Airline Deregulation, Competitive Environment and Safety

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Air traffic has substantially increased since the introduction of deregulation in both the USA and the European Union. Moreover, aircraft accidents involving fatalities have exhibited a downward trend over time. Still, a series of recently publicized accidents has raised again a serious issue, namely whether cost reduction in a deregulated aviation environment is achieved at the expense of safety standards. To address this question, the paper proposes a mathematical model, which highlights the relationship between competitive behaviour and tort liability. The model has important policy implications suggesting that the level of airline penalisation should be reduced when market rivalry is relaxed and conversely.
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1. - Introduction

In August 2005 a Boeing 737-300 of Cyprus-based Helios Airways crashed northeast of Athens, Greece, killing everybody onboard (121 passengers and crew). This was the most serious aviation accident ever in Greece and received great attention by the media. Not surprisingly, the popular argument about the adverse effects of airline deregulation on aviation safety due to

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cost reduction practices was used. Some people raised concerns about the safety standards of low fare and charter airlines, whereas political voices against the privatisation (or closure) of the two loss-making flag carriers, that is Olympic Airlines of Greece and Cyprus Airways of Cyprus, received support.

Nonetheless, statistics provided by the International Civil Aviation Organization (ICAO) do not produce supportive evidence of increased passenger fatalities at a global level (ICAO, 2005) since the mid 1980s, *i.e.* when liberalisation in the airline business was gradually introduced worldwide. In 1986, 24 accidents involving fatalities were reported where 641 passengers were killed, that is 0.04 fatalities per 100 million of passenger-km. In 1996, there were again 24 accidents with 1,146 fatalities, that is 0.05 per 100 million of passenger-km but in 2003 there were only 6 accidents (down from 14 in 2002) involving 334 fatalities, that is 0.01 per 100 million of passenger-km (ICAO 2005). On the other hand, a recent study by Raghavan - Rhoades (2005) reveals that accident rates (when considering departure numbers) have increased in the US airline industry since the deregulation of the market in 1978 at least when the total number of accidents is considered and not just the fatal ones. Moreover, many safety problems emerge (or at least become known to the passengers) only in the case of an accident. Although competitive forces may discipline airlines to operate safely in a self-regulated environment, market failures and the increasingly important link between safety and security render some type of system surveillance necessary at national, international and supranational levels. In this context and following pressure from consumer groups, the European Union introduced a regularly-updated black list of banned airlines in 2005 (Knorr, 2006), while ICAO urges regulators to classify airlines into five categories regarding the integration of safety into their business model (Fisher, 2005).

1.1 *Adverse and Positive Effects of Airline Deregulation on Safety*

Although not ample, the existing academic literature covers several aspects regarding the implications of air transport deregulation for safety. First, there are several theoretical arguments, which stress the possible adverse effects of deregulation on the safety of airline operations. Competitive pressures may induce airlines to relax maintenance procedures and checks to reduce costs; outsourcing of maintenance and training functions may result in a loss of direct quality control; long flying hours, shorter turnaround times and staff shortages may result in mechanical failures, labour fatigue and pilot errors as well as low morale among cabin crew due to unsympathetic rostering (Icon Consulting *et* al., 2001). Moreover, the need to raise aircraft utilisation factors to achieve economies of density may induce airlines to switch to smaller aircraft and/or operate a hub-and-spoke network (Rose, 1992). These commercial decisions may result in increased airport congestion and overload of air traffic control to the detriment of safety management. Passengers deprived of direct services between their origin and destination are obliged to make a stop-over at a hub; hence, individual risk of suffering from an accident may rise as the number of flights increases. In some cases, such deprivation may also result in transport mode substitution mostly in favour of trains and cars; nonetheless, if these modes are less safe than the airplane, then the effect of airline deregulation on passenger safety is again negative (Rose, 1992).

It would be unfair to conclude, however, that airline deregulation has a negative effect on safety without considering the converse argumentation. In this context, the emergence and operational success of low fare airlines primarily in the United States and Europe belies those who believe that a low fare strategy is only financially sustainable to the detriment of safety. Airlines such as Southwest, Ryanair and Easyjet have a very young fleet of owned aircraft and use experienced and reputable pilots to minimise training costs. They fly to and out of secondary airports, hence they help reduce congestion at major airports; moreover, their direct, point-to-point services offer a good alternative to those who wish to by-pass a hub airport (Papatheodorou, 2002). In addition, their reliance on outsourcing of various activities has been rather unproblematic. Over time, specialist companies have emerged in maintenance, repairing, catering and other operations: by building on economies of scale and scope and capitalising on their experience, these companies can successfully deliver outsourced activities at a low cost and without compromising safety standards (Hirshman *et* al., 2005).

