Introducing Competition through Auctions in the Air Traffic Control Market

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***Abstract*— We focus on the potential outcomes of introducing competition *for* the market in air traffic control in Europe. We develop a two-stage, network congestion auction game in which multiple air navigation service providers bid to serve Member State airspaces. Airlines subsequently choose their optimal flight paths such that they minimize their operating costs. The individual Member States set up simultaneous auctions in which they specify minimum service levels and the rules of the auction, such as the right to increase charges as a function of service levels. The winners of the auctions are the service providers that bid and commit to the lowest per km charge. The results suggest that introducing competition for the market via outsourcing service provision may reduce charges by up to half the current levels provided there are sufficient bidders. It would also appear that auctioning the service may lead to defragmentation of the European system as companies win multiple auctions.**

Keywords- auctions; ownership form; competition for the market

I. INTRODUCTION

The COMPAIR project[1] discusses potential options for introducing a variety of forms of competition into the air traffic control system. Currently, the organizational form of air traffic control provision in Europe is based on state bodies and government corporations, with the exceptions of NATS (United Kingdom) a public-private partnership, Skyguide (Switzerland) a non-profit, joint stock company, and Maastrict Upper Airspace known as MUAC, an international, non-profit organization operated by Eurocontrol [1]. The majority have developed within continental Europe with varying degrees of commercialization, which impact access to private financial markets [2,3,4]. Thirty of the air navigation service providers (ANSPs) are currently price capped by the Performance Review Board (PRB) acting as a regulator at the European level. The PRB undertakes five year assessments as to the level of the price cap, with reference period 3 (RP3) assessments currently in progress. Air traffic control charges contribute 6 to 12% to the cost of a ticket according to [5]. In a previous WP-E funded project, ACCHANGE[2], it is argued that the economic regulators are relatively weak as compared to the labor unions such that the system is relatively inefficient from a cost perspective [6,7].

Given the current system, it has been argued that economies of scale are missed due to the fragmentation of the system because each Member State is served by a single provider with geographical monopoly status [8,9]. For this reason, the European Union created nine providers in 2004, known as Functional Airspace Blocks (FABs), by aggregating the current ANSPs across states. The potential need for defragmentation can be seen from a comparison of the European air traffic control system to its American counterpart, the Federal Aviation Agency (FAA), which serves the entire United States with 22 air route traffic control centers. In 2014, the FAA provided a comparable quality of service at a 35% lower unit cost compared to that of the European system. This gap continues to exist despite a considerable decrease since 2006 when it was estimated to be approximately 46% [10]. It should also be noted that literature from the 1990s have clearly argued that the FAA is neither efficient nor well managed [11,12].

In addition to these issues, there has been an on-going effort to increase the use of technology in air traffic control production in both the US and Europe. In 1999, around one third of flights were delayed for more than fifteen minutes in the Eurocontrol area [13]. Delays began increasing again in 2005. By 2008, the European en-route average delay was 90% higher than the agreed targets [14]. This substantial congestion led to the belief that new technologies were needed in order to further increase capacity. This in turn led to the creation of the public-private partnership known as the SESAR Joint Undertaking. SESAR JU has been investing in the development of such technologies, some of which are in the process of being implemented today. However, progress on the creation of FABs and employment of technologies has been slower than expected [15].

[1] http://compair-project.eu/

[2] https://www.tmleuven.be/en/project/acchange

In this research we intend to understand whether a change in ownership form may help to simultaneously resolve the issue of fragmentation and encourage the faster adoption of new technologies. We assume that companies will bid for more than one airspace and should be able to reduce cost inefficiencies accordingly. An additional windfall may also be to reduce or remove the need for economic regulation, were competitive markets to be developed despite the geographical monopoly required to ensure safe air traffic control provision across the European skies under current forms of technology. In this paper, we first discuss the modelling approach developed for the analysis. In Section III, we present a case study covering six countries in Western Europe, which together serve approximately 50% of the air traffic control movements in Europe on an annual basis. In Section IV, we present the transport equilibria outcomes of three scenarios tested and in Section V we draw conclusions and suggest potential future directions.

II. Two-stage network congestion game

The first stage of the auction game describes the air navigation service providers who create a bid consisting of charges and capacities to which they commit. We note that this game is a development from the ACCHANGE project [7] in which the ANSPs decision variables included only peak and off-peak charges. The ANSPs in this research have a substantially larger role and a production function that enables them to choose whether to participate in an auction and their levels of labor and technology in addition to their charges. In stage two, the airline operators choose their flight paths given the first stage auction outcome of the ANSPs. The network underlying the congestion game is composed of a set of origin, transit and destination nodes, and a set of arcs representing services offered.

