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DEBT, MORAL HAZARD AND AIRLINE SAFETY: AN EMPIRICAL EVIDENCE

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DETTE, RISQUE MORAL ET SÉCURITÉ AÉRIENNE : RÉSULTATS EMPIRIQUES

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Résumé

Dans cet article, nous présentons une analyse détaillée de la relation entre les structures financières des entreprises de transport aérien et les décisions de prévention de leurs dirigeants. Nous montrons qu'un accroissement du ratio dette/fonds propres est ambigü par rapport aux décisions de prévention. Tous les modèles estimés ne rejettent pas l'hypothèse de la distribution de Poisson. Plusieurs variables financières sont significatives pour expliquer la distribution des accidents. Plus particulièrement, nos résultats indiquent que l'effet du risque moral sur la prévention est dominé par l'effet de l'investissement lorsque le ratio dette/fonds propres est positif. Par contre, le risque moral domine pour les valeurs du ratio négatives ou lorsque les entreprises aériennes ont des difficultés financières importantes.

Mots clés : Dette, risque moral, sécurité aérienne, accidents aériens, résultats empiriques.
J.E.L. : D82, G21, R40.

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Abstract

For many years, there has been a proliferation of theoretical articles on ex-ante moral hazard without any strong empirical measure of its effect on resource allocation. In this article, we present a detailed analysis of the relationship between the financial structure of airlines and the private safety decisions of managers. We show that an increase in the debt-equity ratio is theoretically ambiguous on safety: there is a trade-off between efficiency in investment and moral hazard. All estimated models do not reject the Poisson distribution assumption. Many financial variables are significant when explaining the distribution of accidents. More particularly, our results indicate that the moral hazard effect on safety is dominated by the investment effect for carriers in good financial conditions, while the moral hazard effect dominates for those experiencing financial difficulties.

Key words : Debt, Moral Hazard, Airline Safety, Airline Accidents, Empirical Evidence.
J.E.L. : D82, G21, R40.

1. Introduction

For many years, there has been a proliferation of theoretical models on information problems without any strong empirical evidence of their effects on resource allocation. The main objective of this article is to propose a detailed analysis of the relationship between the financial structure of carriers and the safety decisions of managers. Particularly, we emphasize the theoretical relationship between debt/equity ratios and private safety decisions. In other words, we study the effects of investments and moral hazard on airline accidents. We also test their empirical significance by using Poisson regression models.

Although technological change has been an important explanatory factor in the increase in aviation safety over time, economic and human factors remain significant ingredients in the study of airline accidents. It is generally recognized that safety is best achieved through a combination of liability, direct regulation and economic incentives. In other words, in the presence of externalities and asymmetrical information on safety activities between airline managers and other participants in the market, free competition is not sufficient to guarantee that carriers will produce the socially optimal level of safety. But, more importantly for our purpose, it is not clear that traditional regulatory policies are optimal when the regulator's knowledge of individual carriers' safety is limited. The problem here is that even though some safety activities and all accidents are observed by the regulator, the private effort expended by airlines to reduce accidents is not perfectly observable. Airlines still have flexibility in both their investment and safety choices and their relative access to different capital markets may affect their accident performance.

This study on the differences in safety performance across carriers identifies the economic factors influencing airline accidents. Some articles have tried to argue that the market may discipline unsafe airline operations as these would curb demand. However, evidence supporting that line of argument was found to be tenuous.[1] Following a crash of a given carrier, positive changes in the demand of competing carriers gave only a weak indication of a substitution effect. Also, whether or not crashes act as proper signals of a carrier's safety level to shareholders and travellers is a controversial issue. Crashes may be interpreted as random, "rare" events by shareholders and travellers, especially when the responsibility of the carrier has not been clearly established. Problems of the public perception of low probability events may compound this effect. The argument that crashes adversely affect the economic position of carriers and thus discipline unsafe airline operations is questionable. Statistical evidence shows that one occurrence does not significantly affect stock prices and potential demand. Moreover, when this is understood by airline managers, it may introduce some degrees of freedom in the choice of airline safety since the anticipated costs of accidents are lower.

Other analyses have tried to relate airline profitability and accident experience. They generally found no significant link between reduced profitability and higher accident rates[2]. One study that included post-deregulation data found that these links were somewhat significant for some groups of carriers. In fact, Rose (1990) provided evidence that lower profit margins are associated with worse safety performance, at least for small carriers. This study will be discussed in detail in Section 5, along with our statistical results.

