“Nash equilibrium” situations among ATM Service Providers in Functional Airspace Blocks. A theoretical study.

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Abstract[1]

In Europe today there are more than 57 main Air Navigation Service Providers (ANSPs), providing Air Navigation Services (ANS) to airspace users. The European Commission (EC) with the Council and the European Parliament (EP) have been introducing since April 2004, regulations establishing the “Single European Sky” (SES). They liberate and regulate the market of particularly Air Traffic Services (ATS) making it gradually part of the “Single Market”. Forced by the regulations the currently fragmented airspace of Europe will have to be organized by 2013 in a small number of Functional Airspace Blocks (FABs)[3]. In this paper we argue that the majority of the main ANSPs (basically and mainly ATSPs) will retain their business and they will be designated in general in airspace volumes parts of a larger FAB. In this case the theoretical study leads to the outcome that two[2] or more Air Traffic Services Providers (ATSPs) will not compete neither on quantity of their “single product”[10] nor on price of the offered services but they will most probably choose to adhere to a strategy that takes strongly into account the respective strategy(ies)[15] of the other(s) ATSP(s). If this is the case it becomes very likely that Nash type equilibria may be settled among ANSPs in FABs.

Keywords

“Nash Equilibrium”, Economics of Air Navigation Services, Natural Monopolies, Game Theory, Concurrent Enterprising, Knowledge-oriented Collaboration.

1 Introduction, background, assumptions and definitions.

Air Navigation Services to airspace users are mainly composed of Air Traffic Services (ATS), Communications-Navigation-Surveillance (CNS) Services, Aeronautical Information Services (AIS) and Aviation Meteorological Services (MET). ATS must and MET may be designated by States for exclusive services in given portions of airspace[1]. In this paper we are dealing mainly with the Air Traffic Services part of ANS due to the fact that they are in essence a natural monopoly[14]. By the regulation they have to be designated to specific parts of airspace[1] where they are entitled to provide Air Traffic Services to airspace users. The fragmented airspace (see Figure 2) has been considered as one of the main causes of inefficiencies of the European ANS when in particular was compared in repeated Performance Review Reports with the situation in US. Fig. 1 indicates economic targets of SESAR achieving an average cost/flight down to ~430€ in 2020 where the US equivalent cost was in 2006.

[1] The paper expresses the personal views of the author.
[2] Consider that 5 out of the current 9 FAB schemes are made by 2 ATSPs

To attain this objective and others like increasing safety performance by a factor of 10, enable a 3-fold increase in capacity which will also reduce delays, both on the ground (airports) and in the air and enable a 10% reduction of the impact that flights have on the environment, designated ATSPs would have to operate organised in FABs[3].

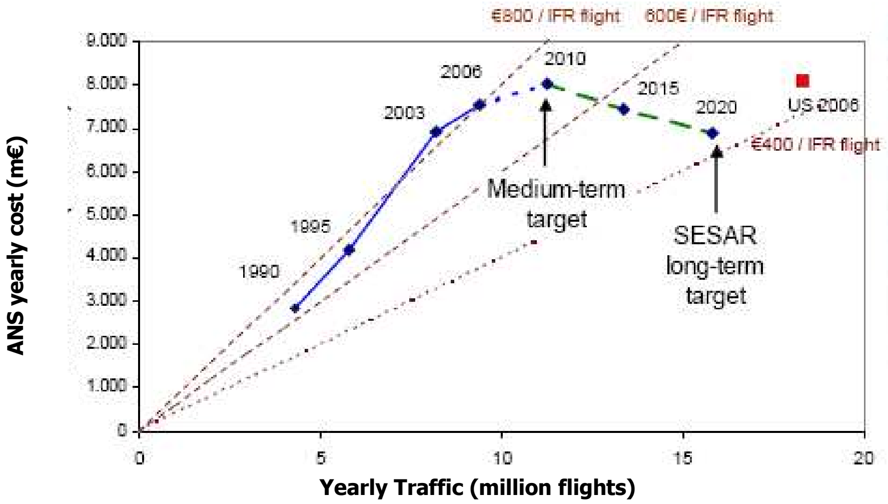

Fig. 1: The SESAR Programme aims inter alia to bring av.cost/IFR flight down to ~430€ in 2020, or to an equivalent of ~ b€7 total. This means a 12,5% real cost reduction while traffic will nearly double (from 9 million flights in 2006 to 16 million flights in 2020)[3].

FABs need to be achieved by 2013 through a multiplicity of approaches ranging from merges to mutual designations and particular to the case cooperations[13]. When in FABs market competition between ATSPs is theoretically impossible.