The truth, however, is that not all low fare airlines have been as successful as Southwest, Ryanair and Easyjet; in fact, bankruptcies and market exit in the sector are not unusual: Debonair, Duo Airlines and Air Polonia are just some examples. Nonetheless, there is no supportive evidence that low fare or charter airlines have a systematically higher rate of incidents or accidents compared to major flag carriers. What seems to matter here is the existence of a strict regulatory and transparent framework in both the USA and the EU, which safeguards compliance to safety standards. This is not necessarily the case in other areas of the world, where accidents occur irrespectively of the actual airline business model. Korean Airlines, the country's flag carrier, was close to expulsion from Sky Team in 1999 due to its poor safety record (Icon Consulting *et* al., 2001).

Deregulation may also activate market mechanisms to discourage airlines from deliberately compromising safety: the popular expression «if you think safety is expensive, then try an accident» conveys this message effectively. The Folk Theorem of game theory (Gibbons, 1992) is particularly useful in explaining the impact of an accident on an airline's financial position. In particular, an airline's management team should weigh the short-term savings of safety reduction against the longer-term damage in case of an accident. The resulting loss in that airline's reputation will most probably lead to a dramatic reduction in its future sales and a rise in insurance premia (Rose, 1992) and may have a devastating effect on the airline's share price (Chance - Ferris, 1987; Borenstein - Zimmerman, 1988). This is particularly the case when the airline is unable to manage accident crises effectively (Siomkos, 2000). Therefore, even if an airline is fully covered against indemnities, it may decide not to under-invest in safety operations. In addition and to avoid the spreading of negative reputation beyond the level of an individual company, airline associations such as the International Air Transport Association (IATA) have introduced strict guidelines for their members and implement safety certification schemes such as the IATA Operational Safety Audit (IOSA).

Nonetheless, there are still cases where an airline may discount the future so heavily that it can make commercial sense to reduce safety provision at present. Consider an airline, which is close to bankruptcy or which faces serious liquidity constraints. In this context, an adequate safety provision may either accentuate market exit or deny the necessary savings to generate future investment and organic growth; as a result, the opportunity cost of cutting safety is rather low. Unfortunately, this argument may be used by financially robust market incumbents to deter successful market entry as few new carriers are likely to have full accessibility to financial markets. This is where detailed and expensive certification schemes on airworthiness can play a positive role. Similar to bonding in the tour operations business, such schemes introduce institutional barriers to entry; given the sunk cost nature of related expenses, only serious and affluent investors would be willing to fund a start-up in the airline business. This very commitment should then convince (partly at least) the financial markets that it is worth relaxing any existing liquidity constraints. Likewise, destructive price competition in a deregulated environment may bring certain airlines closer to bankruptcy and induce them to revert to malpractice. To avoid this outcome, and in addition to safeguarding the appropriate use of airport and other related infrastructure (Moses - Savage, 1990), civil aviation authorities should heavily penalise predatory (that is below average cost) pricing and instigate regular financial audits in collaboration with the competition watchdogs.

1.2 *Institutional Intervention and Tort Liability*

The above argument suggests that market forces in a deregulated environment can only discipline airlines if complemented by a solid institutional framework to address information asymmetries and inefficiencies. In the absence of tight and regular safety controls, a compromise of safety standards is only known to an airline; the passenger becomes aware of it only in the case of an unfortunate incident or most commonly accident. In other words, a principal - agent problem seems to exist (Sappington, 1991): the airline provides an unobserved (by the passenger) maintenance effort; whereas the passenger observes only the outcome, that is whether the flight service has been safely delivered or not. Most passengers are risk averse and face at best oligopolistic market conditions. Hence, optimal contracting (in terms of generating the desired by the passenger effort) may command a price premium: this may provide airlines with an incentive to increase maintenance effort (and reduce the probability of an accident) without compromising profitability. Competitive pressures in a deregulated environment are expected to reduce this premium on the fare level. Nonetheless, if passengers perceive price competition as being directly related to safety (under-)provision, then a typical problem of adverse selection (Akerlof 1970) may occur leading to the complete collapse of the airline sector. Hence, private (that is airline associations) and public institutions and mechanisms should exist to address the possibility of missing markets.

