Modelling open skies agreements and air passenger competition

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Abstract

This work aims to study competitive airline behavior, regarding pricing and supply decisions, and how it adjusts to various structural assumptions, such as the existence of capacity expansion delays, by employing system dynamics simulation techniques. Results show that, in a competitive environment, the airline with the most aggressive market share expansion strategy would start transporting more passengers and sustained an advantage for the first 15 years, of a 60-year horizon, only to be undertaken by its competitor and end up sharing 50% of the market at the end. Furthermore, both airlines undercut their fares to the point of reaching their operating unit costs, which goes in line with a Bertrand competition behavior (Silva and Verhoef 2013), creating benefits to consumers.

1. Introduction

Given the promotion of a more liberal framework for international airline markets, it is pertinent to assess the role of competition in the industry. Specifically, how the entry of new carriers might modify fares and capacity in the medium and long term and how this then impacts on travelers. For this case, system dynamics has proven to be a helpful tool for the simulation and evaluation of the complexities of the airline business cycles, and the effectiveness of competitive strategies in capital intensive industries (Lyneis 2000).

In the interest of this context, the purpose of this work is to study competitive airline behavior, regarding pricing and supply decisions, and how it adjusts to different structural assumptions, such as the existence of capacity delays and different costs structures, by employing system dynamics simulation techniques. Section 2 gives an overview of the literature both from traditional modeling and within the system dynamics field. Section 3 discusses the results and policy implications. We conclude with section 4 covering conclusions and further research.[1]

2. Literature review

2.1. Airline competition models

Given the liberalisation process and subsequent "Open Skies" agreements between the United States and the European Union, member states of the latter started to pursue the promotion of internal competition in the region. One of the main researchers that studied the effect of liberal bilateral agreements in the EU is Marin (1995). The author analyses the impacts on price competition and market structure of intra-European air traffic liberalisation by proposing a theoretical model of firm behaviour in cooperative and non-cooperative scenarios. Specifically, the cooperative scenario resembles a regulated market, where it is assumed that companies behave in an oligopolistic framework with perfect collusion. In the cooperative case, the market price equilibrium outcome will be equal to a monopoly setting and a function of cost variables and market price elasticity of demand. Moreover, the non-cooperative scenario simulates a market with free entry and price competition, resembling the outcome of bilateral agreements. In that case, a Cournot-Nash behaviour is assumed

[1] A full versión of the paper is available upon request.

which yields a competitive price equilibrium, as a function of own costs and firm's own price elasticity of demand.

Following the analysis of European air agreements, Schipper *et al.* (2002) built on previous work and studied a dataset comprised of 34 routes that varied in liberalisation status between 1988 and 1982. The authors use a similar theoretical approach as Marin (1995), but assume that airlines make decisions on price and frequency of route flights. Using a Two-Stage Least Squares technique, they found that on average, in fully liberalised routes, economy fares decreased by 34 percent, and that frequencies increased by 36 percent. However, this work only accounts for short-term effects, and did not consider the effect of alliance formation in the airline industry, which is a global trend that aims to tackle soaring costs and rampant competition (Button 2009). Additionally, another acknowledged limitation is the role of capacity constraints at airports that could impede more frequencies and hence, more competition.

Following on the effects of air travel liberalisation on network structure, Adler and Smilowitz (2007) study the global alliances and merger decisions under competition, given the location of their network hubs, cost structures and revenues. The authors present a four-step game theoretic competitive merger framework, where the examination yields a state where one US airline allies with its European counterpart, and the remaining firms choose not to unite. This outcome proves to be beneficial for both European agents, whereas the non-allied US carrier is greatly affected. Furthermore, Adler and Smilowitz (2007) recognise that future research could also contemplate a combination of non-stop and hub-and-spoke flights within a network, frequency and aircraft size variables for the market share model, and an analysis of the model over time periods, in a larger network setting.

