Cooperation between airports : a focus on the financial intertwinement of European airport operators

COOPERATION BETWEEN AIRPORTS: A FOCUS ON THE FINANCIAL INTERTWINEMENT OF EUROPEAN AIRPORT OPERATORS

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ABSTRACT

Recent airport cooperation initiatives and the lack of detailed research on the cooperation between airports suggest a research gap on this topic. The present study therefore investigates cooperative arrangements between European airports by focusing on their financial intertwinement. Social network analysis tools are used to examine the structural patterns of financial relationships in the airport sector, while a multiple regression quadratic assignment procedure (MRQAP) is applied to measure the impact of financial path dependency and spatial patterns on the occurrence of investment ties. The findings indicate a high degree of stability in investment relations in the airport industry over time. Furthermore, it is suggested that the formation of interorganisational linkages is facilitated by spatial proximity.

KEYWORDS

Airport, cooperation, ownership, social network analysis, multiple regression quadratic assignment procedure, Europe

1. INTRODUCTION

All types of organisations, also airports, interact with other actors in their business environment and form inter-organisational relationships. Such relationships play an important role for the strategy of an organisation. The intensity of these interactions varies from cooperative arrangements to competition at the extreme (De Wit & Meyer, 2005).

Deregulation in the EU air transport market in the late 1980s and early 1990s did not only lead to cost and efficiency pressure for airlines but also for airports as a consequence. Moreover, government thinking on how infrastructure should be owned and operated changed over time. Therefore, in the last 25 years, airports have been developing from infrastructure provider to commercial enterprises. Recent examples show that airports are not only involved in competition, but more and more also in cooperative initiatives. First, they form networks with airlines (Macário & Van de Voorde, 2012; Schaar & Sherry, 2010). For example, terminal 5 at London-Heathrow was built specially for British Airways and its partners (Lopes, 2012). Second, cooperative agreements are also formed with infrastructure or service providers of other transport modes. At Milan Malpensa, the airport authority operates the train service (Lopes, 2012; Suski, 2011) and at Al Maktoum International Airport in Dubai, freight can be transported by plane to the final destination after having arrived by ship (Wilén, 2008). Third, airports are connected with other airports. One example is the connection between Amsterdam-Schiphol and Paris Charles-de-Gaulle through the mutual shareholding (8%) of Schiphol Group and Aéroports de Paris (AdP) since 2008. Ultimately, airports are in contact with other stakeholders, such as (local) public authorities.

Literature about interactions of airports with other actors primarily concentrates on issues related to the competition of airports (see Barrett (2000), Forsyth (2003), Graham (2004, 2014a), Lian & Rønnevik (2011), Lieshout et al. (2016), Niemeier et al. (2012), Paul (2015), Pels et al. (2000, 2003) and Starkie (2002)). Cooperation of actors in the air transport sector is less frequently addressed. Some recent studies include Bilotkach & Hüschelrath (2015), who examine the impact of airline alliances, Graham (2014b), who analyses privatisation in the airport sector, Merkert & Morrell (2012), who review airline mergers and acquisitions, Forsyth et al. (2011), who focus on the trend towards global multi-airport companies

and Fu et al. (2011), who investigate the relationship between airports and airlines. Recent cooperative initiatives, paired with the lack of a systematic understanding of how airports cooperate, show the need to deepen the knowledge in this domain.

The objective of this paper is therefore to analyse the cooperation of European airports and, more specifically, their financial intertwinement. When referring to airports in this paper, the airport authorities or operators are briefly described. A recent report of ACI Europe (2016) on the ownership of Europe's airports reveals the shareholders of airports in different European countries. In this paper, this analysis is inverted by creating airport-by-airport matrices based on their engagement with different shareholders, instead of looking solely at single airports and their financial partners. Subsequently, the structural and dynamic patterns of airports' financial intertwinement are examined. In which European airports do investment companies invest? Are these shareholder-airport relationships stable over time? These questions are answered in this paper by investigating the European airport network from the viewpoint of financial shareholders.

Data on financial participations in airports are collected to explore the structure and evolution of airport cooperation focusing on financial interrelations. Social network analysis is a widely accepted tool for analysing the structure and functioning of organisational networks (Wasserman & Faust, 1994). Consequently, it is employed here to analyse structural patterns of financial relations in the airport sector in depth. In addition, multiple regression quadratic assignment procedure is used to assess the impact of financial path dependency and spatial patterns on the occurrence of investment ties.

This study contributes to the literature on airport cooperation in three distinct ways. Firstly, while interaction between airports has mainly been addressed from a competition theory point of view, the aspect of cooperation is introduced in this paper. Secondly, it is novel to approach airport cooperation from a social network analysis perspective. Thirdly, the use of panel data provides new evidence about the evolution of airport networks.

The remainder of this paper is organised as follows. Section 2 gives insight into the ownership and governance of airports. Section 3 explains the methodology used in this paper. Section 4 deals with the empirical results. Section 5 offers some conclusions and recommendations.

2. FINANCIAL INTERTWINEMENT AS FORM OF AIRPORT COOPERATION: OWNERSHIP AND GOVERNANCE

The term 'cooperation' is generally defined as "*working together with others, whereby the objectives of two or more organizations are mutually beneficial*" (De Wit & Meyer, 2005). In parallel, cooperation between airports can bring along potential benefits, such as shared knowledge and financial resources. Different types and degrees of cooperation exist, such as sister agreements, airport systems, non-legal recognized cooperation, financial intertwinement between airports etc.

A sister agreement, like the agreement between Munich and the airports of Beijing, Denver, Nagoya, Bangkok and Singapore (Graham, 2013) is rather a loose cooperation aiming to share best practices. In contrast, airport systems are a more serious form of cooperation. This is because they are often owned by the same shareholder/public entity. However, cooperation without financial intertwinement often only has a limited influence on airports.

Section 2.1 gives an overview of airport ownership and governance. Next, airport operators and shareholder types are discussed in Section 2.2. In Section 2.3, the relationship between airport ownership and efficiency is addressed.

2.1 Airport ownership and governance

Until the 1990s, ownership of airports was in most cases in the hands of large incumbent airport authorities, such as BAA, Aéroports de Paris (AdP) and Fraport. However, a move towards privatisation of airports could be seen since the deregulation of the airline market in Europe. As a result, three main categories of airports can be distinguished: fully public, fully private or mixed owned (ACI Europe, 2016; Graham, 2014b).

Worldwide, about 14% of airports have private sector participation, while 41% of passenger traffic passes through airports with private sector participation (ACI, 2017). This means that the private sector mainly invests in larger airports as they have more chances of a high return. However, there are differences in the participation of the private sector between continents: 75% of passenger traffic in Europe is handled at airports with private sector participation and 60% in Latin America-Caribbean, while this is only 1% in North America. With regard to the number of airports with private sector participation, Europe and Latin America-Caribbean also take the lead with 31.10% and 25.80% respectively, while in North America less than 1% of the airports have the private sector involved (see Figure 1).

