0542
MDW	-0.0025	-0.0551
HNL	-0.0337	-0.0731
SAN	-0.0108	-0.0627
YVR	-0.0157	-0.0648
TPA	-0.0076	-0.0636
PDX	-0.0145	-0.0722
YUL	-0.0067	-0.0735
YYC	-0.0069	-0.0760
STL	-0.0059	-0.0787

Airport Code	Economies of scope Model A (constant = 0)	Economies of scope Model B (constant ≠ 0)
MCI	-0.0070	-0.0913
HOU	-0.0010	-0.0993
BNA	-0.0037	-0.0999
OAK	-0.0257	-0.0831
AUS	-0.0057	-0.1013
RDU	-0.0062	-0.1022
SMF	-0.0054	-0.1050
CLE	-0.0056	-0.1059
SNA	-0.0014	-0.1131
MSY	-0.0039	-0.1092
SJC	-0.0035	-0.1137
SAT	-0.0087	-0.1062
MEM	0.4508	0.5187
DAL	-0.0009	-0.1258
PIT	-0.0061	-0.1144
MKE	-0.0057	-0.1201
RSW	-0.0013	-0.1361
IND	-0.0342	-0.0842
YEG	-0.0022	-0.1429
CMH	-0.0004	-0.1619
CVG	-0.0211	-0.0919
PBI	-0.0016	-0.1764
ABQ	-0.0047	-0.1594
BDL	-0.0077	-0.1442
JAX	-0.0050	-0.1643
ANC	-0.0756	-0.1426
YOW	-0.0009	-0.2275
ONT	-0.0153	-0.1089
BUR	-0.0035	-0.2139
PVD	-0.0009	-0.2793
OKC	-0.0024	-0.2692
YHZ	-0.0023	-0.2749
TUS	-0.0024	-0.2764
RNO	-0.0036	-0.2553
YWG	-0.0046	-0.2386
SDF	-0.0420	-0.1063
RIC	-0.0033	-0.2872
TUL	-0.0034	-0.3241
ALB	-0.0014	-0.4518
YYJ	-0.0003	-1.2069
YYT	-0.0008	-1.1382
YQB	-0.0002	-1.3852

Airport Code	Economies of scope Model A (constant = 0)	Economies of scope Model B (constant ≠ 0)
Asia Pacific airports – sorted by number of passengers		
PEK	-0.2235	-0.2418
HND	-0.1009	-0.1203
CGK	-0.0710	-0.0918
HKG	-0.5621	-0.6000
BKK	-0.1218	-0.1408
SIN	-0.1547	-0.1735
CAN	-0.1080	-0.1276
PVG	-0.2541	-0.2781
KUL	-0.0596	-0.0829
ICN	-0.2588	-0.2859
SYD	-0.0476	-0.0731
NRT	-0.1308	-0.1537
SZX	-0.0619	-0.0879
MEL	-0.0225	-0.0552
BNE	-0.0083	-0.0536
GMP	-0.0204	-0.0632
CJU (JEJU)	-0.0195	-0.0642
XMN	-0.0208	-0.0666
KIX	-0.0411	-0.0784
AKL	-0.0161	-0.0722
PER	-0.0063	-0.0771
HAK	-0.0127	-0.0844
NGO	-0.0099	-0.0951
HKT	-0.0027	-0.1041
CMB	-0.0125	-0.0976
ADL	-0.0015	-0.1364
CHC	-0.0023	-0.1712
WLG	-0.0005	-0.1887
OOL	-0.0005	-0.1906
PEN	-0.0077	-0.1558
CNX	-0.0018	-0.2265
GUM	-0.0022	-0.3639
DRW	0.0000	-0.6993
HDY	-0.0012	-0.5932
NTL	-0.0002	-2.1300
CEI	-0.0004	-5.0242