In this context, the state may use tort liability as an effective deterring tool against safety under-provision. «A "tort" is an injury to someone's person, reputation, or feelings or damage to real or personal property» (CBO, 2003: VII). In the present context, tort liability refers to punitive and compensatory damages paid by the airline in case of an accident. Airlines may be fully insured against such indemnities, but as argued earlier insurance premia are expensive and their level depends on the existing airline safety records and the level of tort liability sums. As a result, the level of the latter has a real impact on the financial situation of an airline. The tort liability system has generally raised concerns about inducing irresponsible behaviour from active compensation seekers (CBO, 2003). Nonetheless, this is likely to be minimal in the present context as no passenger can pre-determine the exact outcome of a possible airline accident; in the absence of extreme inter-generational solidarity, nobody would consciously fly with a problematic aircraft, as compensation is useless in case of death (heirs and heiresses are the sole beneficiaries).

The system of tort liability is inextricably linked to the concepts of "strict liability" and negligence (Cooter, 1991). In the former case, the injurer should pay damages irrespectively of whether the injurer was at fault or not. On the other hand, under negligence rules, liability is imposed only on injurers who fail to comply. Strict liability is unlikely to be applied to the airline industry as accidents may be the outcome of *force majeure* or external factors beyond the airline's direct control, e.g. a failure in air traffic control systems. Hence, a negligence regime should be used to condemn airlines when the accident was caused either intentionally or in the absence of reasonable care to avoid it. A risk-neutral, rationally self-interested airline will be deterred from under-providing safety operations when the cost savings (from suboptimal efforts to avoid accidents) s are less than the expected costs of liability, the latter being equal to the product of the probability of having an accident p, times the probability of being found liable q, times the level of damages h. In other words, deterrence will occur when $s < p \cdot q \cdot h$ (Cooter, 1991).

The above simple mathematical expression suggests that a large level of damages h should be a sufficient deterrent, especially when transaction and other costs of regulation and litigation procedures (Wolf, 2004) reduce the probability of being condemned and hence the value of q. Nonetheless, a more through investigation of the problem may yield some undesired results. If h is too high, then an airline may find it hopeless to invest on safety measures to reduce the probability of an accident p. This is because a reduction of p beyond certain levels can become very costly (and totally undermine profitability), whereas the product of p times q times h remains above s. For this reason, an airline may either decide to exit the market or stop investing in safety just hoping to be fortunate enough to avoid an accident.

Moreover, it is also very important to consider the impact of alternative market conducts in the airline industry and their relationship with tort liability and the level of maintenance provision.

As a result of deregulation and liberalisation, an airline is free to decide on its corporate strategy versus its (potential or existing) rivals; this may range from a price war and destructive competition to full co-ordination and tacit collusion in the form of a virtual monopoly. Nonetheless, a behaviour that restricts competition may attract the attention of competition authorities, which may then penalise the airlines for (individually or jointly) abusing any potential dominant position they may possess in the marketplace. In the present context, however, the crucial issue to investigate is the impact of colluding behaviour on safety. If a cartel of airlines operates more safely than carriers, which engage in extreme rivalry, then competition authorities may have to rethink their policies when imposing fines on colluding airlines. A related arising issue is whether the actual market conduct should play a significant role when assessing the power of liability sums to discipline airlines in terms of taking all necessary safety precautions. The available academic literature does not seem to effectively address these topics: to further investigate them, the following parts of the paper develop a mathematical model and discuss its policy implications.

2. - The Modelling Exercise

2.1 *The Consumer's Side*

Following Yin (2000), the utility function of consumers can be written as:

$$(1) \qquad U = (f + a)^{\beta} (g + \gamma)^{1-\beta}$$
$$\text{s.t. } p_f \cdot f + p_g \cdot g = Y$$
$$\alpha, \gamma > 0 \text{ and } 0 < \beta < 1$$

where f is the number of flights (leaving non-integer problems aside), g is the quantity of all other goods, p_f is the average air fare, p_g is the price index of all other goods, Y is disposable income and α, β, γ are positive parameters. For $\alpha = \gamma = 0$, *(1)* reduces to the standard Cobb - Douglas function.