We assume that in an initial underlying stage, the Member States decide whether to conduct an auction or not and set minimum levels of service. These are not decision variables of the game, rather are chosen prior to running the specific scenario. Minimum service levels are defined as a function of the forecasted total traffic in each airspace that minimize overall social costs for all actors. The minimum capacity levels may be set according to the average STATFOR demand forecasts, for example, in combination with target delay levels. If the government sets up an auction, we assume that the bidders are symmetric, risk-neutral, bid simultaneously and independently and have access to complete information. In order to ensure that the European Union is not served by a single provider which would create a monopoly, we assume that no company is permitted to participate in more than a maximum number of auctions and only in contiguous airspaces. Alternatively, the ANSPs could be limited to serving a maximum share of the European market.

In the bid process, the ANSP will set a peak and off-peak charge per flight km for a standard aircraft size and specify a total service capacity in terms of flight km either on an annual basis or for a representative day. If the provider offers a service level higher (lower) than the minimum, the charge per km could increase (decrease) for example by +/-20%. Based on the ACCHANGE project [7], we found that an additional 20% in charges permits the ANSP to cover their additional costs from purchasing SESAR technologies without reducing all the benefits from the airlines perspective. If two or more companies bid the lowest peak price, the winner will be chosen based on the off-peak price bid, followed by home bias and finally the total capacity offered. Home bias refers to the fact that each company has a headquarters which determines their home country and any country would prefer home production, thus representing national interests. If all four values are the same then the winner is chosen arbitrarily among the bidders.

We model the ANSPs as labor rent maximizers, private company profit maximizers or not-for-profit capacity maximizers. Each service provider best responds to the choices of its competitors, taking as given the equilibrium service flows that will be chosen by the airline operators in the second stage of the game, thus leading to a sub-game perfect Nash equilibrium. The equilibria outcome indicates that no player in either of the stages would find it worthwhile to deviate from their current choices, given the decisions of all other actors in the market. The airline operators create flows after taking into account the air traffic control charges in each airspace and the levels of congestion, in part caused by the capacity levels chosen by the ANSPs.

A. Business-as-Usual Scenario 1 (ANSPs as labour rent maximisers):

Scenario 1, the base-run scenario, defines a labor rent maximizer ANSP which likely represents the objective of the current state agency or government corporation, as was shown in [6]. Clearly, many potential objectives could be envisioned for a government corporation, for example revenue maximization, and we have tested these in order to check their viability. However, labor rent maximization resulted in outcomes most similar to those that we see today. The ANSP decision variables include labor and technology levels, which jointly determine capacity, as well as peak and off-peak per charges.

The objective function maximizes labor subject to the production function. The production function is estimated based on current levels of labor and technology [16] and parameters drawn from the ATM Masterplan[4]. Current levels of technology are represented by t=1 and any adoption of SESAR technologies will increase this value such that complete adoption of SESAR step 1 will set t=2. The analysis is invariant to this scale choice as long as the technology elasticity parameter is adjusted accordingly. Constraints require the ANSPs to earn limited profit levels. Additional constraints set price caps on the charges where relevant and ensure that peak prices are greater than or equal to off-peak price bids. The price caps for each reference period are assessed by the Performance Review Board and the European Commission and are based on a determined unit cost as set out in EU regulations 691/2010 and 390/2013. For the purposes of the illustration in this research, we assume a standard aircraft size of 150 seats and computed the price cap per flight km accordingly. Finally, we set lower bounds on labor levels of at least 100 air traffic controllers [17] and lower and upper bounds on technology ($1 \leq t \leq 2$).

B. For-Profit Scenario 2 (ANSPs as private companies):

We define a profit maximization objective function per service provider in this scenario. The costs include labor and investment in technology. The revenues draw from the peak and off-peak charges multiplied by equilibria airline flows plus additional revenues from achieving higher than expected service levels less penalties paid for poor service level standards below those set by the government in the auction.

Constraints limit the maximum number of bids in which a company may participate. Further constraints define capacity levels as a function of labor, levels of technology employed and size of airspace, which in turn is a function of the number of tenders in which the company participates. Additional constraints cap the charges if relevant and set lower bounds on labor levels and lower and upper bounds on technology. The winner of the auction is based on the lexicographic rules described previously (lowest peak price, lowest off-peak price, home bias and finally capacity levels offered). Finally, if an ANSP fails to win any bids, their capacity levels drop to zero and we assume that they leave the market.