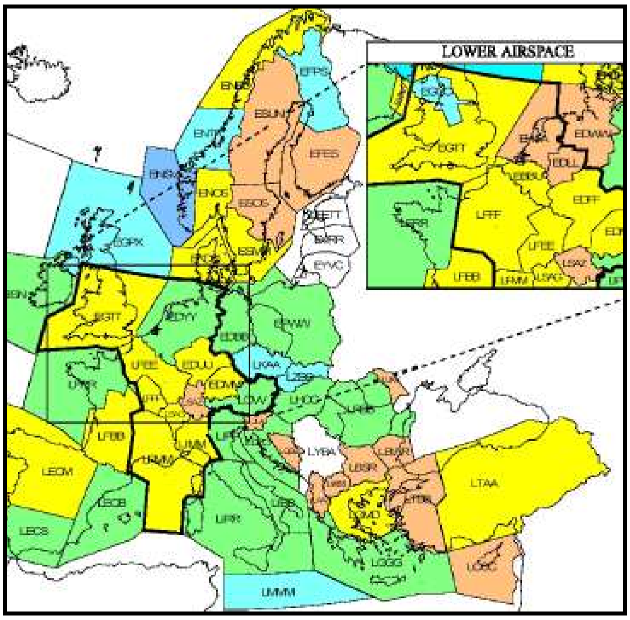

Figure 2: The currently fragmented airspace of Europe

[3] From the report of the Performance Review Commission "Evaluation of Functional Airspace Block (FAB) initiatives and their contribution to performance Improvement" Produced by the EUROCON TROL Performance Review Commission upon the invitation of the European Commission DG-TREN, October 2008.

However, the hypothesis of this study is that ATSPs participating in FABs will be mutually designated at least initially to different parts of airspace which will not differ significantly from the current designations (see the case of UK-IR FAB). In this case participating ATSPs will have to choose specific strategies regarding their financial performance including unit price/output characteristics. These "indices" according to SES II[4] would be reflected into the performance plans of their State and of their FAB. It is also anticipated that initially and for a certain significant period of the FAB evolution, there will be most possibly different charging areas within the FAB[2], most probably corresponding to the airspace designated to each ATSP.

The combination of strategy choices and consequent differentiations (indication of an indirect underlying competition) regarding unit price v.s. output[5] will bring gradually to a certain "equilibrium" which once settled will influence the global performance of the system. It makes therefore sense to study and model the evolution and establishment of such "equilibria" using respective applicable parts of the theory of games and economics. The most challenging part of this theoretical work was to prove in an unbiased manner that the classic economic theories and models of competition in particular the Nash model and equilibrium[16] can be applied with the necessary adaptation to the ANS/ATS business and its particular market. This would allow the explanation and interpretation of existing phenomena and enable the prediction of new ones. It is in essence the ultimate value of any theoretical advancement.

1.1 Assumptions made to set the foundations and the framework of the study.

A number of assumptions were developed as necessary to set up the framework of the theoretical study and to be applied in a deductive way:

- Supply is the offered capacity in a given airspace and is measured not in the specific EUROCONTROL (FAP tool results) manner i.e. a/c movement/hour in a sector, but as service units to airspace users in the frame of a year;
- Demand is the same as in the ATS i.e. capacity demand but addressed in service units/year;
- Price is the unit price equal to the CRCO definition of the Unit Rate but the actual one i.e. for simplicity over/under-recoveries were not considered therefore price unit is total cost/total quantity;
- Supply and demand evolutions were generally considered as linear except when specifically mentioned e.g. in cases of elasticity measurements;

The economics of ATSP business were also basically addressed to cater for simplicity while preserving affordable accuracy. In Fig. 3 a single ATS Service Provider (ATSP) responds normally by linearly decreasing unit price P as demand increases until the ATSP reaches its capacity limit Q_c. At this point supplementary investment and resources will be needed to accommodate the extra demand Q_N, at a higher unit price P_N. Note that if demand falls back to the original Q_c level, the new unit price P_{CN} is now higher than the original P_c, denoting that cumulative investment and the acquired resources/assets necessary to generate additional supply for accommodating the higher demand, have to be depreciated and recovered while fixed operating costs at higher capacity may be also higher[14].

[4] Single European Sky package II mainly addressing regulated performance.
[5] The reader familiar with ATS should see these classic *price* and *output* economic terms as cost-base/unit price and safety/capacity/efficiency pairs of performance. To simplify the issue of environment protection is considered to be inherently included in this set of performance indicators. For example achieving broad flight efficiency alleviates adverse environmental effects while improving safety and avoiding catastrophes has similar positive effect to environment.

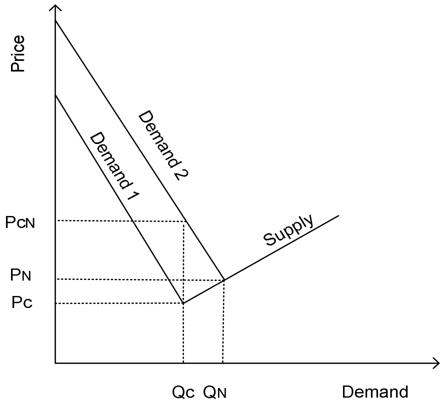

Fig. 3: Price-demand behavior of ATS provision in linearly changing demand conditions and at the limits of capacity supply (service units)

More specific and important assumptions:

More specific and important assumptions were made regarding the practical formulation of FABs their development and establishment and the positioning of ATSPs in them. "A FAB means an airspace block based on operational requirements and established regardless of State boundaries, where the provision of air navigation services and related ancillary functions are optimised and/or integrated"[6]. However all FABs under development today (see Fig. 4) are having their borders exactly on national borders. There are nine FABs under development today, one have been already achieved (UK-IR see Fig. 4). FABs can be created in a number of different ways driven by the regulations[1] including SES II. Member States may decide to designate in parts of their airspace different or the same ATSP, thus possibly either reducing or maintaining the number of ATSPs operating currently in the EU region and in the ECAAs[7]. Our assumption for the study is that the number of the main ATSPs will remain more or less the same as today and that designations of airspace will maintain the current status with the necessary adaptations and delineations mainly regarding internal to the FAB sectorizations.