To maximise utility, we set the Lagrangian function as follows:

(2) $$L = (f + a)^{\beta} (g + \gamma)^{1-\beta} + \lambda (Y - p_f \cdot f - p_g \cdot g)$$
$$\text{s.t. } \lambda > 0$$

Hence, by setting $\partial L/\partial f = 0$, $\partial L/\partial g = 0$ and $\partial L/\partial \lambda = 0$ and solving for p_f and p_g, we derive the following inverse demand functions:

(3) $$p_f = \frac{\beta(\gamma p_g + Y)}{f + a(1-\beta)}$$

and

(4) $$p_g = \frac{(1-\beta)(\alpha p_f + Y)}{g + \gamma\beta}$$

2.2 *The Producer's Side*

For simplicity, we assume that flights are produced by a monopolist airline, which is facing potential entrants in all instances; as a result, the airline may engage in strategic competitive behaviour (to be discussed later). The assumption of a monopolist airline instead of an oligopoly of carriers allows us to conveniently leave aside any real life asymmetries among airlines (such as cost structure, revenues and reputation) and primarily focus on issues of tort liability and market conduct. For this reason and in order to allow for strategic behaviour, it was decided not to use a monopolistically competitive market structure, where the multitude of participating companies minimizes the role of interdependence.

Flights are produced under increasing returns to scale as follows:

(5) $$C_f = c_0 + f(c_1 + c_2 m)$$

where C_f is total cost of flights, c_0 is a fixed cost element, c_1 is a constant marginal cost coefficient related to flight operations, c_2 is a constant marginal cost coefficient related to aircraft maintenance and m is the level of aircraft maintenance per flight.

We also assume that the total flight safety level is given by:

$$S = \theta m + Z \tag{6}$$

where S is total safety level, θ is a positive maintenance parameter and Z is a set of random disturbances. If the expected value of Z is zero, that is $E(Z) = 0$, then $E(S) = \theta m$.

Based on the above, we define the probability of having an accident on one flight according to the inverse exponential function:

$$J_1^1 = e^{-\theta m} \tag{7}$$

where J_1^1 is the probability and e is the base of the natural logarithm. For simplicity, we assume no gradients in the seriousness of an accident, *i.e.* all accidents are treated the same. The choice of the inverse exponential function is arbitrary but has some desirable mathematical properties. In particular, for $m = 0$, $J_1^1 = 1$, and an accident is deterministically inevitable. On the other hand, for $m \to \infty$, $J_1^1 \to 0$, so no accident occurs. Unfortunately, however, no airline is prepared to offer an infinite level of maintenance as it would certainly go bankrupt.

Let H be the liability amount to be paid to victims by the airline for each accident. In this case, the total airline cost C becomes the sum of operating costs plus the expected liability:

$$C = C_f + E(H) \tag{8}$$

Hence, for one flight the total cost C^1 is:

$$C^1 = c_0 + c_1 + c_2 m + e^{-\theta m} H \tag{9}$$

The probability of having i accidents in f flights is given by the binomial distribution (Hogg - Craig, 1989), that is:

$$J_f^i = \frac{f!}{i!(f-i)!}(e^{-\theta m})^i(1-e^{-\theta m})^{f-i} \tag{10}$$

where the exclamation mark represents a factorial. For $i = 0$ and $f \to \infty$, $J_f^i = 0$: in other words, as the number of flights tends to infinity, the probability of having at least one accident tends to 1. Given *(10)*, the expected liability sum becomes:

$$E(H) = \sum_{i=1}^{f} \frac{f!}{i!(f-i)!}(e^{-\theta m})^i(1-e^{-\theta m})^{f-i} i H \tag{11}$$

Equation *(11)* can be simplified[1] as follows:

$$E\,(H) = e^{-\theta m} f H \tag{12}$$

As pointed out in the beginning of the modelling exercise, the monopolist airline is facing potential entrants, which may subsequently have an important impact on its competitive behaviour. This is because of the possible prevalence of contestability conditions in the market; in other words, the fear of a potential entrant following a hit-and-run strategy to seize any existing super-normal profits, may discipline the incumbent and make it adopt a more moderate pricing strategy to discourage any such entry. To quantify the degree of market contestability and hence of the competitive conduct, the concept of the Lerner Index is used (Scherer - Ross, 1990):

$$LI = \frac{p_f - MC}{p_f} \tag{13}$$

[1] Proof of this can be found in the *APPENDIX*.

where *LI* is the value of the Lerner index and *MC* is the marginal cost of flights. In the case of perfectly contestable conditions and in the absence of increasing returns to scale, $p_f = MC$ implying a zero value for *LI*. In this case, the monopolist would engage in limit pricing *à la Bertrand* to pre-empt any potential market entry. Since increasing returns to scale are present in our context the least possible value for *LI* is where price equals average cost *AC*; this is because $AC > MC$ hence marginal cost pricing would lead to financial destruction. In general, a higher value of *LI* is associated with a larger divergence between price and marginal cost due to the sustainable exercise of market power by the monopolist.