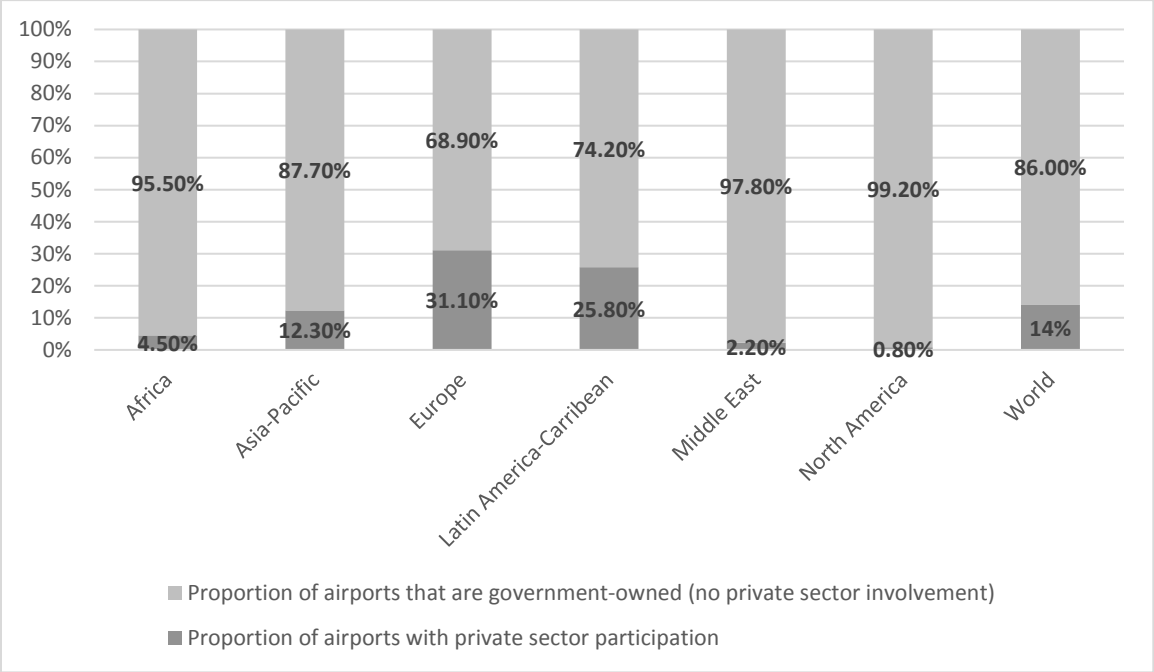

Figure 1 - Airports by Ownership Structure and Region
Source: ACI (2017, p. 5)

Of the airports in Europe, about 59% are fully under public ownership in 2016, which signifies a significant drop from 78% in 2010. While public ownership has dropped since 2010, especially mixed ownership gained share with an increase from 13% in 2010 to 25.2% in 2016 (see Figure 2).

Figure 2 - Airport Ownership Structure in Europe in 2010 (left) and 2016 (right)
Source: ACI Europe (2016)

In Europe too, it can be seen that private partners especially invest in larger airports: while about 41% of the airports in 2016 were under mixed or private ownership, almost three quarter of all passengers (73.5%) travelled through those airports (ACI Europe, 2016).

In the case of (partially) private ownership, shareholders can possess stakes in multiple airports, resulting in the financial intertwinement of the involved airports. Graham (2014b) identifies five types of privatisation, being share flotation on the stock market, trade sale (sale of the airport or parts of it to a partner/consortium), concession (right to operate airport for a specific period), project finance and management contracts (ownership remains with the government, only management is transferred to private partner). ACI uses a slightly different categorisation: according to the organisation, in 2016, 41% of the airports with private sector participation were under concession contracts, 24% were freeholds[1], 23% were listed on the stock exchange and 8% were under management contracts (ACI, 2017).

In sum, airport ownership and governance can be divided into different groups (see Table 1) which also reflects the possibility of financial intertwinement between actors.

Ownership	**Governance**
Full public ownership	Under direct government control
	Part of public administration (non-corporatized)
	Corporatized
Mixed ownership	Concession contracts
	Stock exchange
	Management contracts
	Trade sale
Fully private ownership	Trade sale (freeholds)
	Stock exchange

Table 1 - Ownership and governance types

2.2. Airport operators and shareholder types

The move towards privatisation of airport operations has attracted different (private) actors' interest to purchase or manage airports. In the early stages of airport privatisation, especially established airport

[1] Freeholds are an ownership form in which the private sector has full ownership and management of the airport for an unlimited time (ACI, 2017). Freeholds can be seen as specific form of trade sales.

operators such as BAA, AdP, Fraport, Shiphol and Aer Rianta took initiative to expand their market with (financial) involvement in other airports. Since the 1990s, also companies such as property, utility, infrastructure and construction companies as well as investment banks, pension and private equity funds, started to gradually invest in airports (Graham, 2014b).

Examples of property, utility, infrastructure and construction companies are the Spanish company Abertis, Ferrovial (also Spanish), the French company Vinci, Global Infrastructure Partners (GIP) and the German Hochtief. Some of those companies even developed their focus from an investment point of view to the operation of airports (Graham, 2014b). Hochtief for example founded its subsidiary Hochtief AirPort in 1997 to more specifically take their airport involvement into hands. In 2013, Hochtief AirPort was taken over by a subsidiary of the Canadian Pension Fund PSP Investment AviAlliance (AviAlliance, 2013).

Investment banks, pension and private equity funds started their involvement late in the privatisation process (Graham, 2014b). However, in the last decade, they became more and more involved with airport investment and management. Canadian pension fund Ontario Teachers' Pension Plan (OTPP) is now for example a major player in the European airport sector with stakes in airports such as Brussels Airport, London City Airport, Birmingham Airport and Copenhagen Airport. On the other hand, private equity investment fund Macquarie Airports recently decreased its international involvement to focus on the operation of Sydney airport.

Finally yet importantly, airlines can also be involved as operator and/or investor of airports. British Airways for example partially financed the Eurohub of Birmingham Airport and also Lufthansa was financially involved with the development of the second terminal at Munich Airport.

Reasons for airlines to invest in (parts of) airports usually include the aim of having more control over the facilities as well as to develop a strong brand presence (Graham, 2014b). However, reasons of actors to invest in airports can vary. While construction companies often look for possible involvement of large construction projects at airports, pension funds aim to diversify their portfolio. Moreover, airports are seen as stable long-term investments for many pension funds. Airport groups on the other hand especially look for international involvement, market expansion and cost sharing. Often, more than one reason leads a partner to become involved with a specific airport. Cruz and Sarmento (2017) for example show that the construction and utility company Vinci offered the winning bid for ANA as a gateway to the airport sector, but also with expectations to be able to optimise the management of existing airports, expectations of new construction projects and revenue increase based on traffic growth and indirect gains from other projects.

Another potential benefit of cooperation through financial intertwinement is the creation of a network of airports that potentially also facilitates cooperation in other areas (ACI Europe, 2016; Momberger Airport Information, 2012).