Although research in airline competition is vast, the classical approaches might be limited in their modeling capacity to reproduce the airline market system and its complexities. As Adler and Smilowitz (2007) point out, there is a need to include dynamic simulation in competition models to observe medium and long term effects of carrier decisions. Additionally, Silva *et al.* (2014) recommend the implementation of different types of airlines, and Hansen (1990) suggest the inclusion of other agents such as aircraft manufacturers, travelers, and unions in the analysis.

2.2. System dynamics airline and competition models

One of the main studies that favor the use of system dynamics in forecasting and structural analysis, with an application in the airline industry, comes from Lyneis (2000). The author explains that the aircraft manufacturing market faces a highly cyclical behaviour, which coincides with the rest of the airline industry (Vasigh *et al.* 2013). Because these cycles, such as demand fluctuations over time, the decisions of an airline on capacity expansions are challenging, as there is a risk of over (under) investing. Passenger demand is influenced by external variables such as GDP, and price and frequency elasticities, and can also be classified by region and type of traffic. On the airline side, endogenous carrier decisions such as required fleet, frequency, costs, among others are influenced by airline demand and other elements such as external costs (fuel price, inflation, regulations and congestions). These items also affect decisions from manufacturers of aircraft which must invest in capacity to reduce backlogs and to develop new technologies. According Lyneis this complex structure and its interactions makes forecasting difficult, and hence ineffective for minimising undesirable business cycles risks.

Similarly, Liehr *et al.* (2001) also acknowledge the highly cyclical nature of the airline industry and analyse its composition to recommend "cycle management" measures to mitigate shocks. As a recommendation to mitigate these effects, Liehr et al. suggest the creation of an autonomous unit within the airline to ensure quasi-continuous capacity flow.

Furthermore, Pierson and Sterman (2013) build up from previous work and developed an aviation industry behavioural dynamic model, which endogenously accounts for capacity expansion, demand, pricing, wages, among other feedback elements. By employing historical data, and estimating model parameters, they find that delays in aircraft manufacturing are not a relevant feedback on the profit cycle, as pointed by Liehr *et al.* (2001). The authors suggest that a less intense use of pricing management techniques might increase profit returns for investors. However, a closer look at a more disaggregated airline competition model is also advised to validate this recommendation.

Standard literature in airline competition, such as Marin (1995) and Schipper *et al.* (2002), employs neoclassical economic theory, where it is assumed that carriers will only make decisions on the production levels necessary to reach an equilibrium price where both firms maximize their profit functions. However, these games are usually estimated in a static setting, where firms' objectives and market structures are assigned a set of linear equations that are solved simultaneously, and yield a Nash equilibrium outcome (Viscusi *et al.* 2005).

An SD approach allows for the use of non-linear equations for the objective setting, which is analyzed by using dynamic simulation. This situation creates and interesting opportunity to build up from existing studies, theory and models to look closer at airline behavior.

3. Results[2]

With the model specification, we tested two structural scenarios, one where only one airline would serve a route, and the other where there will be two airlines competing. In the competitive scenario, we examined different strategies that two identical agents could assume: conservative-conservative, where both airlines would seek a 50% of market share; aggressive-conservative (also conservative-aggressive), where one airline aims to obtain an 80% of market share, whereas the other one plays a conservative strategy; and, aggressive-aggressive, where both airlines compete for an 80% market share.

The model simulations were done with VENSIM PLE, where we assumed a 60-year horizon, with a time step of 0.083 years, which is equivalent to a month. This means that every month the airline will decide on changes to price, given the observed adjustments on demand and supply. Additionally, ***Table 1*** presents the different parameters that were considered in the model simulations.

Table 1. Parameters employed in the model.

Parameter	Description	Unit	Base value
Demand elasticity of industry	Elasticity for intra-North America air travel at national level (InterVISTAS, 2007).	Dimensionless	-0.88
Initial reference per capita demand	The equilibrium demand at the reference price. It is represented as an average of 2 RT trips in a 400 mile route per person (illustrative).	Seat*miles/period /person	800
Reference population	The population within the OD with a propensity to travel by air (illustrative).	Person	1250
Sensitivity of Demand/Supply balance on price	The strength of balance effect of changes in D/S in the price target (arbitrary, based on Pierson and Sterman (2013).	Dimensionless	0.4

[2] The model structure and specificacion is available upon request.