Based on the concept of the *LI* and using standard monopoly theory, we may write:

$$\frac{p_f - MC}{p_f} = \frac{1+r}{|\varepsilon|} \tag{14}$$

where ε is own price elasticity of demand and *r* is a coefficient of competitive conduct, which takes values between zero and minus one, $-1 < r < 0$. When $r = 0$, then the standard static monopoly outcome occurs. On the other hand, when $r = -1$, then $p_f = MC$ as in the case of perfect competition or perfectly contestable markets. This is equivalent to the case where $LI = 0$. In practice, the least value of *r* is such that yields a price p_f equal to average total cost.

The own price elasticity of demand may be calculated as follows:

$$|\varepsilon| = \left| \frac{\partial f}{\partial p_f} \frac{p_f}{f} \right| = \frac{\alpha(1-\beta)+f}{f} \tag{15}$$

while from *(8)* and *(12)*, we have:

$$MC = \frac{\partial C_f}{\partial f} + \frac{\partial E(H)}{\partial f} = c_1 + c_2 m + e^{-\theta m} H \tag{16}$$

Solving *(14)* for p_f yields:

(17)
$$p_f = MC \frac{|\varepsilon|}{|\varepsilon| - (1+r)}$$

Given *(3)* and *(15)*, equation *(17)* is equivalent to the following second degree equation with respect to *f*:

(18)
$$\begin{gathered} MC \cdot f^2 \\ + [-2\alpha\,(\beta - 1)\,MC + \beta\,(\gamma p_g + Y)\,r] \cdot f \\ + [\alpha^2\,(\beta - 1)^2\,MC + \alpha\,(\beta - 1)\,\beta\,(\gamma p_g + Y)] = 0 \end{gathered}$$

This equation has two roots, of which one is always negative and the other one is the optimal number of flights f^*:

(19)
$$f^* = \frac{1}{2MC}[2\alpha(\beta-1)MC - \beta(\gamma p_g + Y)r + \sqrt{\beta^2(\gamma p_g + Y)^2 r^2 - 4\alpha(\beta-1)\beta(\gamma p_g + Y)(1+r)MC}\,]$$

We note that for f^* to be positive, β must satisfy the constraint

(20)
$$\beta > \frac{\alpha \cdot MC}{\alpha \cdot MC + (\gamma p_g + Y)}$$

The economic rationale behind the existence of such a lower limit for β lies on the assumption that flights are produced under increasing returns to scale: hence, a very small weight of flights in the utility function would render their production meaningless, as demand would be too low to recover costs.

To simplify the following discussion, we rewrite f^* as

(21)
$$f^* = \frac{A\,MC - Br + \sqrt{B^2 r^2 - 2A\,B(1+r)MC}}{2MC} = \frac{A\,MC - Br + \sqrt{D}}{2MC}$$

where we set

$$A = 2\alpha\,(\beta - 1) \qquad < 0$$

(22) $$B = \beta\,(\gamma p_g + Y) \qquad > 0$$

$$D = B^2 r^2 - 2A\,B\,(1 + r)\,MC \qquad > 0$$

2.3 *Comparative Statics*

Equation *(19)* may be useful in terms of answering questions based on comparative statics. More specifically, it makes good sense to assess the impact of an increase in maintenance level m on the optimal number of flights f^* *ceteris paribus*. To do so, the partial derivative $\partial f^*/\partial m$ is calculated. We use the chain rule

(23) $$\frac{\partial f^*}{\partial m} = \frac{\partial f^*}{\partial MC} \cdot \frac{\partial MC}{\partial m}$$

The two partial derivatives are

(24) $$\frac{\partial f^*}{\partial MC} = -\frac{B[-A(1+r)MC + r(Br - \sqrt{D})]}{2MC^2\sqrt{D}}$$