2.3. Relationship between airport ownership and efficiency

Both airport ownership and governance influence the management and operations of airports. However, scientific literature does not agree whether privately run airports are more efficient than public run airports or the other way around. Studies by Oum, Adler and Yu (2006), as well as Oum, Yan and Yu (2008) show for example that for the most part, privately owned airports are run more efficiently than publicly owned airports. Vasigh and Haririan (2003) on the other hand expose that the private airports in the UK were actually less efficient than the public airports of the US. On an additional note, studies of authors such as Georges Assaf and Gillen (2012), Gillen (2011) and Oum, Yu and Fu (2003) do not show a clear link between airport ownership and efficiency. In addition, other factors besides ownership,

such as commercialisation of the airport or other policies such as competition, can play a significant role in the efficiency of airlines (Gillen, 2011).

While airport ownership and governance is already thoroughly analysed, a systematic understanding of how airports are financially intertwined is still lacking. However, this is important to understand the movements of changes in ownership of airports as well as their underlying reasons. Therefore, the empirical part of this study concentrates on financial ties between airports. Knowledge in this domain is useful for strategic decisions of shareholders, as well as different airport stakeholders.

3. METHODOLOGY

In order to analyse the formation and dynamics of financial linkages between airports, data on European airports and their private shareholders are collected. Subsequently, social network analysis tools are applied to show how European airports are financially intertwined and to assess the degree of integration and stability of the network. In the following subsections, data collection methods and the quantitative approach are explained in detail.

3.1 Data

The starting point of the data collection is to identify active airport shareholders and to trace their investments in European airports. Airports are considered to be European when they are located within geographical Europe. A sample of 32 shareholders is selected on the basis of the report of Momberger Airport Information (2012). This report provides an overview of investment companies and the airports they hold shares in in March 2012. Based on the list of airports mentioned in this report, a unique hand-selected dataset on shareholder-airport relationships is constructed for July 2012 and December 2015 by retrieving financial information from official websites for the selected airports and their shareholders. The dataset is then crosschecked, and complemented with other publicly available sources of financial information, i.a. annual reports.

The initial sample dates from July 2012. In this sample, 32 different shareholders and 160 European airports are included, resulting in 175 single investments. In order to investigate how shareholder-airport relationships evolve over time, investment data are also collected for December 2015. To detect temporal changes in the shareholder-airport network, the second sample has been restricted to airports present in the 2012 sample. This allows distilling changes in investment cooperation between the given set of airports over time. After controlling for this additional requirement, the 2015 sample counts 35 different shareholders maintaining a total of 167 single investment linkages in 160 different European airports.

Three restrictions apply to the data collection. Firstly, only European airports for which the share of the shareholder in the airport is known are selected. Due to this limitation, several airports are excluded from the analysis. Examples of omitted airports include a few Polish airports in hands of PLL (Porty Lotnicze Polish Airport State Enterprise), some British airports owned by RCA (Regional and City Airports) and a large number of French airports controlled by SNC – Lavalin investment. In all of these cases, a clear identification of investment stakes is not possible. Secondly, only European airports listed by an IATA-code, or an ICAO-code, if no IATA-code is available, are included in the database. In line with this approach, five airports are added to the database based on their ICAO-code, being Madrid Cuatro Vientos Airport (LECU), Son Bonet Airport (LESB), Vöslau Airport (LOAV), Venice-Lido Airport (LIFV) and Ancenis Airport (LFFI). One airport is excluded from the database, being the French airport of Notre-Dame-les-Landes, owned by VINCI Airports. This airport has not yet been operational at the time of data collection and consequently does neither possess any IATA nor ICAO code. Thirdly, only shareholders linked to airports present in the 2012 dataset are included in the dataset of 2015. As a

result, it is possible that not all recent shareholders having shares in multiple airports in 2015 are included in the dataset.

3.2 Method

To explore the structure and functioning of organisational networks, social network analysis tools (Wasserman & Faust, 1994) are widely used. In Bringmann, Vanoutrive and Verhetsel (2016) the method is utilised to investigate structural patterns of venture capital transactions. Broekel and Boschma (2012) apply the method to knowledge networks in the aviation industry and Uzzi (1997) refers to it when analysing interfirm networks. While network models have become increasingly common in the field of organisational studies, their application to (air) transport networks remains rare. Firstly, the airport network is therefore depicted visually and examined in an exploratory way. Structural network characteristics are described and a number of statistics, quantifying structural properties of graphs, such as density measures and Jaccard indices, are provided. Secondly, multiple regression quadratic assignment procedure (MRQAP) (Krackhardt, 1988) is adopted to estimate the likelihood of tie formation between airports via their investment linkages. Given the network structure of the data and the resulting non-independence of observations, more conventional regression techniques like ordinary least square regression (OLS) or logistic regression models cannot be used for network data as they do not take into account the correlation of error terms. MRQAP, in contrast, resolves the autocorrelation in the standard error by running a number of permutations (Double-Decker semi-partialling) of the sample. In a first step, the model is estimated using standard multiple regression. Consequently, it is calculated how many of the permutations yield a coefficient of the size as estimated in the first step.

The regression underlying is the following model:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \varepsilon \qquad \text{Eq. (1)}$$

where Y refers to the network matrix of airport interrelations via their shareholders in 2015 and α is a constant term. Airports are considered to have a connection (tie), if they are financed by the same shareholder. Independent variables are indicated by X_1 and X_2. Both independent variables refer to the dyad level and are expressed in matrix form. In the following models, X_1 represents the one-mode airport network in 2012, whereby X_2 captures the spatial dimension of investment ties, i.e. whether airports are located in the same country or in adjacent countries.

Using MRQAP, it is tested if prior financial relations have an impact on later investments. For this, the airport network of t-3 is regressed on the airport network in year t. Furthermore, it is assessed if spatial proximity between airports promotes their financial intertwinement. In other words, do airport shareholders concentrate their investment activities in particular geographical areas, leading to more frequent cooperation between co-located airports or are investment linkages spatially diverse? These questions are addressed by regressing both a matrix capturing the existence of an investment tie in t-3 and variables related to the location of airports on the one-mode airport matrix in t.

4. EMPIRICAL RESULTS

This section offers the results of the analysis of the financial intertwinement of 160 European airports. Exploratory insights into the structural characteristics of the European shareholder-airport network and the consequently derived airport-airport network are provided in subsection 4.1. Subsequently, the dynamics of investment linkages (subsection 4.2) are discussed.

4.1 Network structure

An exploratory analysis of the different network graphs of 2012 and 2015 respectively is carried out to obtain insights into overall network structures and to identify sub-group patterns. Financial intertwinement is investigated at three levels: shareholder-airport links, airport interconnectedness and shareholder interconnectedness.