C. Non-Profit Scenario 3 (ANSPs as non-profit companies):

Scenario 3 defines a non-profit ANSP maximizing capacity and minimizing profits with a parameter acting as a balance between the two objectives. Since the first element in the objective function is in terms of annual flight-km that may be served and the second element is in terms of monetary profits, it is necessary to set the parameter such that both objectives are considered approximately equally. Currently, we assume that the ANSPs will aim for approximately zero profits in order to meet their mandate. All remaining constraints are the same as the second scenario.

D. Airlines

We assume that multiple airlines are being served in this market and each airline operator, given their network type and schedule, attempt to minimize their costs. The airline cost functions, which are modelled in the second stage of the game, are composed of five categories, all of which are impacted to some degree by the service providers. This objective function includes operating costs, costs from flying off-peak (equivalent to the loss of revenues due to lower airfares charged in the off-peak), congestion costs, ANSP charges and a cost for not flying. In order to account for elastic demand, there exists an outside option flow, which represents the choice to reduce service should the total costs of being served cause the flight to be too expensive. Furthermore, the operating costs and congestion costs are impacted by the effective capacity provided by the winning ANSP which in turn is dependent on the level of technologies employed. In other words, we assume lower airline operating costs and congestion costs if full SESAR technologies are employed, as outlined in substantial detail in the 2012 ATM Master Plan3. The level of technologies employed is determined by the winning ANSP in the first stage.

The first set of constraints of the cost minimization model sum the incoming less the outgoing flows to be equal to the (negative) demand at the (origin) destination and zero when using a transit point. The total flows are reduced by those flights that have been dropped via the outside option. Additional constraints ensure that the total flow is less than or equal to the effective capacity set by the wining ANSP in the first stage.

In a user equilibrium outcome, we assume that each airline chooses paths and time windows taking into account only its own costs and taking the flows of the other airlines as given. Specifically, each airline considers only its own congestion costs and ignores the external congestion costs imposed on the other airlines. Since the pioneering work of [18], there has been a huge and well established literature analyzing the efficiency of congested service systems, including network congestion games. The standard approaches to analyze such settings include Wardrop equilibria [19] and the potential game approach [20,21], both of which consider atomistic and identical customers who each demand an infinitesimal flow in the face of exogenous congestion cost functions. A different approach assumes that competing customers are non-atomistic and have market power in that each customer controls a non-negligible fraction of the total flow (e.g., [22]). The two approaches arrive at the same equilibria outcomes only under specific assumptions [23]. The two-stage game of price competition between service providers in the presence of congestion developed here is the first to consider oligopolistic markets in both stages of the game, i.e. allow for non-atomistic, heterogeneous airline operators with market power in the second stage who react to the first stage ANSP charges. Sub-game perfect Nash equilibria allow airline operators to consider self-imposed congestion across the various routes, potentially leading to interior point flows that do not occur with atomistic Wardrop equilibria. This is critical to the issue of existence of equilibria in the two-stage game when airlines are heterogeneous, hence impact the comparative conclusions we can draw from the analysis.

III. Case Study: Air Traffic Control in Western Europe

In this section, we first describe the network to be analyzed, then the ANSPs and finally the airlines that are considered within the game.

A. Network

The network analyzed is depicted in Fig. 1 and includes six ANSPs, represented by the colored arcs, six major airports in each of the six regions, three regional airports and four additional nodes (yellow arrows) to aggregate flights to and from the region. Despite this being a clear simplification of reality, the network game should be sufficiently rich as to