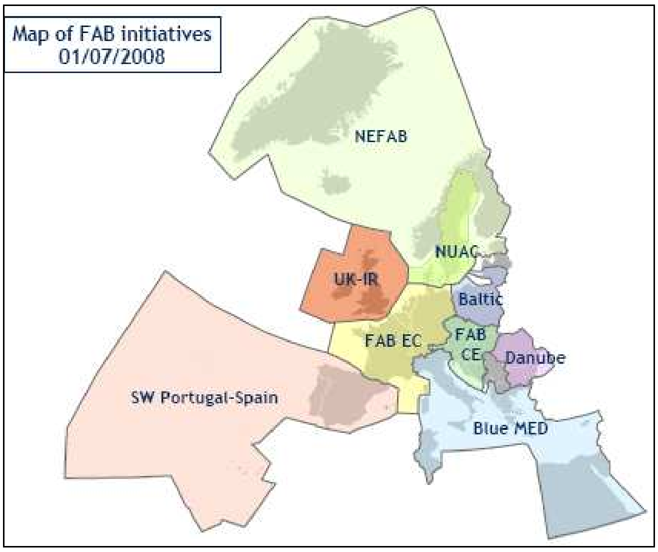

Fig. 4: Schemes of FABs under development in Europe. The UK-IR FAB has been implemented.

Hence Fig. 4 provides a picture of the medium/long-term future (i.e. up to 2020) with a good accuracy.

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[6] Single European Sky legislation package II
[7] European Common Aviation Areas

	2013 benefits in M€	2013 benefits as % of 2006 total economic costs	*% from flight efficiency or delay*	2018 benefits in M€	2018 benefits as % of 2006 total economic costs	*% from flight efficiency or delay*
Blue Med	14 – 49	1 – 5%		14 – 71	2 – 7%	
Danube *	29 – 52	12 – 22%	*99%*	29 – 52	12 – 22%	*99%*
FAB CE	6	1%	*53%*	21 – 30	4 – 6%	*55%*
FAB EC	260	8%	*77%*	1150	36%	*83%*
NUAC	47	17%	*72%*	51	18%	*81%*
UK-Ireland	12	1%	*100%*	40	4%	*63%*

*: Assumptions and expert judgements would need to be confirmed.

Fig. 5: Summary of initially quantified cost benefits in six FABs[3].

The next assumption is far more crucial and more difficult to assert: Most probably and unless specific regulative intervention is exercised there will be different multiple charging areas within the FAB at least during the early stages (short-term) of its existence. Moreover it is assumed that the charging areas will overall correspond with the airspaces designated to each ANSP in the FAB. This setting will make difficult to achieve as quickly as expected the anticipated benefits that FABs will supposedly bring, in particular regarding cost/flight efficiency[3]. This specific aforementioned assumption is not a mere theoretical hypothesis. It has been supported by evidences produced by studies made so far for FABs[3] and related performances[4]. The Table in Fig. 5 illustrates clearly that cost efficiency benefits anticipated for 2013 will be marginal and will be generated mainly by the gains expected in flight efficiency. As we may observe the situation does not change drastically (with the exception of FAB EC) in 2018. In addition to this, investment cost for establishing a FAB and running it initially are expected to be considerable[6] picking up to approx. 5% of the total Air Navigation Services cost in Europe, the year 2014. The plot of the cumulative Net Present Value (NPV) in Fig. 6 indicates that expected FAB benefits vs. their cost are breaking even after 2018.