4.1.1 Shareholder-airport connection

Figure 3 displays the structure of the shareholder-airport network for 2012 and for 2015. In Figure 3, both the airports and their respective shareholders are represented by dots[2]. Airports are denoted by their IATA or ICAO-code, while investment companies are identified by means of Arabic numerals. A list of shareholders used in the figures of this paper is provided in Appendix A. The decoding of the IATA-codes can be found in Appendix B. Financial linkages (edges) between nodes are indicated by a grey line.

Most strikingly, Figure 3 shows the presence of one large cluster of airports around a single shareholder. This cluster refers to the airports controlled by AENA (Aeropuertos Españoles y Navegación Aérea). In 2012, AENA had stakes in 53 airports, among which 49 fully controlled Spanish airports and a 10% share in the airports of Belfast (BFS), Cardiff (CWL), London Luton (LTN) and Stockholm (NYO). By 2015, the number of airports AENA participates in dropped by 5 (BFS, CWL, LTN, NYO and TOJ) and AENA's focus remains exclusively on Spanish airports. Nonetheless, also the share in the airport of Madrid-Torrejon (TOJ) was sold. The latter, together with the airports of Ciudad Real (CQM), La Seu d'Urgell (LEU) and Lleida-Alguaire (ILD) are the only Spanish airports not under the control of AENA. The airports of Madrid-Torrejon, La Seu d'Urgell and Lleida-Alguaire are fully public airports, while the abandoned airport of Ciudad Real was sold to CR International Airport SL.

Besides the prevalent cluster of AENA, also several smaller airport clusters existed in 2012 as well as in 2015. Around the investment companies ANA (Aeroportos de Portugal), HIAL (Highlands & Islands Airports), PPL (Polish Airports State Enterprise) and VINCI Airports, smaller agglomerations of airports are visible. HIAL exploits around ten airports in the Highlands and on the Scottish islands. In Poland, PPL holds at least a minority interest in the majority of airports. Multiple shareholders also have shares in several airports within the same urban area. Examples are AdP (Paris), ADR (Rome), BAA (in 2012), SEA (Milan) and VINCI Airports (Nantes). Other shareholders, in turn, spread their participations in airports across different countries. An example is Fraport, which owns shares in two German airports (FRA, LEB) as well as in two Bulgarian airports (VAR, BOJ). In 2015, Fraport also obtained a 65% share in 14 Greek airports. These Greek airports are not shown in Figure 3, as they were not present in the database of 2012; and consequently, fall out of the scope of this analysis. Some of the shareholder clusters are also connected to other shareholder clusters. Examples are the linkage between CAD and OTPP through Copenhagen Airport (CPH) in both 2012 and 2015, and Aeroporti Holding and Sintonia through Turin Airport (TRN) and Florence Airport (FLR) in 2012.

When comparing the graphs of 2012 and 2015 (see Figure 3), three distinct development paths become apparent as the network evolves: (1) Long-term shareholders: some investment companies continue to be financially involved in the same set of airports over time, (2) Diversifying shareholders: these shareholders are active during the entire period of observation, however with changes in their airport portfolio, and (3) Temporal shareholders: investment companies solely present in the European airport

[2] The position of the airports in a social network analysis is random as a result of the software use.

investment market either in 2012 or in 2015. It is not excluded that companies currently present in the latter group become long-term or diversifying shareholders in the future.

Examples of shareholders maintaining their airport portfolio are AdP (Aéroports de Paris), Fraport, HIAL, PPL, Schiphol Group, SEA (Società Esercizi Aeroportuali), Stobart, TAV (Tepe Akfen Airport Holding) and VINCI Airports.

Investment companies who varied their airport portfolio between 2012 and 2015 are ACA (Aéroports de la Côte d'Azur), Keolis and RCA (Regional and City Airports). In 2015, investment companies PSP Investments and DAA are for example connected through the airport of Düsseldorf. This was not yet the case in 2012, since PSP only obtained the stake in Düsseldorf Airport in May 2013.

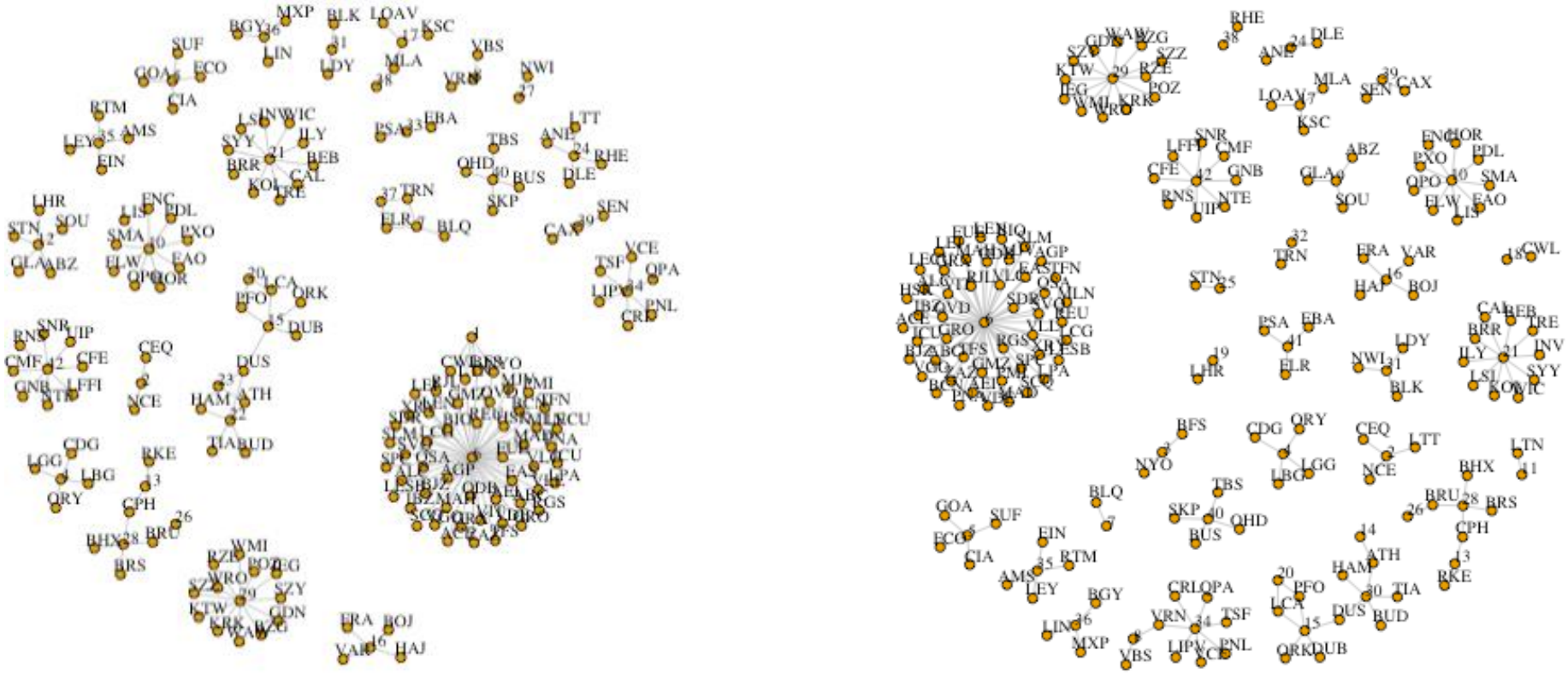

Figure 3 - Shareholder Airport Affiliation Network 2012 (left) and 2015 (right)
Source: Own composition