[3] https://www.atmmasterplan.eu/

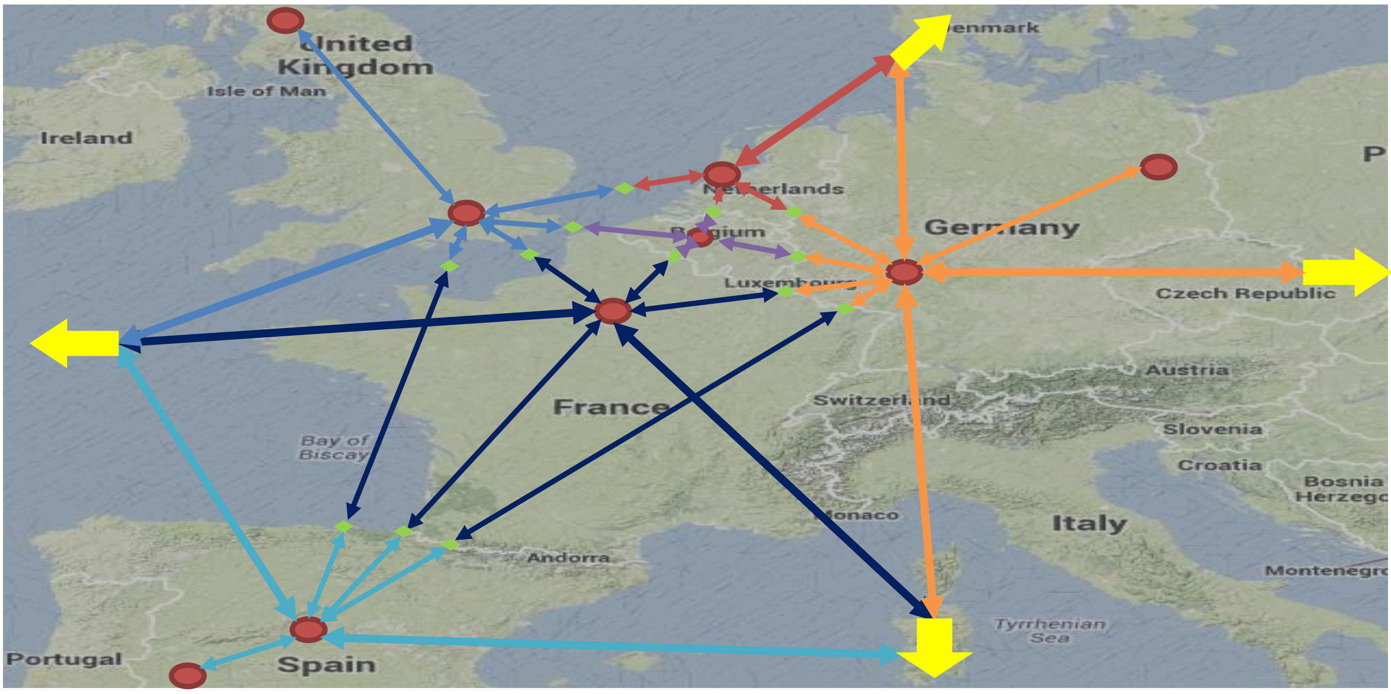

Figure 1. European air traffic control network case study

enable us to understand how the players will react to changes in institutional or regulatory rules, but simple enough to present results clearly.

B. Air Traffic Control Providers

We focus on six ANSPs and collected data on ENAIRE (Spain), Belgocontrol (Belgium), DFS (Germany), DSNA (France), LVNL (Netherlands) and NATS (UK). In addition we also include the Maastricht Upper Airspace Control Centre (MUAC), which is in charge of the upper airspace (above 24,500 feet) in Belgium, Luxembourg, the Netherlands and Northwest Germany. MUAC acts on behalf of these ANSPs but the airlines are charged by the individual ANSPs through Eurocontrol, hence this activity has been included as if the ANSPs were providing the service. According to the ATM Cost-Effectiveness 2016 Benchmarking Report [16], this set of ANSPs were responsible for 47.4% of European traffic (in terms of flight hours controlled) and 54.0% of total en-route ATM/CNS costs. Eurocontrol's performance review unit also publishes the en-route ATFM delay minutes per ANSP and their costs which are based on [24]. Out of the total European ATM system, 58% of the delay minutes were attributed to the ANSPs in this case study. Consequently, the total costs to the airlines flying in the relevant airspace as a result of these delays amounted to €988 million which mostly draws from additional fuel burn and crew costs.

When considering private for-profit or non-profit companies, we assume that the salaries and current expenditures on technology remain the same according to the location of the company i.e. the headquarters. The additional cost of new technologies and the benefits in terms of expanded capacities and reduced delays to the ANSPs and airlines are drawn from the 2012 ATM Master Plan.

C. Airlines modelled in the network congestion game

Hundreds of airlines fly over European airspace providing both scheduled and charter services. For the sake of simplicity, we aggregate the airlines into three groups which best represent the structure of commercial aviation today. The groups cover airline alliances, low cost carriers and non-aligned carriers. The aligned airlines group is represented by three airlines: Lufthansa-Brussels (LH), British Airways-Iberia (BA) and Air France-KLM (AF), the main European airlines in the three airlines alliances that exist today. Each aligned airline is modelled with a two-hub system. LH utilizes Frankfurt and Brussels, BA utilizes London and Madrid whilst AF utilizes Paris and Amsterdam. For the purposes of this case, the low cost carrier group is represented by Easyjet (EJ) because the airline was ranked second amongst low cost carriers in terms of seat capacity in Western Europe in 2014. Ryanair is the largest carrier of this type but is deemed ultra-low cost which perhaps make it less representative of the low cost carrier group. Emirates airline was chosen as the representative carrier for the non-aligned carrier group. The Dubai based airline was ranked first among world airlines in terms of available seat kilometers in 2014 and Europe was their largest market based on seat capacity. The airline groups achieve different costs levels which are mostly a direct function of the level of service they provide, output, network, average stage length and employment costs of the airlines' country of registration. There is a substantial difference in costs between the different airline groups; the cost per available seat kilometer for the aligned carriers in 2014 was approximately 8 euro cents, for Emirates it was 7 euro cents and for EasyJet it was 6.4 euro cents. Lufthansa has the highest variable cost, therefore is the first airline to respond to any increases in costs in the equilibria outcome.