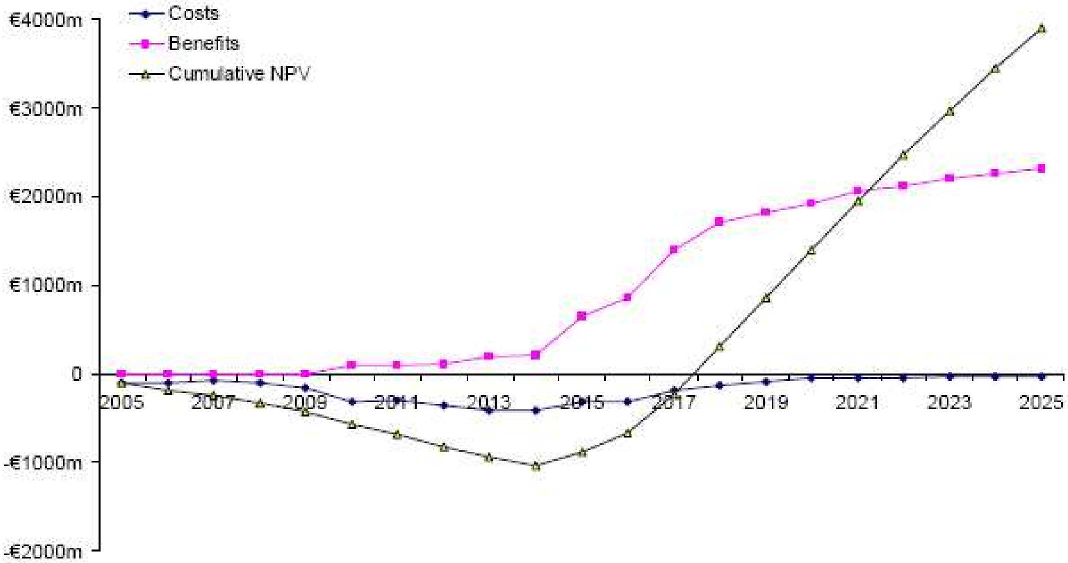

Fig. 6: FAB benefits vs. their cost will start breaking even after 2018[6]. The figure does not include the cost of SESAR and the cost of ANS (performance) regulation.

As mentioned, this cost does not include the cost of deploying and implementing SESAR in a FAB, neither the cost that will be generated by National Supervisory Authorities and other competent bodies (e.g. PRB) in regulating (i.e. setting, monitoring, reporting and enforcing), performance according to SES II[20]. As a result the assumption of multiple ATSPs and multiple charging areas in a FAB is a valid one and is applied in this study.

1.2 Definitions used in this study. Building the modelling conditions.

Economic equilibrium in a FAB is the situation when among mutually designated ATSPs and their airspace users there is a situation where demand is met by capacity at a mutually accepted unit price (see Fig. 7). This equilibrium is in practice mostly of dynamic nature and has often periodic variations regarding demand. Due to the nature of the cost base of the ATSPs (i.e. mostly fixed cost) price elasticity of demand[21] is limited (i.e. elasticity <1). Each part of the FAB with its designated ATSP may have a partial equilibrium and the FAB an integrated one. At the point of equilibrium, market forces mainly supply and demand are equalising each other in a stable manner due also to reduced elasticity.

Normally small surplus capacity (over-supply) is maintained to cater for demand fluctuations and thus preserving the equilibrium although in sub-optimum conditions. Overall a reasonably surplus capacity is accepted by airspace users.

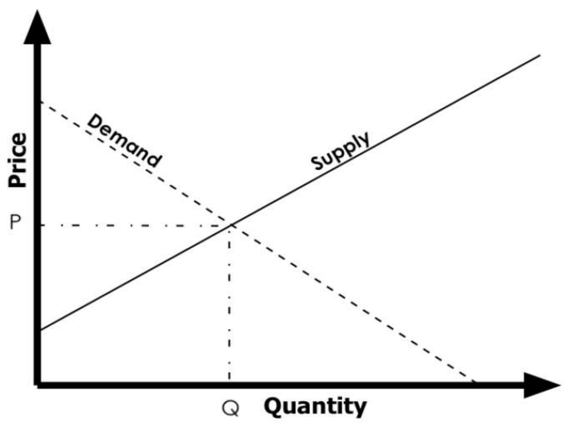

Fig. 7: Economic equilibrium in a FAB. The demand for Service Units (Q) is met by offered Capacity (Supply) in an acceptable unit price P (unit rate).

The following definitions were adapted from the respective literature[8][9][10][16][17] to fit the case of FABs and the particularities of ATSP business and then applied in the study as corollaries.

Cournot Equilibrium (CE):

A fixed number ATSPs produce a homogeneous product (service units); there is no open explicit collusion although ATSPs do cooperate in the framework of their FAB; pending on the elasticity of the designated airspace, ATSPs do have certain market power i.e. their supply (capacity) decisions may affect unit price; there is an underlying competiton on offered capacity. Finally ATSPs are economically rational and act strategically, usually seeking to maximize revenues vis a vis regulated limits (i.e. full cost recovery, price-cap, etc.). In practice the Cournot equilibrium is set on the basis of settling quantity (i.e. capacity)

Bertrand Equilibrium (BE):

Similar assumptions as per CE above; in practice only two ANSPs may be considered for this model (duopoly) i.e. it is basically applicable on 5 out of the 9 FABs developed or under development; equilibrium is achieved by a unit price settlement i.e. down to price of the marginal cost vs. quantity (capacity) settlement as per CE.

The model also requires that demand is linear. The impact is that ATSPs may alter their output adapting to demand but if they attempt to modify unit price this will lead to a downward spiral settling the new equilibrium at lower unit price. This model can only be applicable in mutually elastic airspace i.e. when airspace user may easily choose the lower unit price airspace.

Nash Equilibrium (NE):

In contrast to the previous definitions, the NE does not refer directly to a given set of P, S, and Q values (as per Fig. 7) but is the equilibrium formed by a composite set of strategies from which no ATSP has an incentive to unilaterally deviate. The model involves two or more ATSPs, where each is assumed to know the equilibrium strategies of the other, and no ATSP can profit by changing its own strategy unilaterally.