Parameter	Description	Unit	Base value
Price adjustment time	As the model period unit is one year, it is assumed that the adjustment time is one month.	Period	0.083
Reference price	The price of a roundtrip seat in the route (illustrative)	$/seat	1000
Sensitivity of attractiveness to price	Lower bound elasticity from Brons et al. (2002)	Dimensionless	-3
Target market share (airline 1 & 2)	The desired proportion of market from the airline.	Dimensionless	Depends on strategy (50%, 80%)
Sensitivity of price to market share (airline 1 & 2)	The strength of differences between the current and the target market shares in the target price of the airline (arbitrary).	Dimensionless	0.25
Desired surplus (airline 1 & 2)	The percentage of additional desired capacity, compared to demand (arbitrary).	Dimensionless	0.15
Number of miles flown per seat	A trip of 400 miles RT * 50 times per period (illustrative).	Miles/period	20000
Time to adjust order (airline 1 & 2)	The time required to fulfill the order (arbitrary).	Period	0.5
Manufacturing lead time	The time required to build the capacity (arbitrary, based on Vasigh et al., 2013).	Period	2
Initial capacity (airline 1 & 2)	The number of seats for the initial period (illustrative).	Seats	50
Retirements (airline 1 & 2)	The time an aircraft is employed in the airline (arbitrary).	Period	7
Fuel costs per available seat mile (ASM) (airline 1 & 2)	Estimated cost for Delta Airlines. (Vasigh et al., 2013, table 4.5, p. 117)	Cents*seat*miles/ period	4.93
Maintenance costs per ASM	Estimated cost for Delta Airlines. (Vasigh et al., 2013, table 4.5, p. 117)	Cents*seat*miles/ period	1.09
Crew costs per ASM (airline 1 & 2)	Estimated cost for Delta Airlines. (Vasigh et al., 2013, table 4.5, p. 117)	Cents*seat*miles/ period	1.11

Other operating costs per ASM (airline 1 & 2)	Estimated cost for Delta Airlines. (Vasigh et al., 2013, table 4.5, p. 117)	Cents*seat*miles/ period	0.67
Non-operating costs per ASM (airline 1 & 2)	Estimated cost for Delta Airlines. (Vasigh et al., 2013, table 4.5, p. 117)	Cents*seat*miles/ period	8.48
Normal capacity utilization (airline 1 & 2)	Estimated historical average load factor (Pierson and Sterman, 2013)	Dimensionless	0.8
Normal profit margin (airline 1 & 2)	Estimated industry profit margin. (Vasigh et al., 2013)	Dimensionless	0.02

3.1. Monopoly scenario

When the model is adjusted to assume that there is only one airline in the market it is possible to observe different, maybe unexpected behaviors. ***Figure 1*** presents a selection of the results from the simulation; in this case, we observe a decrease in price, which might look counterintuitive. However, in this case, the specifications from the model assume that capacity from the airline cannot be used in other routes, which translates into excess capacity via a D/S balance below zero, at the beginning of the simulation period. This situation forces the airline to lower its fares in the long run. Moreover, this decrease in prices also occurs at a very slow pace, reaching its inferior limit at year 42 (compared to competitive simulations) and might not even occur if we allow for capacity transfers.

Additionally, it is possible to observe that there exist cycles that affect capacity, demand, and net income, just as observed in Liehr *et al.* (2001).