Congestion impacts the cost categories to varying degrees. To be specific, the more indirect the flight path, the higher the fuel and staff costs for the airline and the higher the operating cost. We assume that the marginal congestion cost is linear in frequencies hence the total congestion cost increases in the square of frequencies. Indeed, the greater the delay in airspace, the higher the congestion costs for the airlines, which frequently amount to more than the air traffic control service charges [25,24]. Congestion in air transport is caused in part by limited airport capacity, due to runway and terminal handling restrictions, and limited air traffic control capacity en-route. We note that delays are reasonably low currently (the PRB delay target is set at an average half minute over a year), hence such an assumption seems reasonable for this market. However, we also note that this is a clear simplification of reality and only relevant for high-level strategic modeling approaches. Finally, we include a revenue loss to airlines moving flights from the peak to off-peak in order to correctly balance the desire to avoid congestion and reduce costs yet meet passenger demand.

Two additional assumptions need to be specified in order to apply the model to the case study. First the demand function for flights between each origin-destination (OD) pair is set per airline, based on their scheduled timetable and an airline can decide to fly in the peak, to fly in the off peak or not to fly. The cost of not flying, the outside option, is set at twenty times the sum of the ANSP charges for the least costly flight path from origin o to destination d because demand elasticity with respect to costs is considered to be relatively low. Given the fact that ANSP costs are approximately 6 to 12% of the airline's total operating cost, the likelihood of cancelling flights due to air traffic control costs is relatively low. The value of twenty was chosen by testing the model with multiple values such that in the base case no flights are cancelled but for a reasonably small increase, airlines begin to consider off-peak periods and then cancellations.

IV. Case Study Results

In this section, we discuss the base-run results, which represent the transport equilibria outcome of Scenario 1 and compare it to the results of the 2014 market for purposes of verification. Subsequently, we present the analysis with respect to for-profit companies defined in Scenario 2 and the results of the non-profit corporation outlined in Scenario 3. All scenarios were run for a representative day with the assumption that 80% of traffic is served in the peak period and the remainder in the off-peak. The final results are presented on an annual basis for purposes of comparison.

A. Base-run Scenario 1

In this scenario we estimate the behavior of labor rent seeking ANSPs that are price capped and refer to this as the base-run. As shown in Table 1, the results of the mathematical analysis suggest that all ANSPs will charge according to the price cap in both peak and off-peak periods. The operating profit levels of the ANSPs are currently approximately 20% which is assumed in the base-run [26]. The labor level decision variables are approximately equivalent to current staff levels and technology levels are also set at current levels (t=1). Consequently, the results of the base-run suggest that the ANSPs have no interest in investing in new technologies. The mix of current technologies and high labor levels creates more than sufficient capacity to meet the demand of 2014. Revenues and profits are at the expected levels for the six countries analyzed and the airlines choose to serve all demand with CASKs similar to those reported in their financial statements (greater detail can be found in Deliverable 4.1 of the COMPAIR project [27]). Consequently, the modelling approach suggests that we are able to reproduce the 2014 transport equilibria outcome according to the assumptions described in Section II.

B. For-profit Scenario 2

If we assume that the ANSPs intend to maximize profits but are not required to participate in an auction, similar to the current situation in the UK, the results of the game suggest that labor levels are reduced substantially in favor of higher levels of technology for four of the six providers. However, two of the providers choose to purchase technology levels at close to the current transportation equilibria, suggesting that simply defining ANSPs as for-profit entities does not guarantee the adoption of new technologies alone. On the other hand, economic regulation remains very important in this scenario since all providers set their charges at the price cap both in the peak and the off-peak. Due to the reduction in capacities, close to the minimal levels set by the Member States, the ANSP profits have doubled compared to the base-run outcome.

The outcome of the scenario in which governments introduce a tender system and ANSPs are modelled as for-profit entities is presented in Table 2. As a result of the auction, three companies each win two tenders, thus serving two of the countries in the case study. We note that when six companies participate in the auction, no equilibria outcome is found in the game. When twelve companies participate, the outcome is that three win service provision based on the lexicographic rules. It is clearly important that sufficient companies participate in the auction in order to ensure an equilibrium outcome. We also note that we changed the lexicographic order and placed home bias first but this did not result in a different equilibria outcome.