(25) $$\frac{\partial MC}{\partial m} = c_2 - \theta e^{-\theta m} H$$

The partial derivative *(24)* is always negative, therefore the sign of *(23)* is determined by the sign of *(25)*. If $H > c_2/\theta e^{-\theta m}$ then m and f^* are positively correlated in *(23)*. Let H^* be the value for which $H^* = c_2/\theta e^{-\theta m}$. By taking the partial derivatives of H^* with respect to θ and *m*, we get:

(26)
$$\frac{\partial H^*}{\partial \theta} = \frac{c_2(-1+\theta m)}{\theta^2 e^{-\theta m}}$$

and

(27)
$$\frac{\partial H^*}{\partial m} = \frac{c_2}{e^{-\theta m}}$$

Equation *(27)* is always positive. Hence an increase in maintenance level *m* increases H^* and makes the condition $H > H^*$ more difficult to meet. In economic terms, a higher quantity of maintenance *m* will lead to a decrease in the optimal number of flights f^* (due to the associated total cost) unless the liability amount *H* is sufficiently high: in the latter case, it is rational to make more flights (at a higher safety level and lower accident probability) to generate sufficient revenue to pay *H*. Moreover, if $\theta m > 1$, then *(26)* is also positive. Building on the above, a sufficient level of maintenance productivity θ will generate such confidence in safety level *S* to reduce the incentive of the airline monopolist for maintenance improvements *m*.

Equation *(19)* may also be used to highlight the relationship between the competitive conduct *r* and the optimal number of flights f^*. The monopolist airline's competitive conduct is another choice variable, which in reality depends on the number and type of potential incumbents. Nonetheless, and to avoid further complications in the mathematical modelling, the present exercise treats *r* as exogenously determined. This assumption, however, does not invalidate the importance of calculating the respective partial derivative $\partial f^*/\partial r$. Using the notation of *(22)*,

(28)
$$\frac{\partial f^*}{\partial r} = -\frac{B}{\sqrt{D}}\frac{AMC - Br + \sqrt{D}}{2MC}$$

Following the assumption made to ensure that f^* is positive in equation *(19)*, the derivative in *(28)* is always negative. In other words, when r increases (tends to zero) and the competitive conduct becomes more restrictive (*i.e.* competition is relaxed), the optimal number of flights f^* decreases. This is the standard outcome of microeconomic theory. As the monopolist becomes able to exercise their market power, they will restrict output to command higher prices, reduce total costs (including maintenance) and hence to increase profitability.

Despite this rather trivial result, the derivative in equation *(28)* is useful to apply the following chain rule:

$$\frac{\partial m}{\partial r} = \frac{\partial m}{\partial f^*} \cdot \frac{\partial f^*}{\partial r} \tag{29}$$

This estimates the impact of the competitive conduct on the level of maintenance. Based on the previous analysis, the sign of $\partial m/\partial f^*$ is determined by the sign of $c_2 - \theta e^{-\theta m}H$, and $\partial f^*/\partial r$ is always negative. Consequently, if $H < c_2 /\theta e^{-\theta m}$ then the derivative *(29)* is positive. From equation *(27)* an increase in m facilitates the condition $H < H^*$; similar conclusions hold when $\theta m > 1$ given *(26)*. In economic terms, a more restrictive competitive conduct r (*i.e.* r gets closer to zero) will increase the maintenance level m unless the liability amount H is high enough in relative terms; this is because the restrictive monopolist will reduce the number of flights (to increase profitability); fewer flights, however, will allow the monopolist to increase maintenance levels and further reduce $E(H)$ without increasing total costs. On the other hand, when H is relatively high, a restrictive monopolist who reduces the number of flights will also reduce the maintenance level to generate sufficient cost savings to cover H; this strategy is rational in spite of raising $E(H)$.

The above result is striking and rather against common sense, which suggests that the obvious way to provide incentives for safety level improvement is by raising the tort liability amount to be paid. The mathematical model shows that the liability policy should first consider the underlying market structure. If the market tends to become more concentrated and less competitive then it may make good sense to reduce the liability amount H. On the other hand, as the market becomes more competitive (that is r goes down to –1) and the number of flights increases (and profitability goes down), it makes good sense to increase the liability amount; this provides an incentive for safety improvement to counter the scale (that is the number of flights) effect on $E(H)$. Otherwise, maintenance levels may deteriorate, as the airline reduces maintenance to compensate for lost profitability.