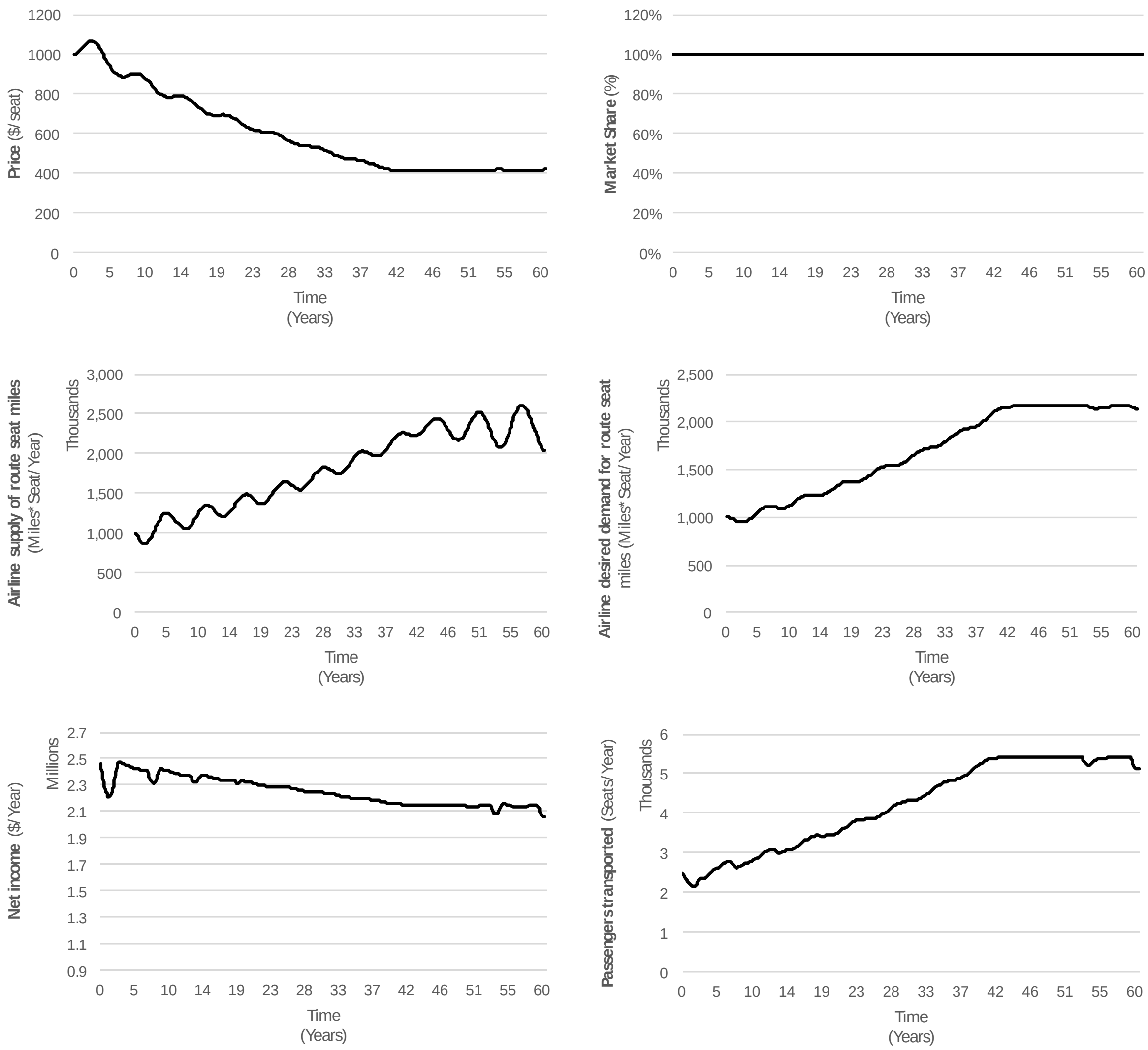

Figure 1. Monopolistic scenario results. (Own work)

3.1. Competitive scenario

For the case of the competitive scenario, we assume that both carriers possess equal characteristics but might follow different strategies. Moreover, the results presented in ***Figure 2*** depict the aggressive-conservative scenario, which shows the most variability in market share and other variables. In this case, the price level of airline 1 drops abruptly for the first ten years, to later reach a floor which is its unit operating cost. This behavior can be explained because of two effects: the initial spare capacity, compared to the airline demand, which yields a D/S balance lower than one; and, the result of the difference between the current and the target market share; both situations push prices down.