The results suggest that a German based company serves the Netherlands and Germany with a single unit charge across both airspaces. A Belgian company serves the UK and Belgium with Belgian airspace charges at a higher level than that of the UK. Although the two regions have a similar number of potential bidders, in this case the larger British market required a more competitive bid in order to win. The third, French company serves Spain and France with two separate charges. The reason that the French charge is lower than the Spanish charge is connected to the number of potential bidders in each of the airspaces. In Spain, we have assumed that only Spanish and French companies will bid (due to airspace contiguity constraints) whereas in France, ten potential bidders exist (with headquarters located in Spain, the UK, Germany, Belgium and France). We note that in this equilibria, all three companies set peak and off-peak charges at the same level. We also note that overall, charge levels have reduced by approximately one half compared to the base-run (Table 1). The labor levels are halved as compared to the current level and SESAR technologies are adopted in full creating sufficient capacities to serve 2014 airline demand. **Consequently, this outcome achieves the two major policy preferences of the European Union; namely technology adoption and defragmentation of the Single European Skies.** Furthermore, under this scenario it may be possible to reduce or remove economic regulation because the charges, an outcome of the bidding process, are halved in comparison to current levels and the companies achieve a profit of approximately 3% of operating income. We would suggest that if the number of competitive bids is lower, the charges are likely to increase but it is unlikely that they would double.

TABLE 1: ANSP CHARGES, LABOUR & TECHNOLOGY LEVELS PLUS OPERATING PROFITS

Business as usual ANSPs	Price in € per peak / off-peak per km						Labour	Tech level	Revenues (000 €)	Profits (000 €)
	UK	Netherlands	Germany	Belgium	France	Spain				
NATS	1.11 1.11						605	1.00	737,598	283,054
LVNL		0.61 0.61					172	1.00	207,680	17,067
DFS			0.81 0.81				1,472	1.00	1,071,714	223,823
Belgocontrol				0.95 0.95			310	1.00	267,411	25,965
DSNA					0.81 0.81		2,442	1.00	1,720,356	190,538
ENAIRE						0.86 0.86	805	1.00	663,726	204,237
Annual Totals							5,806		4,668,486	944,683

TABLE 2: ANSP FOR-PROFITS WITH TENDER

For-profit 2014 ANSPs	Price in € per peak / off-peak per seat per km						Labour	Tech level	Revenues (000 €)	Profits (000 €)
	UK	Netherlands	Germany	Belgium	France	Spain				
6. Germany		0.45 0.45	0.45 0.45				1,021	2.00	790,995	8,096
7. Belgium	0.32 0.32			0.49 0.49			276	2.00	243,748	9,242
10. France					0.29 0.29	0.43 0.43	1,219	2.00	999,481	44,963
Annual Totals							2,517		2,034,225	62,302

TABLE 3: ANSP NON-PROFITS WITH TENDER

Non-profit 2014 ANSPs	Price in € per peak / off-peak per km						Labour	Tech level	Revenues (000€)	Profits (000 €)
	UK	Netherlands	Germany	Belgium	France	Spain				
1 UK	1.01 0.79						295	1.00	318,158	31
5 Germany		0.15 0.15	0.81 0.76				625	1.92	583,224	497
7 Belgium				0.81 0.81			100	1.53	98,413	(408)
10 France					0.24 0.24	0.75 0.75	939	2.00	794,344	953
Annual Totals							1,959		1,794,139	1,073

C. Non-profit Scenario 3

We investigate the possibility of defining ANSPs as non-profit entities, similar to the Canadian and MUAC approach, but also participating in auctions. The equilibria outcome in Table (3) leads to four companies winning auctions as compared to three in the for-profit scenario. The result achieves lower economies of scale than the for-profit outcome and higher prices in most countries, although less than the current price cap. In particular, the UK provider serves only British airspace and offers a significantly lower charge in the off-peak. On the other hand, many bids for the Dutch airspace lead to a low charge which is slightly cross-subsidized by the winning German company that also serves German airspace. The adoption of new technologies is sporadic with two companies employing SESAR technologies, one utilizing half the capabilities and the UK company avoiding their use entirely. We note that overall revenues are slightly lower and profits are very low as compared to the for-profit case. This is partially due to the lower capacity levels offered which is a result of the objective function to maximize capacity but also to minimize profits. The equilibria outcome is thus a mix of the current situation and the for-profit scenario with some defragmentation of the skies and employment of new technologies where labor wages are relatively high. However, this equilibrium is not stable because the Belgian company is making losses and would either need a bailout in the longer term from the Belgian government or a new tender would need to be organized.