3. - Discussion and Concluding Remarks

Safety is the most important feature of the airline product par excellence. When airline markets were heavily regulated and the majority of carriers (at least in Europe) operated as government-owned agencies, the pursuance and satisfaction of safety standards was partly related to national pride: this was especially the case for smaller or less developed states, where the aviation sector was promoted as the modernisation facet of the society (Raguraman, 1997). Nonetheless, the situation is different in a deregulated and liberalised airline environment, where private airlines are free to compete against each other in various dimensions: in this context, tort liability may be effective not only in protecting passengers but also in accrediting the airline industry with the necessary reputation of maintaining high safety standards thus avoiding the potential collapse of the market due to passengers' suspiciousness (Knorr, 2006).

From a policy perspective, the mathematical model aims at contributing by suggesting that the monetary level of liability imposed on airlines should also consider an inherent feature of the liberalised environment, namely the degree of corporate rivalry. This steps beyond the current practice, which uses a blanket approach on airline penalisation irrespectively of the actual market conduct. In particular, the paper suggests that in spite of the adverse effects that limited competition may have on (higher) fares, there may be positive externalities on the safety side, which should be preserved by keeping tort liability levels low. Conversely, if the airline market is characterised by strong rivalry and low profitability, it is advisable to raise the liability amounts to deter carriers from compromising safety standards. The acknowledgement of some potential positive elements in restricting competition *vis-à-vis* the problems of excessive market competition in a deregulated aviation environment is not a new idea: for example Graham - Guyer (1999) raise environmental concerns about the rapid increase of flights in Europe after liberalisation. Nonetheless, this paper aims at jointly addressing alternative market conducts using adjusting levels of tort liability to propose a new industrial policy on aviation safety.

To derive these conclusions, the paper assumes an airline monopoly, which behaves strategically to face potential market entry; its conduct effectively ranges from limit pricing (*i.e.* equal to average cost to deter new airlines) to full profit maximisation in static conditions. This approach was used as a substitute of a detailed oligopolistic context to avoid modelling and other complications. Although this may appear as a limitation of the model, it is believed that the results are robust: this is because the essence of strategic behaviour encapsulated at present by the Lerner Index may be easily applied in a Cournot oligopolistic model modified to account for conjectural variations (*i.e.* an estimate of the sum of all rival firms' reactions to a change in a company's output) as shown by Scherer - Ross (1990). Future research may undertake this task; other suggestions to test robustness include experimentation with alternative accident probability functions (other than the exponential) and introduction of a safety price premium and/or safety-adjusted flights in the consumer utility function.

Admittedly, the successful application of this new industrial policy on aviation safety in a deregulated environment is not easy to implement in practice. In fact, there is an issue of competence and jurisdiction: antitrust authorities may have expertise on assessing market power and collective dominance in the airline market but may not have sufficient knowledge of safety issues;

conversely, the civil aviation administrators are competent in safety topics but cannot undertake a competition investigation. A possible, though crude, solution to the problem would be to mathematically associate the level of tort liability damages to a structural measure of the market, such as the Hirschman - Herfindahl concentration index (Scherer - Ross, 1990). When the HH index is high, the tort liability amount could be automatically reduced and *vice versa*. In this way, competition authorities would be indirectly designated the competency to decide on the level of tort liability. The problem of course is that a concentrated market structure and the existence of a dominant position do not necessarily imply a restrictive conduct and the abuse of market power (Papatheodorou, 2006). Still, this association may provide a useful benchmark; periodical reviews of the competitive conduct on a formal basis may then introduce any necessary re-adjustments to the level of tort liability.

APPENDIX

To prove that the expected liability sum $E(H)$ can be simplified from equation *(11)* to equation *(12)*, the following standard result (Weisstein, 1999) is used:

$$\sum_{i=0}^{f} \frac{f!}{i!(f-i)!} x^i y^{f-i} = (x+y)^f$$

By differentiating both sides with respect to x, we have

$$\sum_{i=1}^{f} \frac{f!}{i!(f-i)!} i\, x^{i-1} y^{f-i} = f(x+y)^{f-1}$$

and by multiplying them by x we get

$$\sum_{i=1}^{f} \frac{f!}{i!(f-i)!} i\, x^{i} y^{f-i} = xf(x+y)^{f-1}$$

Both sides are then multiplied by (constant) H and $x = e^{-\theta m}$, $y = 1 - e^{-\theta m} = 1 - x$ are accordingly substituted to get *(12)*.

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