Because of this performance, airline 1 quickly starts gaining share, which translates into seat capacity growth, and a higher number of desired demand and passengers transported. However, because airline 2 holds a market share objective of 50%, it then reacts to the strategy of its competitor by lowering its fares and catching up with its capacity, after 15 years. At the end, after 20 years, airline 1 cannot maintain its competitive advantage and loses its share to airline 2. This reaction is explained by the impossibility of airline 1 to keep pushing fares downwards in the long term due to its cost structure. This might not be completely plausible, as for the last years airlines have been improving their cost structure via technological improvements and business organization, which aids in keeping competitiveness (Vasigh et al. 2013).

In this case, the first 15 years of the simulation period are similar to what Schipper *et al.* (2002) presented. However, in the long run, if there are no improvements in technology or business strategy, then airlines are not able to keep lowering fares, which was not anticipated by the authors.

Interestingly, the supply for seat miles cycles of airline 2 bears lower peaks and tend to begin shortly before airline 1 starts expanding its capacity. This might be because airline 1 reaches its 15% surplus objective before its competitor. Nevertheless, this creates a situation where due to fleet retirements and delays in the delivery of new seats, airline 2 might face a temporary undersupply of seats which cause its fares to slightly increase, because of D/S balance growth. This effect is later compensated with the provision of previously ordered capacity. However, it is not possible to reach an equilibrium, as a consequence of these cycles, which overshoots the model.

Furthermore, for the first years of the simulation, there is a considerable drop in net income that is explained by the initial excess capacity from both airlines, and the lack of new orders for the first five years. Nonetheless, as airlines compete for market share via price, they are not able to transport many passengers until they receive the new seats ordered two periods ago. Also, regardless the impossibility of maintaining market share in the model, airline 1 increases its net income considerably when it leads the route, which makes it attractive for any airline to pursue an aggressive strategy.

Furthermore, regarding the NPV of net income payoffs for different strategies in the basic scenario, Table 8, depicts how combinations of these schemes yield different results from the last model. In this case, if both players go for a conservative strategy, there will be incentives to deviate and be aggressive. Moreover, if players choose to be aggressive, then they are attracted to follow a conservative strategy. For this set of combinations, a Nash equilibrium will be either A-C or C-A, which is relatively consistent with the findings of Sterman et al. (2007). Again, a sensitivity test for the attractiveness to price from the traveler could yield more a precise set of results.