Finally, we tested the potential outcome were non-profits to serve the market without an auction, as occurs today in Canada and Switzerland. The results suggest that in four of the six countries the charges are set below current levels and that new technologies would be adopted in a different set of four of the six countries. Overall, this solution would appear to be preferable to a for-profit, no auction system as is currently the case in the UK. However, we note that there is the possibility that losses, in the region of 5% of revenues, could cause issues over time.

V. CONCLUSIONS

Introducing an auction system at the level of each European State would be one means to create change in the system. A regular auctioning system may help to achieve a number of aims of the European Union embodied in the Single European Skies (SES) initiative. The major aims of the SES include a reduction in costs via defragmentation and increases in capacity offered via adoption of new technologies.

The creation of for-profit ANSP companies and the introduction of competitive tendering processes would likely lead to the defragmentation of the skies because companies would bid for more than one airspace. Such a tender system would also lead to lower charges than occurs today, in part due to the economies of scale achieved through defragmentation and in part due to the bidding process that creates a competitive environment at least once every five to ten years. Another advantage of this system would be the potential to remove the economic regulatory bodies currently involved in setting the price caps of the existing system. Based on the results of the analysis, it would likewise appear that another aim of the single skies initiative could be achieved, namely adoption of new SESAR technologies.

In this research, we similarly analyze the potential to replace the current system with non-profit organizations of the type created in Canada with airlines on the management board. However, as opposed to the Canadian system, we test the likely outcome were the non-profits to participate in a competitive tendering process. The non-profit organizations suffer from a less clear mandate than that of the for-profit companies. We define their objective function as balancing charges to earn little to no profit and maximizing capacity. The equilibria outcome lies in-between the current solution and that of the for-profit scenario. The non-profits would lead to defragmentation of the skies although possibly to a lesser extent than that of the for-profits. New technologies would be partially adopted only and mainly by the larger companies and charges, although lower than the current price caps, are higher than that of the for-profit solution outcome in most cases. We do note, however, that if auctions are not introduced then partial aims of the SES are more likely to be achieved through non-profits than through a series of non-competitive, for-profit companies.

Based on a series of sensitivity analyses, it is clear that in a competitive scenario there will be substantial pressure to reduce capacities, hence the auction requirements would need to set minimum levels in the bid process. It would also be necessary to track the progress of the companies in order to ensure that the service level targets are indeed met. Creating a peak and off-peak pricing system that is also dependent on service levels, as occurs today in the UK, may help to encourage the companies to produce sufficient service levels such that congestion and delays would be less of an issue. Regulatory bodies involved in measuring delay levels and safety levels would clearly need to continue in their current roles.

The obvious question that arises is whether the gains from the first round of auctions could be sustained in subsequent rounds, five to ten years later. Clearly, it would be important to ensure sufficient bidders over time. This may be accomplished by setting a maximum number of auctions across Europe in which a company may bid or alternatively, by setting a maximum market share. A minimum of two bidders in subsequent rounds would be necessary, not to ensure cost efficiency or technology adoption, rather to ensure that the charges do not return to their pre-competitive levels. We would argue that provided the entry barriers to bid are not excessive, such a level of competition is possible over time. However, in the case of insufficient bids, it may be reasonable to add a restriction in the auction that charges set in the previous round act as a reference point in the new round.

We note that stakeholder feedback was sought over different stages of the two year COMPAIR project through workshops, advisory board meetings, interviews, a survey and presentations at conferences and workshops. There was general agreement that at least some competition is needed in order to increase the efficiency of the European air navigation service environment. Most stakeholders agreed that the main obstacle in the way of achieving such an improved environment is the lack of sufficient political will to initiate and execute the necessary changes. There was a feeling that the current auctioning process for terminal control may prove a good basis for moving forward. It was also discussed that in the Middle East, arguably a region with many critical military operations and delicate sovereignty challenges, ANS provision through tenders is not uncommon and private providers such as SERCO operate en-route airspaces over multiple countries.

Future research that may be of interest would be to extend the analysis to cover the whole of Europe although some time would need to be invested in solving the large scale optimization problems involved. It may also be of substantial interest to consider an extension of the model to include a cost-benefit analysis that would combine the charges, the labor and technology levels and capacity and delay levels in order to determine the preferable scenario from an individual Member State perspective and a pan-European perspective with respect to overall social welfare. Finally, the game theoretic analysis presented here is static and a dynamic form may provide greater insight into issues surrounding the impact of auctions over time.

Additional, potentially interesting directions include the idea that the ANSP companies would not need to serve contiguous airspace. This would open up a wider set of potential bidders in the market however to analyze this would require a separation of air traffic controllers labor costs from those of management, which is not yet reported by the Performance Review Unit. One other very promising direction would be to create a governmental agency which would buy capacity from the ANSP companies and sell it to the airlines, as has been created in the electricity markets. For this to be possible technically, it would require the ability for air navigation service providers to track aircraft trajectories rather than airspace.