Ultimately, shareholders active in 2012 and no longer present in the sample of 2015 include Abertis Airports, BAA, HTA (Hochtief AirPort), IAEL (Infratil Airports Europe), Omniport, SAT (Società Aeroporto Toscano) and Sintonia. Reasons for their disappearance are either that they have stopped investing in airports (e.g. Abertis), they have changed name (e.g. BAA became Heathrow Airport Holding, Hochtief AirPort became AviAlliance) or they have merged with another investment company (e.g. SAT). IAEL (Infratil Airports Europe) owned two airports in 2012: the airport of Glasgow Prestwick (PIK) and the airport of Kent (MSE). At the end of 2013, the airport of Glasgow Prestwick (PIK) was sold to the Scottish Government, whereas in May 2014, the airport of Kent (MSE) stopped operations. After the closure of the latter, IAEL did not possess any shares in European airports anymore. HTA (Hochtief AirPort) is also no longer present in the network graph of 2015. This is however not because of a discontinuation of operations, but due to the renaming of the company in AviAlliance at the end of 2013. AviAlliance, in turn, is part of PSP (Public Sector Pension Investment Board Canada), which is present in the 2015 network graph. Consequently, in Figure 3, shareholder 29 in 2012 corresponds to shareholder 40 in the network of 2015.

4.1.2 Airport interconnectedness

Figure 4 displays a one-mode network of the relationships between airports for 2012 and for 2015. In a one-mode network, rows and columns of the relationship matrix refer to the same entity i.e. to assess airport interconnectedness, an airport-by-airport matrix is constructed.

A relationship exists if they are financed by the same shareholder. However, given the one-mode nature of the network graph, shareholders are not displayed here.

The pronounced concentration of dots in the middle of the network graphs in Figure 4 corresponds to the distinct and visible cluster of airports in Figure 3, which is the airport network of AENA, connecting primarily Spanish airports in 2012 and exclusively Spanish airports in 2015. Figure 4 clearly illustrates that large airport sub-networks are in general not mutually connected, but rather remain confined. Besides the large clusters connecting many airports, also dyad and triad network structures of airports are common. Few airports such as CWL, LHR, LTN, etc. remain isolated, being not financially associated with any other European airport. Overall, network connectivity is relatively low in the graph. Comparing the network graph of 2015 with that of 2012, the network visually appears very stable over time. The visually striking sparsity and stability of the network is also confirmed when applying quantitative methods specifying structural properties more precisely.

The network density score expresses the share of actually existing ties as a ratio of the total number of potentially possible ties. It is calculated by dividing the actual number of ties by the potential number of ties N/((n*(n-1)/2). For the airport-by-airport network, the network density score appears very low in both years. In 2012, 12.7% of possible linkages between airports were existing, whereas in 2015, the network became even slightly sparser with only 11% of possible ties actually occurring.

The Jaccard index is used to compare network graphs to their similarity. It amounts to 0.87 for the airport-airport network. In that, 87% of investment connections have remained the same from 2012 to 2015. This suggests that the network is characterised by a high degree of stability. Given that the Jaccard index only takes into account ties that have existed at one point in time, the unstable part of the network (13%) can refer either to newly emerging financial engagements or to financing relationships that ceased to exist.

The density scores that are estimated when excluding the large number of AENA owned airports from the sample is much lower compared to the full sample. For 2012, the density score equals 0.05 and in 2015 to 0.04. This implies that only about 4-5 percent of possible ties are realised in the network and therefore that few European airports are intertwined on the basis of their financiers.

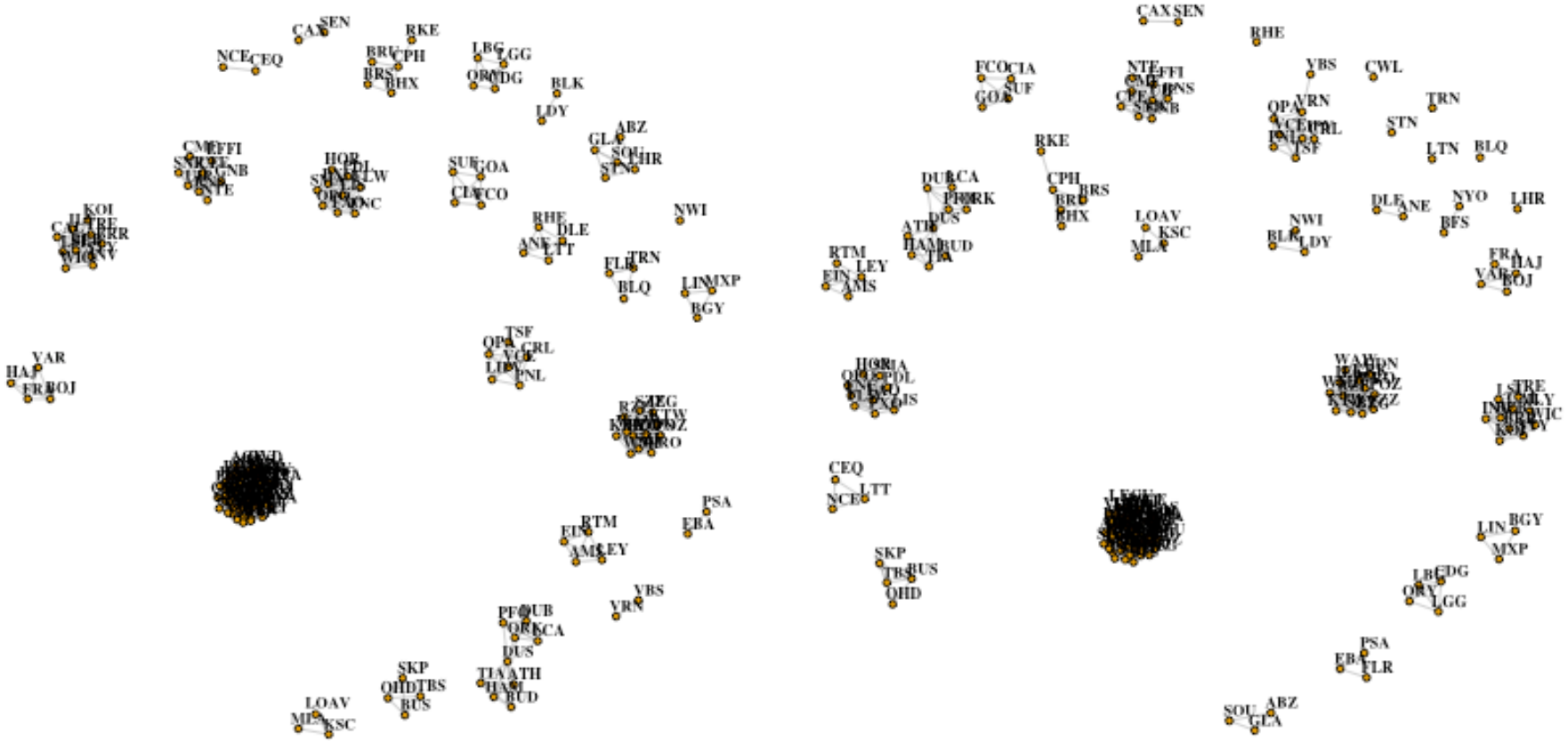

Figure 4 - One-Mode Airport Network 2012 (left) and 2015 (right)
Source: Own composition

Excluding AENA, the airport cooperation network appears even more stable throughout the years. The Jaccard index amounts to 0.91 when excluding AENA investment ties from the networks in both years. This implies that 91 percent of ownership linkages between airports have abided between 2012 and 2015.