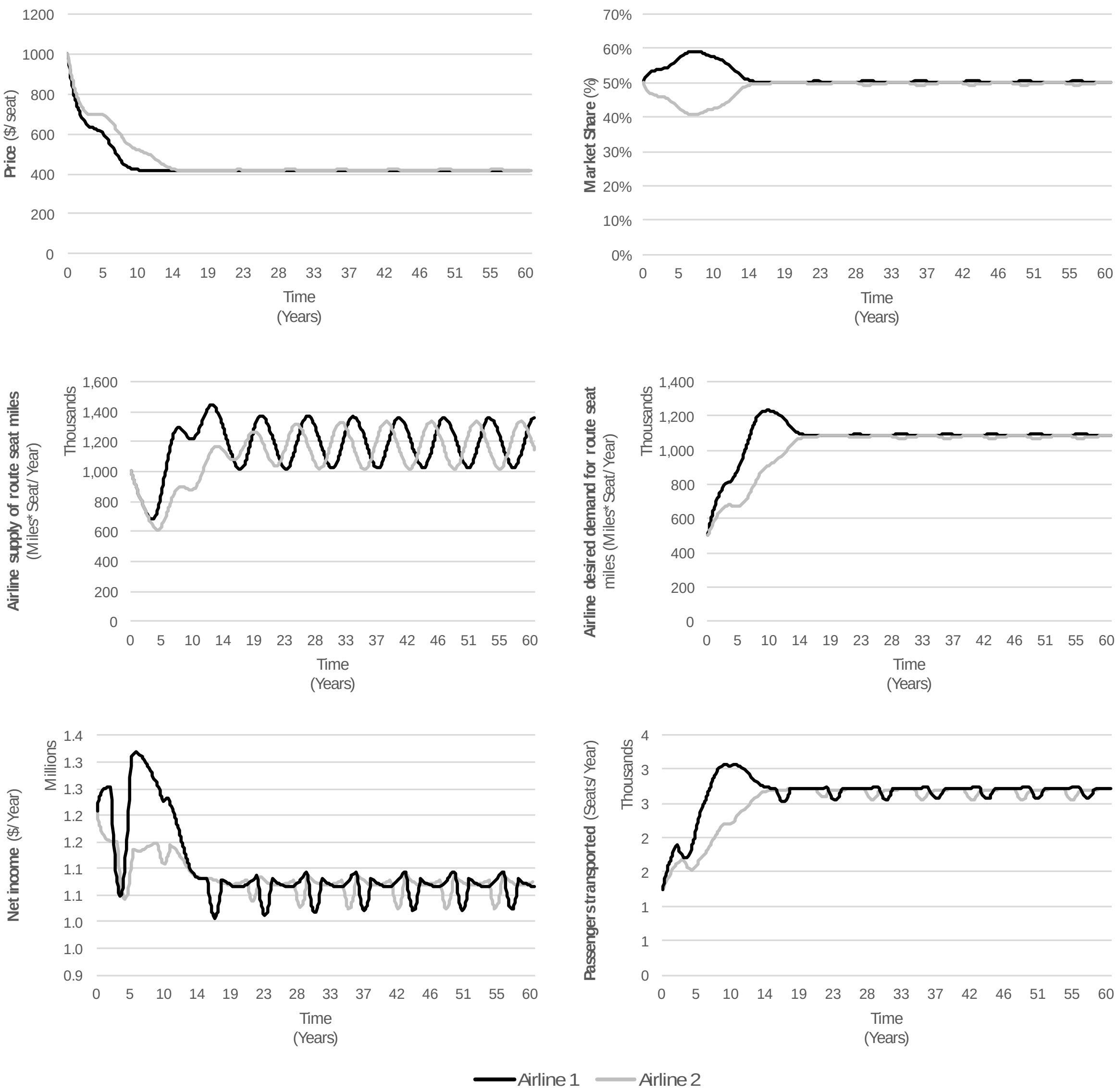

Figure 2. Competitive scenario results, for the aggressive-conservative strategy. (Own work)

Furthermore, regarding the Net Present Value (NPV) of net income payoffs for different strategies in the competitive scenario, for the first 20 years of the simulation, ***Table 2***, depicts how decisions from both agents can change the route outcomes, in terms of incomes. In this case, if both players go for a conservative strategy, there will be incentives to deviate and be aggressive. Moreover, if both players choose to be aggressive, then they are attracted to follow a conservative strategy. For this set of combinations, a Nash equilibrium will be either A-C, or C-A, which is relatively consistent with the findings of Sterman et al. (2007).

Table 2. NPV of net cumulative income payoffs for C - A strategies of the competition model, for the first 20 years of the simulation period (Million $). (Own work)

<table>
<tr><td rowspan="4">A1</td><td colspan="3">A2</td></tr>
<tr><td></td><td>Conservative (50%)</td><td>Aggressive (80%)</td></tr>
<tr><td>Conservative (50%)</td><td>15.73 | 15.73</td><td>15.3 | 16.12</td></tr>
<tr><td>Aggressive (80%)</td><td>16.12 | 15.3</td><td>14.73 | 14.73</td></tr>
</table>

In the case of the benefits for the consumer of having more competition in a route, ***Figure 3*** depicts the total number of passengers transported per each scenario. It is possible to observe that the monopoly arrangement is clearly the one where the less number of travelers use the route, compared to the aggressive-aggressive scenario, where the output is slightly larger that in the aggressive-conservative situation.