If each ATSP has chosen a strategy and no ATSP can benefit by changing its own strategy while the other keep theirs unchanged, then the current set of strategy choices and the corresponding advantages/disadvantages constitute a Nash equilibrium (NE). The conditions of feasibly converging and maintaining a NE include that participating ATSPs will all:

- do their utmost to maximize their expected benefits as originally planned (strategy);
- be perfect in executing the strategy;
- have sufficient intelligence to act as necessary;
- know the planned equilibrium strategy of all of the other;
- believe that a deviation in their own strategy will not cause deviations by any other;

Finally there is common knowledge that all participating ATSPs meet these conditions, including this one. Therefore, not only must each ATSP know that the others meet the conditions, but also they must know that they all know that they meet them, and know that they know that they know that they meet them, and so on, i.e. the perfect knowledge distribution and exchange situation (i.e. in case of a the occurrence of a marginal change, the system gets knowledge of it and its consequences, immediately.

Strategy of an ATSP:

For the sake of the study it is the planned or achieved point of operation as a set of Price, Quantity and Supply values (see Fig. 7). With respect to the elasticity properties of the given airspace (see 1.3 below) this point may have dynamic or stable characteristics. Further the notion of strategy in ANS/ATS may include additional attributes in particular regarding management[15].

1.3 Elasticity of airspace

In this section we introduce the novel notion and definition of *airspace elasticity* taking into account the classic definition of unit price elasticity of demand[21].

An airspace is considered as elastic (i.e. exhibits a negative elasticity $\Delta Q/Q_2/\Delta P/P_2 > 1$) when a change in unit price causes an opposite sign change in demand i.e. lower unit prices lead to increased demand until the supply (capacity) limit is reached.

Alternatively when unit price is increasing (increased base cost with stagnated or decreasing demand) then demand is dropping by a ratio higher to 1 driving the unit price even higher. This situation may lead to spiralling effects in both directions[5]. Elastic airspaces are those, which due mainly to their geographical positioning and size, offer the option to circumnavigate instead of crossing (e.g. Central Europe) with acceptable time/fuel penalties.

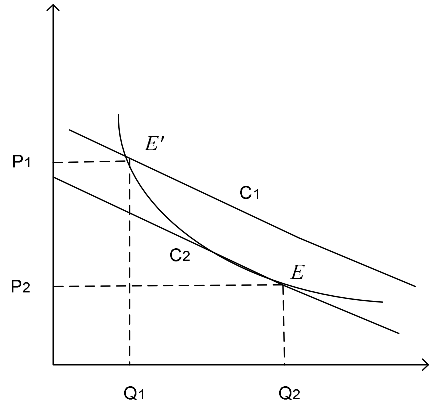

Fig. 8: Airspace elasticity: ATSPs operating at point E' of the price/demand curve are rather inelastic regarding price elasticity of demand due to their airspace geographical properties (inelastic airspace). Operating at point E has the opposite effect i.e. small relative variations of price cause large variations in demand (high elasticity).

In contrary if for an aircraft becomes necessary to cross an airspace as to reach destination, this airspace is relatively inelastic regarding unit price elasticity of demand (i.e. elasticity=$\Delta Q/Q_1/\Delta P/P_1 < 1$). In this case variations of unit price do not affect considerably demand. See Fig. 8 for a graphic illustration of the effect. We found the airspace elasticity as a notion, a considerable factor acting as a sort of competitive advantage of the ATSP who operates in an inelastic airspace. It also helps to the settlement and maintenance of equilibria.

2 Literature research

There is, as expected, a significant volume of work done regarding the applicability of Cournot and Betrand models as well as regarding Nash equilibrium cases in particular related to game theory. We were unable to find work specifically related to economic situations in Air Navigation Services. We focused mainly to area of ATS provision. In past work we have proven that in particular ATS is a "natural monopoly"[14], in the sense that "opening" the market to potential competition will not bring significant benefits to the users and might even increase the unit price they will have to pay to "competing" providers. Further to this theoretical criterion, current technology and safety requirements prevent in practice a pure market-driven competition in ATS. Castelli L. et al[18] have examined charging scenarios for the case of CEATS, in essence proving that the most efficient scheme is the one with a single charging area including upper and lower airspace. Bonanno G. in his paper[12] although dealing basically with the special case of product (vertical) differentiation (i.e. not the ideal case where the firms' products are "single" or assumed to be perfect substitutes i.e. the *homogeneous-goods* case), provides a good depiction of the Cournot-Nash and Bertrand-Nash combinations. Over all the classic theories and models developed by Cournot A.[10], Bertrand J.[8], Nash J.[16] and subsequent papers were used with appropriately innovative adaptations. Therefore the main contribution of this theoretical study work was about introducing novel approaches as to create valid and self-consistent analogies, connecting classic economic theories with the modelling of the situations that can be generated by the particularities of the ATS business and its market[14].

3 Theoretical study; method and main results

3.1 General Case Study

We first examined the applicability within a FAB of the Cournot, Bertrand and Nash equilibrium models so as to come to consistent outcomes of interest. After excluding for a number of analysed reasons the Cournot and Bertrand (see tables below), we came to the conclusion that "Nash equilibrium" has a much better fit and longer-term applicability in a FAB situation among ATSPs. In addition it provides corollaries that are consistent with observations.