4.1.3 Shareholder interconnectedness

In some cases, investment companies invest in each other. As a result, some airports are financially intertwined through interconnected shareholders. Secondary linkages are however not considered in the prior analyses, which focus on direct linkages. Examples of such shareholder-shareholder relationships are therefore briefly discussed in this section. Table 2 displays the relationships between shareholders for 2012 and 2015. Only shareholders related to the airports present in the database are included in this list.

Table 2 shows that almost all shareholder-shareholder connections of 2012 are still present in 2015. The only exceptions are the financial participation of Schiphol Group in FWAG and of Sintonia in ADR.

From the list of investment company shareholder stakes in 2015, it becomes apparent that AdP is affiliated with other investment companies. The company retains 38% of share capital of TAV and an 8% stake in Schiphol Group. Schiphol Group, in turn, as well as VINCI Airports, holds an 8% share in AdP. Hence, AdP and Schiphol Group both have a mutual share of 8% in each other. Since AdP controls the airport of Paris Charles-de-Gaulle and Schiphol Group Amsterdam-Schiphol, these two airports are financially intertwined. Besides their financial connectedness, the airports are also related through the airlines for which they are the respective hubs and their joint participation in the SkyTeam Alliance. Paris Charles-de-Gaulle is the hub for Air France, while Amsterdam-Schiphol is the hub for KLM, both members of the SkyTeam Alliance.

2012			2015		
Shareholder	Has shares in	Share	Shareholder	Has shares in	Share
AdP	Schiphol Group	8%	AdP	TAV	38%
				Schiphol Group	8%
			Ardian	F2i	29.4%
			CAI	Toscana Aeroporti	51.1%
			DAA	Hermes Airports	20%
				Aeroport de Tahiti	19%
			F2i	SAGAT	54.5%
				Sea	44.3%
			Ferrovial	HAH	100%
				AGS	50%
			IFM Investors	MAG	35.5%
				FWAG	29.9%
MEIF	CAD	N/A	MEIF	CAD	N/A
				AGS	50%
			SAGAT	Aeroporti Holding	55.5%
Schiphol Group	AdP	8%	Schiphol Group	AdP	8%
	FWAG	1%			
Sintonia	ADR	33.4%	VINCI Airports	AdP	8%
				ANA	100%

Table 2 – Shareholder-shareholder relationships in 2012 and 2015
Source: Own composition based on official websites and reports

Another observation from Table 2 is the 29.4% share of Ardian in F2i, and the respective 54.4% and 44.3% share of F2i in SAGAT and Sea. SAGAT further has a 55.5% share in Aeroporti Holding. Consequently, the airports financially tied to Ardian (London Luton - LTN), F2i (Naples – NAP), SAGAT (Turin – TRN) and, respectively, Aeroporti Holding (Bologna – BLQ) and Sea (Milan Linate

– LIN, Milan Malpensa – MXP and Bergamo BGY) are also indirectly financially intertwined via the stakes of their shareholders in other financial intermediaries.

4.2 Network evolution

Section 4.1 presented the macro structural features of the airport network. To measure the interdependence of networks at the tie level, MRQAP techniques are applied in this section. It is possible in this way to determine the (dis-)similarities between different networks at the micro-level.

Model 1 (Table 3) estimates the impact of pre-existing financial relations on future financial cooperation. For this, a matrix of airport-airport linkages in 2012 is regressed on the airport network of 2015. The goodness-of-fit measures show a reasonable model fit, in that, it is to assume that the present ties did not randomly occur, but rather that they are statistically significant. Existing and absent ties are equally well predicted by the model. The results point out a high correlation between the two networks and confirm prior exploratory findings stressing the relative stability of the airport network. The existence of a co-investment related tie in 2012 is found to have a statistically significant positive effect on the persistence of a financial linkage in 2015. If a financing linkage has been denoted in 2012, then the odds that there is any financial intertwinement in 2015 gets multiplied by Exp(b) = 6071. Or, expressed differently, the log odds of being financially intertwined increase by the multiple of 8.711 if airports were financed by the same shareholder in 2012. The negative estimate for the intercept however suggests that the occurrence of a financial connection between airports is rare and that the airport network based on financing linkages is relatively sparse. This finding is in line with the foregoing qualitative analysis of the airport network in section 4.1.2 where the sparsity of the network was derived visually.

Variables	*Estimate*	*Exp(b)*	*Pr(<=b)*	*Pr(>=b)*	*Pr(>=|b|)*
(intercept)	-3.959	0.019	0.42	0.58	0.42
Airport Network 2012	8.711	6071.956	1	0	0
Chi-Squared test of fit improvement	30778.08 on 2 degrees of freedom, p-value 0				
AIC	4493.250				
BIC	4509.538				
Pseudo-R^2 Measures:					
(Dn-Dr)/(Dn-Dr+dfn)	0.547				
(Dn-Dr)/Dn	0.873				
Fraction Predicted 1s Correct	0.991				
Fraction Predicted 0s Correct	0.981				

Notes: Number of permutations = 100

Table 3 – Model 1: Effects of prior financial ties

In addition to the path dependency of financial ties, it seems likely that spatial factors impact the formation of airport cooperation. Shareholders often prefer investments in geographical proximity, i.e. the same jurisdiction, to limit risks related to differences in the business environment. In the case of airports, the historical background of a regulated air transport market as well as the fact that most airports are still (partially) government-owned also plays a role. Therefore, it is hypothesised that more ties exist between airports located in the same country or, respectively, in a neighbouring country than between airports that are spatially further apart. To test the level of geographic segregation in the airport network, a co-national matrix and a matrix of country adjacency were constructed and included in Model 2 (see Table 4) and Model 3 (see Table 5). If airports are located in the same country, the odds of being linked

via the same shareholders is about 382.3 times higher than if airports are located in different countries (see Model 2). However, having a common shareholder in 2012 has a much larger effect on the existence of a financial tie in 2015 than the geographical location of airports. Being interrelated in 2012 increases the odds for a financial association in 2015 by a factor of 3358.57.