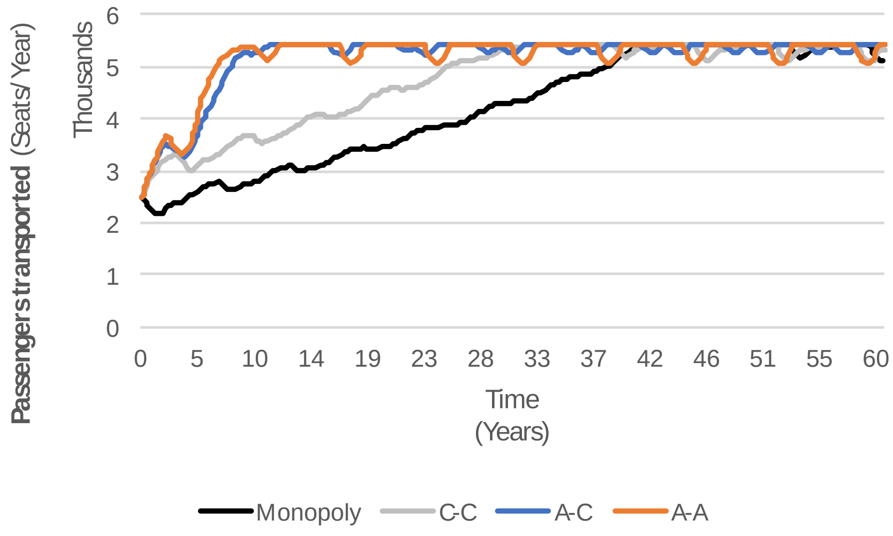

Figure 3. Total passengers transported for each scenario. (Own work)

Moreover, ***Table 3*** illustrates an estimated consumer savings for each competitive strategy. This estimation is based on OFT (2010), where they build a methodology for estimating savings from prosecuting non-competitive market arrangements such as cartels. In this case, the base calculation is the monthly turnover from the monopolistic situation, which then is multiplied by the difference in prices between the non-competitive scenario and the three competitive cases. Afterward, total savings estimation is discounted through the evaluation period and compared with the monopolistic turnover. In this case, it is possible to observe how consumer savings increase if competition between airlines becomes more aggressive.

This goes in line with Marin (1995), where the conservative scenario is the closest to the monopolistic situation (although it also offers some savings to consumers), and the most aggressive case offers greater benefits to consumers.

Table 3. Estimated consumer savings for each competitive strategy, compared to monopoly scenario, for the first 20 years of the simulation period. (Own work)

Strategy	Consumer benefit
Conservative-Conservative	23%
Aggressive-Conservative (Conservative/Aggressive)	38%
Aggressive-Aggressive	43%

4. CONCLUSIONS AND FURTHER RESEARCH

This work has explored the possibilities of employing system dynamics to model competitive airline behavior regarding pricing, capacity expansion decisions, and costs when carriers pursue different strategies. Such analysis is motivated by the promotion of the liberalization of the air markets around the world, and the need to estimate how the industry will behave, considering its specific cyclical characteristics.

The simulations of the competition model with capacity delays and a cost structure presented cycles on the supply side, as expected. These effects were transferred to the passenger demand and profit aspects of the model. Moreover, the results showed that the airline with the aggressive strategy would start earning market share and sustained an advantage for the first 15 years, only to be undertaken by its competitor to end up sharing 50% of the market, each. Furthermore, both airlines undercut their fares to the point of reaching their operating unit costs, which goes in line with a Bertrand competition behavior.

Moreover, it was found that consumer savings increase as airlines pursue a more aggressive goal in the market, compared to the monopoly situation.

As further research options, modeling dissimilarities concerning costs, resembling a legacy carrier against a low-cost airline scenario, could modify these results, bringing differences to the final shares of demand.

Regarding the airline strategies, it would be convenient to allow for the carrier to forecast future demand for capacity expansions and attempt to anticipate and respond to strategies from its competitors, as explored by Sterman et al. (2007). Furthermore, the model boundary could be expanded to include route network structures, such as hubs or point-to-point arrangements.

The potential of system dynamics in the simulation of competition is vast and could aid in the understanding the medium and long-term outcomes of air liberalization.

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