A) Studying the CE model:

Table 1: Comparative analysis of the applicability of the CE model.

ID No	Supporting arguments	Counter-argument	Pure rejecting arguments (PRA)
1.	Fixed number of ATSPs	No counter-argument	ATSPs do not collude but rather cooperate in particular within FABs
2.	One common (identical) product (i.e. service unit).	No counter-argument	They need to plan as to achieve certain capacity (i.e. supply of service units) in a given time, but this is done at central pan-European level and not as a result of their one strategy.
3.	Posses certain market power in particular vs. the buyers (i.e. airspace users);	Under heavy scrutiny on setting unit prices.	They know the quantity (capacity) target for their counterparts in a FAB (i.e. ATSP's strategy is known to everybody that they know that everybody knows!)
4.	Tendency/willingness to maximise revenues (but not by playing with the quantity);	Under regulation and scrutiny regarding full cost recovery or price-cap.	ATSPs simply cannot settle with a fixed quantity that maximises their revenues as they are obliged to respond proactively on demand.

Pure rejection argument no 4 (CE-PRA4) is the overwhelming reason for rejecting the CE model as a possible equilibrium in a FAB.

B) Studying the BE model:

Table 2: Comparative analysis of the possibility of the BE model.

ID No	Supporting arguments	Counter-argument	Pure rejecting arguments (PRA)
1.	Two ATSPs (duopoly)	Yes in 5 out of 9 FABs but not a general case argument. Nevertheless BE can be possible theoretically worked out also for the case of more than two ATSPs.	Investment depreciation and amortisation of other costs plus the standard operating cost (i.e. mainly wages) make practically very difficult to reduce unit prices without risking large deficits. Generally ATSPs do not gable.
2.	Willingness to reduce unit price as to increase revenues by triggering demand.	The argument stands only in the case of elastic airspaces (e.g. Czech Rep. case)	Demand is not linear (i.e. vs. marginal cost evolution. It has been observed to have a rather particular exponential distribution.
3.			Very high % of fixed costs and the full cost recovery (or price-cap) do not allow a settlement to a global common unit price just exactly/above the marginal cost. In practice ATSPs operate constantly at this point but with varying unit prices.

The extracted three Pure Rejection Arguments represent sufficient conditions to conclude that establishing a BE equilibrium in a FAB is a very unlikely outcome.

C) Studying the NE model:

Table 3: Comparative analysis of the applicability of the NE model.

ID No	Supporting arguments	Counter-argument or Comment	Possible rejecting arguments (PRA) Comment
1.	The ATSP strategy in a FAB is a complex set including all parameters i.e. Price, Quantity and Supply and not only price or quantity.	Valid	ATSPs do not operate in a "perfect" market environment where unit prices are set by the forces of demand and supply. *However the sort of natural monopoly that they enjoy in practice brings quicker to a settlement of NE type.*
2.	Impossibility to alter/direct demand to one's favour only.	Valid with some reserves regarding the case of a FAB with highly elastic airspaces.	
3.	ATSPs are fully aware of the strategy of the others in the FAB and beyond as targets are set at pan-European level and published. They also know that the other ATSPs in the FAB and beyond (borders) they will be fully informed of any change they plan to implement that may alter the achieved settlement.	Valid	
4.	Increasing or decreasing quantities and prices, provides no benefits in the medium/long-term. Overall an ATSP in a FAB has nothing to gain by changing only its own strategy unilaterally while the others keep theirs unchanged.	It has been observed. This is a pure NE case.	

The supporting arguments in Table 3, were considered sufficient to conclude that converging to a Nash Equilibrium among ATSPs in a FAB is very probable. n the next section will examine the consequences of this conclusion and its corollaries. The Nash equilibrium concept has been used to analyze the outcome of the strategic interaction among several decision makers (ATSPs). It is a way of predicting what will happen if several ATSPs are making decisions at the same time, and if the decision of each one depends on the decisions of the others.

According to Nash it is impossible to predict the result of the choices of multiple decision makers if those decisions are analyzed in isolation. Instead, we must ask what each ATSP would do, *taking into account* the decision-making of the others. This is exactly the case of the ATSPs in a FAB (developed or under development) wether there is a settling process in progress or it has been already achieved.

Maintaining the assumption that everybody knows what the others plan to do, let us suppose that in a NE settled FAB, ATSP A decides to reduce drastically its unit cost in anticipation that increased demand will recover initial losses and will generate increased revenues later. This of course will happen to the detriment of the other ATSPs who immediately react announcing price reductions annulating the possible expected benefits of A. Two equilibria outcomes become possible: a) after the announcement nobody dares to change anything thus preserving the existing equilibrium b) everybody reduces cost to the initial benefit of the airspace users but all ATSPs are worse off. Since nobody dares to increase prices/cost unilateraly this is a possible new equilibrium.

	ATSP B selects '0'	ATSP B selects '1'	ATSP B selects '2'
ATSP A selects '0'	*0, 0*	*2, -2*	*2, -2*
ATSP A selects '1'	*-2, 2*	*1, 1*	*3, -1*
ATSP A selects '2'	*-2, 2*	*-1, 3*	*2, 2*

Table 4: Two ANSPs with 3 choices in a possible Nash equilibrium situation.