Variables	*Estimate*	*Exp(b)*	*Pr(<=b)*	*Pr(>=b)*	*Pr(>=|b|)*
(intercept)	-15.597	0.000	0	1	0
Airport Network 2012	8.119	3358.573	1	0	0
Country	5.946	382.298	1	0	0
Chi-Squared test of fit improvement	34225.34 on 3 degrees of freedom, p-value 0				
AIC	1047.988				
BIC	1072.420				
Pseudo-R^2 Measures:					
(Dn-Dr)/(Dn-Dr+dfn)	0.574				
(Dn-Dr)/Dn	0.970				
Fraction Predicted 1s Correct	0.988				
Fraction Predicted 0s Correct	0.995				

Notes: Number of permutations = 100

Table 4 – Model 2: Effects of prior financial ties and co-nationality

In a second step, the geographical focus was extended and the adjacency of airports' countries of origin is taken into account. In other words, does a shareholder investing in, for example, Brussels Airports rather holds a stake in geographically more proximate airports such as Schiphol Airport, Charles de Gaulle Airport or Frankfurt Airport than in spatially distant entities like Athens International Airport or Dublin Airport? Model 3 shows that being financially intertwined in 2015 is positively related to a prior financial tie, but also to the relative geographical location of an airport. Airports situated in neighbouring countries have a higher likelihood of being financially connected than airports located in countries that are not sharing a common border. The positive coefficients of both spatial variables suggest that investment activities are geographically restricted. These results are nevertheless solely indicative, further research exploring the spatial patterns of airport cooperation in more detail is suggested.

Variables	*Estimate*	*Exp(b)*	*Pr(<=b)*	*Pr(>=b)*	*Pr(>=|b|)*
(intercept)	-17.093	0.000	0	1	0
Airport Network 2012	9.563	14233.100	1	0	0
Neighbouring Country	5.901	365.402	1	0	0
Chi-Squared test of fit improvement	34151.42 on 3 degrees of freedom, p-value 0				
AIC	1121.905				
BIC	1146.337				
Pseudo-R^2 Measures:					
(Dn-Dr)/(Dn-Dr+dfn)	0.573				
(Dn-Dr)/Dn	0.968				
Fraction Predicted 1s Correct	0.987				
Fraction Predicted 0s Correct	0.996				

Notes: Number of permutations = 100

Table 5 – Model 3: Effects of prior financial ties and country adjacency

A further robustness check that is introduced concerns variations in the duration of financing linkages based on the type of shareholder. In model 4, it is estimated whether ownership ties of institutional investors (e.g. pension funds and private equity firms), are less persistent than investment relations of entities that are more involved in the management of airports. The results in Table 6 suggest that the difference in investment patterns between more financially oriented investment funds and shareholders that perform a dual role of financing and managing airports are not statistically significant distinctive.

Variables	*Estimate*	*Exp(b)*	*Pr(<=b)*	*Pr(>=b)*	*Pr(>=|b|)*
(intercept)	-6.982	0.001	0.00	1.00	0.00
Airport Network 2012	8.639	5649.964	1.00	0.00	0.00
Inst. Investor	0.217	1.242	0.71	0.29	0.46
Chi-Squared test of fit improvement	32388.51 on 3 degrees of freedom, p-value 0				
AIC	2884.818				
BIC	2909.25				
Pseudo-R^2 Measures:					
(Dn-Dr)/(Dn-Dr+dfn)	0.560				
(Dn-Dr)/Dn	0.918				
Fraction Predicted 1s Correct	0.868				
Fraction Predicted 0s Correct	0.999				

Table 6 - Model 4: Effects of institutional investor

In a similar way, it has been cross-checked if public entities show differences in the continuity of their ownership. Here, it is assumed that shareholder ties tend to be more persistent compared to professional investors. Consequently, the models have been tested singling out the effect of AENA, the largest public corporate entity in our sample, on the duration of financial relationships (see Model 5 in Table 7). No statistically significant effect has been found between public shareholders and other (professional) investors (model not reported, available on request). The statistically insignificant effects of different shareholder types on the duration of investment linkages has nevertheless to be interpreted with caution. Given the relatively short time span that our sample covers, it is not possible to identify medium and long-term differences in shareholding patterns. Though the results are indicative that in the short run, the investment linkages across all types of shareholders are very stable.

Variables	*Estimate*	*Exp(b)*	*Pr(<=b)*	*Pr(>=b)*	*Pr(>=|b|)*
(intercept)	-6.982	9.283	0.00	1.00	0.00
Airport Network 2012	8.640	5.650	1.00	0.00	0.00
AENA	0.217	1.242	0.70	0.30	0.55
Chi-Squared test of fit improvement	32388.51 on 3 degrees of freedom, p-value 0				
AIC	2884.818				
BIC	2909.25				
Pseudo-R^2 Measures:					
(Dn-Dr)/(Dn-Dr+dfn)	0.560				
(Dn-Dr)/Dn	0.918				
Fraction Predicted 1s Correct	0.868				
Fraction Predicted 0s Correct	0.999				

Table 7 - Model 5: Effects of AENA

5. Conclusion

Recent airport cooperation initiatives and the lack of extensive research on cooperation of airports in general show that there is a research gap on this topic. In this study, the cooperation of European airports and, more particular, their financial intertwinement, is analysed. A social network analysis is adopted to examine the structural patterns of financial relationships in the airport sector, while a multiple regression quadratic assignment procedure (MRQAP) is applied to measure the impact of financial path-dependency and spatial patterns on the occurrence of investment ties.

This paper indicates that while one large and many small airport clusters were identified, the overall connectivity between airport networks stays relatively low. Furthermore, investment relations in the airport industry are characterised by a high degree of stability over time and the formation of interorganisational linkages is facilitated by spatial proximity. The results of this study contribute to the existing knowledge on the organisation of airports in different ways. While the existing literature mainly focuses on airport competition, this study broadens our understanding on airport cooperation. In addition, a key strength and novelty of the study is that airport cooperation is approached from a social network analysis perspective. Combined with the use of a unique, hand-selected panel dataset, this approach enhances the understanding of the evolution of airport networks.

An issue that was not addressed in this study is the presence and evolution of secondary linkages in the airport network. Further research in this field is highly encouraged to extend our knowledge on the financial intertwinement of airports and investment companies. The analysis would benefit from comparing data over a longer time span than three years, since trading airport shares is often a long-lasting process. To move the debate on airport cooperation forward, also a better understanding of the spatial patterns of airport cooperation is indispensable. Although this study shows that the links between airports are often determined by spatial proximity, the role of global airport shareholders such as Macquarie and Ontario Teachers' Pension Plan should be more closely analysed. Based on the results of this study, a first typology of airport shareholders could be made. To deepen our understanding of airport shareholders, this typology should be extended and refined. Finally, another avenue for future research is the analysis of specific costs and benefits of financial intertwinement between airports. Questions in this respect include how their financial intertwinement with other airports affects the airports' performance on other aspects, such as services provided to passengers, traffic volume, etc.