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References

[1] Elias, B., 2017. Air Traffic Inc.: Considerations regarding the corporatization of air traffic control. Cornell University; DigitalCommons@ILR.

[2] Button, K., McDougall, G., 2006. Institutional and structure changes in air navigation service-providing organizations. Journal of Air Transport Management, 12(5), 236-252.

[3] Cook, A. (Ed.)., 2007. European air traffic management: principles, practice, and research. Ashgate Publishing, Ltd.

[4] McDougall, G., Roberts, A., 2008. Commercializing air traffic control: have the reforms worked? Canadian Public Administration, 51(1), 45-69.

[5] European Commission, Single Sky: Commission acts to unblock congestion in Europe's airspace, MEMO/13/525, June 2013.

[6] Blondiau, T., Delhaye, E., Proost, S., Adler, N., 2016. ACCHANGE: Building economic models to analyse the performance of air navigation service providers. Journal of Air Transport Management, 56, pp.19-27.

[7] Adler, N., Hanany, E., Proost, S., 2018. Competition in congested service networks with application to air traffic control provision in Europe. Working Paper, Tel Aviv University.

[8] Button, K., Neiva, R., 2013. Single European Sky and the functional airspace blocks: Will they improve economic efficiency? Journal of Air Transport Management, 33, 73-80.

[9] Adler, N., Hanany, E., Proost, S., 2014. Managing European Air Traffic Control Provision. In Fourth SESAR Innovation Days, 25th–27th November 2014.

[10] Eurocontrol, 2016. U.S. – Europe comparison of ANS cost-efficiency trends 2006-2014 – Update.

[11] Kettl, D.F., DiIulio Jr, J.J., 1995. Cutting government. The Brookings Review, 13(4), p.40.

[12] Treanor, J. L., 1997. Privatization v. Corporatization of the Federal Aviation Administration: Revamping Air Traffic Control. J. Air L. & Com., 63, 633.

[13] Raffarin, M., 2004. Congestion in European Airspace. Journal of Transport Economics and Policy, 38(1), 109-125.

[14] Eurocontrol, 2008. Performance Review report. An assessment of air traffic management in Europe during calendar year 2007.

[15] Baumgartner, M., Finger, M., 2014. The Single European Sky gridlock: A difficult 10 year reform process. Utilities Policy, 31, pp.289-301.

[16] Adler N., Delhaye E., Kivel A. and Proost S., 2018. Motivating Air Navigation Service Provider Performance. Working Paper, KU Leuven University.

[17] Eurocontrol, 2016. ATM Cost-Effectiveness (ACE) 2014 Benchmarking Report with 2015-2019 Outlook, Brussels.

[18] Pigou, A.C., 1920. The economics of welfare. Palgrave Macmillan.

[19] Wardrop, J.G., 1952. Some theoretical aspects of road traffic research. Proceedings of the Institute of Civil Engineering, 1, 325–378.

[20] Rosenthal, R.W., 1973. A class of games possessing pure-strategy Nash equilibria. International Journal of Game Theory, 2, 65-67.

[21] Monderer, D., Shapley, L., 1996. Potential games. Games and Economic Behavior, 14, 124-143.

[22] Cominetti, R., Correa, J.R., Stier-Moses, N.E., 2009. The Impact of Oligopolistic Competition in Networks. Operations Research, 57(6), 1421-1437.

[23] Haurie, A., Marcotte, P., 1985. On the relationship between Nash—Cournot and Wardrop equilibria. Networks, 15(3), 295-308.

[24] Cook, A.J. and Tanner, G., 2015. European airline delay cost reference values. Technical Report. Eurocontrol Performance Review Unit, Brussels.

[25] Ball, M.O., Barnhart, C., Dresner, M., Hansen, M., Neels, K., Odoni, A., Peterson, E., Sherry, L., Trani, A.A. and Zou, B., 2010. Total delay impact study: a comprehensive assessment of the costs and impacts of flight delay in the United States. UC Berkeley Transportation Library.

[26] Piers, R., Hawley, M., Obbink, B. K., Smeltink, J., Roelen, A., Beerman, R., van Wanrooij, N., (2017). Support study for an ex-post evaluation of the SES performance and charging schemes. Report for European Commission: Directorate-General for Mobility and Transport.

[27] Adler, N., Brudner, A., Kivel, A., Proost, S., 2017. Report on Introducing Competition in European Air Traffic Control Provision using Game Theoretic Principles. Deliverable 4.1. COMPAIR project.