To simplify the study let us examine the case of 2 ATSPs A & B in a FAB having three strategies to select: 0 for no price change, 1 for moderate price increase and 2 for more drastic price increase. In any choice they both get the smaller of the two chosen integers in points. In addition, if one chooses a larger integer than the other, then looses two points that are won by the other. The situation has a unique pure-strategy Nash equilibrium (i.e. where no ATSP can make a advantageous deviation unilaterally): when both chose 0 (i.e. no change, highlighted in light red). Any other choice of strategies can be improved if one of the ATSPs lowers his choice to one integer less than the other ATSP's choice. In the table, for example, when starting from the green square, it is in ATSP's A interest to move to the purple square by choosing a smaller integer, and it is in ATSP's B interest to move to the blue square by choosing a smaller integer. However these two squares are not an equilibrium. Obviously the best choice for both is the green square where both opt for more drastic price increase.

3.2 Side effects and possible adjustments not directly related to economic equilibria. The effect of organisational isomorphism in a FAB.

It has been discussed that conventional organizations may follow even unintentionally trends towards isomorphism to obtain not only resources, but also to achieve institutional legitimacy in their functions and activities. On the other hand ANSPs having no imminent financial worries they proceed to isomorphism in order to cooperate and finally to collaborate with their pear organizations in a FAB[13]. It is considered that isomorphism is an additional factor (of purely organisational nature of course) towards enforcing the establishment of Nash type of equilibria in FABs. In a way once the process of isomorphism is launched it is very hard for the management of an ANSP to reverse it and therefore modifications of established strategies on or near the Nash equilibrium point are to be maintained.

3.3 Case Study: the BLUE MED FAB[19]

The theoretical analysis was complemented by a brief case study applied in one of the FABs under development which was chosen for fulfilling a number of criteria. The criteria for selecting the specific FAB example were:

- Number of participating ATSPs (ANSPs) more than two;
- Sufficient available data for the main participating ATSPs (CRCO and STATFOR);
- Largely varying base costs, unit prices and yearly supplied service units;
- A mix of inelastic and highly elastic airspaces;
- Contains a mix of EU and ECAA countries[8]

[8] BLUE MED includes also Tunis and Egypt but these airspaces are not expected to follow and apply immediately fully the EU regulations regarding FABs.

Table 5: Comparative data analysis of the ATSPs/ANSPs participating in the BLUE MED FAB.

State/ATSP	Chargeable Base Cost 2008 in €	Actual service units 2008	Actual unit price 2008	% of total base cost	% of total SUs	%SU/%TBC FAB Cost efficiency
Albania/NATA	15.585.077	324.951	47,96	1,87	2,17	1,16
Cyprus/DCA	40.892.722	1.310.890	31,19	4,90	8,75	1,79
Greece/HCAA	174.888.560	4.258.001	41,07	20,94	28,43	1,36
Italy/ENAV	593.672.357	8.660.349	68,55	71,09	57,83	0,81
Malta/MATS	10.069.836	421.760	23,88	1,21	2,82	2,34
Total	835.108.552	14.975.951	55,76[9]	100,00	100,00	

Table 5 above illustrates the major variations in the BLUE MED FAB regarding unit price and supply/demand characteristics. If a single charging area is applied, MATS for example would have to nearly double their unit price. Air traffic may be distorted at the borders of Albania (elastic airspace) and perhaps of Cyprus if neighbours of the FAB follow a much lower unit price strategy. However as a NE looks to have been established no major unilateral changes are expected. It is anticipated that BLUE MED would have as every FAB, different charging areas corresponding to the airspaces that the ATSPs mentioned in the Table 5 will be designated.

4 Conclusions and future work

4.1 Conclusions

In this study we followed the general Walrassian[11] principle that the ANS/ATS market in a FAB will inevitably come to a dynamic equilibrium of a typical supply/demand form but including in addition more specific strategies[15]. In an effort to model the equilibrium settlement process and its results, we examined the applicability of three models i.e. the Cournot, Bertrand and Nash types of equilibrium. It was found that the Nash equilibrium fits better (explains and predicts phenomena). Some corollaries of these findings and conclusions appear to be of importance regarding the design and application of further regulatory intervention. Indeed it appears that shortly after establishing their FAB, participating ATSPs are expected to reach their Nash Equilibrium. Reaching this point ATSPs will have no further business interest or incentives to change and adapt to high performance yielding strategies without risking acquired benefits. This appears to be the scenario in particular if FABs and their ATSPs are left to operate in their particular business environment made by market forces on one hand and fixed costs and national interests and underlying protectionism in many cases, on the other. The highly expected cost benefits will be most probably obtained by mainly improving flight efficiency(see Fig. 5). The long term target of SESAR (see Fig. 1) i.e. reducing overall ANS composite cost in Europe by 12,5% in 2020 (while air traffic will nearly double!) appears to be very ambitious.

Therefore additional and specific to target regulation may be needed. Regarding the nature of the latter, the enforced application of a single charging area in a FAB has to be carefully examined and tested prior to a global application. Structural reforms and approaches would be needed in advance to bring base costs on the same denominator.