Acknowledgement
This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

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Appendix A – Shareholders (legend of Figure 3**)**

Number	Shareholder
1	Abertis Airports
2	ACA (Aéroports de la Côte d'Azur)
3	ADC & HAS Airports Worldwide
4	ADP (Aéroports de Paris)
5	ADR (Aeroporti di Roma SpA)
6	AENA (Aeropuertos Españoles y Navegación Aérea)
7	Aeroporti Holding
8	Aeroporto Valerio Catullo di Verona Villafranca SpA (= Garda Aeroporti)
9	AGS Airports Limited
10	ANA (Aeroportos de Portugal)
11	Ardian
12	BAA
13	Copenhagen Airports International A/S
14	Copelouzos
15	DAA
16	Fraport AG
17	FWAG (Flughafen Wien AG)
18	Government of Wales
19	HAH (Heathrow Airport Holdings)
20	Hermes Airports
21	HIAL (Highlands & Islands Airports Ltd)
22	HTA (Hochtief AirPort GmbH)
23	HTAC (Hochtief AirPort Capital GmbH & Co. KgaA)
24	Keolis
25	MAG (Manchester Airports Group)
26	MEIF (Macquarie European Infrastructure Fund)
27	Omniport plc
28	OTPP (Ontario Teachers' Pension Plan Board)
29	PPL (Polish Airports State Enterprise)
30	PSP Investments (Public Sector Pension Investment Board Canada) - AviAlliance (Capital)
31	RCA (Regional and City Airports) - Rigby Group
32	SAGAT SpA
33	SAT (Società Aeroporto Toscano SpA)
34	SAVE SpA
35	Schiphol Group
36	SEA SpA
37	Sintonia SA
38	SNC-Lavalin Investment
39	Stobart Group Plc
40	TAV Airports Holding Co
41	Toscana Aeroporti SpA
42	VINCI Airports

Appendix B – IATA (*ICAO) Airport codes (legend of Figure 3 and Figure 4)

ABC	Albacete-Los Llanos	FRA	Frankfurt am Main
ABZ	Aberdeen Dyce	FUE	Fuerteventura Island
ACE	Lanzarote	GDN	Gdańsk Lech Wałęsa
AEI	Algeciras	GLA	Glasgow
AGP	Málaga-Costa del Sol	GMZ	La Gomera
ALC	Alicante	GNB	Grenoble-Isère
AMS	Amsterdam-Schiphol	GOA	Genoa Cristoforo Colombo
ANE	Angers-Loire	GRO	Girona
ATH	Athens Eleftherios Venizelos	GRX	Granada Federico Garcia Lorca
BCN	Barcelona	HAJ	Hannover-Langenhagen
BEB	Benbecula	HAM	Hamburg
BFS	Belfast	HOR	Horta
BGY	Bergamo/Orio Al Serio	HSK	Huesca-Pirineos
BHX	Birmingham	IBZ	Ibiza
BIO	Bilbao	IEG	Zielona Góra
BJZ	Badajoz	ILY	Islay
BLK	Blackpool	INV	Inverness
BLQ	Bologna Guglielmo Marconi	JCU	Ceuta
BOJ	Burgas	KOI	Kirkwall
BRR	Barra	KRK	Kraków-Balice Johannes Paulus II
BRS	Bristol	KSC	Košice
BRU	Brussels	KTW	Katowice
BUD	Budapest Liszt Ferenc Int'l	LBG	Paris-Le Bourget
BUS	Batumi	LCA	Larnaca
BZG	Bydgoszcz Ignacy Jan Paderewski	LCG	A Coruña
CAL	Campbeltown	LDY	City of Derry
CAX	Carlisle	LECU*	Madrid-Cuatro Vientos
CDG	Paris-Charles de Gaulle	LEI	Almeria
CEQ	Cannes Mandelieu	LEN	Leon
CFE	Clermont-Ferrand Auvergne	LESB*	Mallorca-Son Bonet
CIA	Rome Ciampino	LEY	Lelystad
CMF	Chambéry-Savoie	LFFI*	Ancenis
CPH	Copenhagen-Kastrup	LGG	Liège
CRL	Brussels South Charleroi	LHR	London-Heathrow
CWL	Cardiff	LIN	Milan-Linate
DLE	Dole-Jura	LIPV*	Venice-Lido
DUB	Dublin	LIS	Lisbon Portela
DUS	Düsseldorf	LOAV*	Vöslau
EAS	San Sebastián	LPA	Gran Canaria
EBA	Marina di Campo	LSI	Sumburgh
EIN	Eindhoven	LTN	London-Luton
FAO	Faro	LTT	La Môle
FCO	Rome Leonardo da Vinci - Fiumicino	MAD	Madrid-Barajas
FLR	Florence Peretola	MAH	Menorca
FLW	Flores	MJV	Murcia-San Javier
FNC	Madeira Funchal	MLA	Malta
		MLN	Melilla

MXP	Milan-Malpensa
NCE	Nice-Côte d'Azur
NTE	Nantes Atlantique
NWI	Norwich
NYO	Stockholm-Skavsta
ODB	Córdoba
OHD	Ohrid St. Paul the Apostle
OPO	Porto
ORK	Cork
ORY	Paris-Orly
OVD	Asturias
PDL	João Paulo II
PFO	Paphos
PMI	Palma de Mallorca
PNA	Pamplona
PNL	Pantelleria
POZ	Poznań-Ławica
PSA	Pisa
PXO	Porto Santo
QPA	Padova
QSA	Sabadell
REU	Reus
RGS	Burgos
RHE	Reims-Champagne
RJL	Logroño-Agoncillo
RKE	Copenhagen-Roskilde
RNS	Rennes-Saint-Jacques
RTM	Rotterdam The Hague
RZE	Rzeszów-Jasionka
SCQ	Santiago de Compostela
SDR	Santander
SEN	London-Southend
SKP	Skopje Alexander the Great
SLM	Salamanca
SMA	Santa Maria
SNR	Saint-Nazaire-Montoir
SOU	Southampton
SPC	La Palma
STN	London-Stansted
SUF	Lamezia Terme
SVQ	Sevilla
SYY	Stornoway
SZY	Olsztyn-Mazury
SZZ	Szczecin-Goleniów
TBS	Tbilisi
TFN	Tenerife North
TFS	Tenerife South
TIA	Tirana Mother Teresa
TRE	Tiree
TRN	Turin
TSF	Venice-Treviso
UIP	Quimper-Cornouaille
VAR	Varna
VBS	Brescia-Montichiari
VCE	Venice Marco Polo
VDE	El Hierro
VGO	Vigo
VIT	Vitoria
VLC	Valencia
VLL	Valladolid
VRN	Verona-Valerio Catullo
WAW	Warsaw Chopin
WIC	Wick
WMI	Warsaw-Modlin
WRO	Wroclaw-Copernicus
XRY	Jerez
ZAZ	Zaragoza