[9] This would have been the price of a service unit if the FAB airspace was a unique charging area.

ATSPs operating in highly elastic airspaces (see para. 1.3 above) on the border of their FAB and could create unintentionally incentives to airspace users to deviate from their airspace.

This - in essence a side effect - should be avoided as in the long-term traffic deviations are not conducive to efficiency. Overall and in particular in two-tier FABs with considerable size differences among ATSPs, next to equilibrium settling one may observe adaptation of organisational characteristics as part of organisational isomorphic processes[13].

4.2 Suggested further work

It is suggested to pursue the following path of further study: develop a set of as real as possibly strategies and build a set of classes of generic ATSPs with predefined characteristics and assume two situations: a) equilibrium in the FAB is still unsettled. In this case what is the most probable NE that can be reached in the given initial conditions?, b) NE has been settled (describe it) and then one of the ATSPs decides to modify strategy towards initially drastically increasing its benefits; calculate the new NE.

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References

[1] Regulation (EC) No. 549/2004 of 10th March, 2004: Single European Sky; Framework Regulation. Regulation (EC) No. 550/2004 of 10th March, 2004: The Provision of Air Navigation Services. Regulation (EC) No. 551/2004 of 10th March, 2004: Organisation and Use of Airspace and Regulation (EC) No. 552/2004 of 10th March, 2004: Interoperability of the European Air Traffic Management Network

[2] Regulation (EC) No. No 1794/2006 of 6 December 2006, laying down a common charging scheme for air navigation services

[3] Performance Review Commission “Evaluation of Functional Airspace Block (FAB) initiatives and their contribution to performance Improvement” Produced by the EUROCON TROL Performance Review Commission upon the invitation of the European Commission DG-TREN, October 2008.

[4] ATM Cost-Effectiveness (ACE) 2007 Benchmarking Report 2007. Commissioned by the Performance Review Commission. May 2009.

[5] Regulatory Policy Institute, 2003. Study on the implementation rules of economic regulation within the framework of the implementation of the Single European Sky. Final Report, European Commission, DG Energy and Transport, Brussels.

[6] Steer Davis Gleave, 2004. Study on the financing of air traffic management (ATM) to achieve the Single European Sky. Final Report, European Commission, DG Energy and Transport, Brussels.

[7] Andrew F. Daughety “Cournot Competition” Department of Economics and Law School, Vanderbilt University, Nashville, TN 37235-1819, Sep.2006.

[8] Bertrand, J. 1883. Review of Walras’s *Théorie mathématique de la richesse social* and Cournot’s *Recherches sur les principe mathématiques de la théorie des richesses*. Translated by Friedman, J.W., in Daughety, A.F. 1988. *Cournot oligopoly - characterization and applications*. New York: Cambridge University Press (reprinted 2005).

[9] Bertrand, J. (1883) "Book review of theorie mathematique de la richesse sociale and of recherches sur les principles mathematiques de la theorie des richesses", Journal de Savants 67: 499–508.

[10] Cournot, A. 1838. *Researches into the mathematical principles of the theory of wealth*. Trans. N.T. Bacon, New York: Macmillan, 1929.

[11] Walras, Léon (1877, printed 1954). *Elements of Pure Economics*, Harvard University Press 1954

[12] Bonanno G. “Vertical differentiation with Cournot competition” Off-print from “ECOITIOMIC NOTES”, vol. 15 no. 2. Published by Monte dei Paschi di Siena, Siena, 1986.

[13] Papavramides, T.C., "Organizational Isomorphism in European Air Navigation Services", 16th International Conference on Concurrent Enterprising, Leiden – The Netherlands, June 2009.

[14] Papavramides, T.C., Aupée P., "Achieving Sustainable Performance in Natural Monopolies: The role of Strategic Planning in the European Air Navigation Services". Proceedings of IEMC2004, Singapore, Oct. 2004

[15] Papavramides, T.C. "Emerging Strategic Management Patterns in Air Navigation Services of South Eastern Europe". *Proceedings of IEMC2005*, St. John's, Newfoundland, Sep. 2005.

[16] Nash, J. "Equilibrium points in n-person games" *Proceedings of the National Academy of Sciences* 36(1):p.p.48-49, 1950.

[17] Nash, J. "Non-Cooperative Games" *The Annals of Mathematics* 54(2): p.p.286-295. (1951)

[18] Castelli, L., Debels P., and Ukovich, W. "Route-charging policies for a central European cross-border upper airspace" *Journal of Air Transport Management, Volume 11, Issue 6, November 2005, Pages 432-441.*

[19] BLUE MED PROJECT PHASE 1: FEASIBILITY STUDY FINAL REPORT *Final Release* Edition 2.0 24/06/2008.

[20] Papp E. K., Papavramides, T. C. "The Economics of the ATM Regulation in EU. The impact of the Single European Sky". Conference on Air Traffic Management Economics. Belgrade, 10 September 2009.

[21] Stiglitz J. E., & Driffil J. "Economics", W.W. Norton & Company, Inc. 2000 p.p. 276-281.