Some studies have examined the link between a decrease in airline safety and the arrival of inexperienced new carriers. But safety levels, as measured by maintenance expenditures, percentages of satisfactory inspections and near midair collisions, were not found to be lower for new entrants than for established carriers.[3] The increase in commuter traffic was proposed as another source of potential decrease in overall safety for the travelling public, since prior to

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1 See Chalk (1986, 1987), Mitchell and Maloney (1989), Karels (1989), Borenstein and Zimmerman (1988) for econometric evidence.

2 Graham and Bowes (1979), Golbe (1986), Rose (1990). See Rose (1992) for an excellent survey of the different issues.

3 See Kanafani and Keeler (1989).

deregulation the safety record of commuter carriers was substantially lower than that of trunks. However, the safety record of U.S. commuter carriers showed a dramatic improvement following the 1978 safety revisions. Also, since commuter service implies fewer takeoffs and landings than between small communities and large hub jet flights, the risk for travellers to and from those communities has been reduced.[4] Because the Canadian market is much thinner than the American one, the influx of inexperienced carriers (with potentially lower safety records) has not been so important in Canada[5]. However, a great number of communities are being served by smaller carriers and their safety record has been surveyed.

Overall, previous studies found that increased competition in the airline industry did not adversely affect the level of safety. One of the major problems faced by these analyses concerns the measure of safety performance. Because fatal accidents are quite rare, they really are an imperfect measure of safety. They provide a very limited number of observations with which the statistical significance of explanatory factors can be tested. Results indicating no statistical significance are thus not particularly revealing. Accidents defined as occurrences involving bodily injury or damage to property are relatively more frequent than fatal accidents, but are still quite rare.

This article improves on previous studies by constructing a model of the firm where the safety incentives and disincentives of different hierarchical levels are specified and their relationship to the profitability of the firm and to regulatory constraints is established. The model's predictions are tested by using a more comprehensive database than that in previous analyses. In fact, one of the primary goals of this study was to construct a database that included a large number of accidents to alleviate statistical problems and to span a wide variety of carriers exhibiting different financial structures. The possibility of considering incidents as an additional measurement of

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4 See Oster and Zorn (1989).

5 On the Canadian airline industry, see Gillen, Oum and Tretheway (1985, 1989) and Withers (1989).

safety was explored. However, the data was not found to be of satisfactory quality to undertake an extended econometric analysis. Finally, we estimated Poisson models and the adequacy of the results was evaluated using dispersion tests.

In contrast to other articles, the data base of this article includes extensive data on the financial position of the firms as well as maintenance or safety expenditures. It was thus possible to determine the profitability of the firms with precision. Debt/equity ratios were used to test the hypothesis that higher levels of debt induce firms to undertake riskier activities. They also permitted the testing of hypotheses related to investments in flying equipment and safety outputs.

The discussion in the following sections is organized as follows. Section 2 presents a framework for: i) the economic analysis of aviation safety; and ii) the understanding of the effects of different financial variables on aviation safety. Particularly, it shows how the capital structure of an airline may affect its safety behavior and how debt/equity ratios can be associated with accidents. Section 3 presents the econometric model, while Section 4 is devoted to the dataset and the variables. The statistical results are reviewed and interpreted in Section 5 and a short conclusion highlights the policy implications of our study.

2. A Framework for Economic Analysis of Airline Safety[6]

Problems of externalities and asymmetrical information alone would entice economists to recommend that the safety of airline operations be regulated. What remains to be specified are the means by which safety regulation is most efficient in providing the socially desirable level of safety without presenting an undue burden. Because compliance with safety standards and level of care cannot be perfectly observed by regulators, there exists a problem of asymmetrical information that reduces the effectiveness of direct regulation. On the other hand, the incentives

6 This section is based on previous reports by G. Dionne, N. Fortin and R. Gagné (1990) and G. Dionne, R. Gagné and C. Vanasse (1991).

created by limited liability do not lead to socially optimal levels of safety, given the possibility that the parties would not be able to pay fully for harm done or would not be sued (Shavell (1984); see Danzon and Harrington (1992) for a recent survey of the main issues).

Here, in addition, we suggest that financial incentives and disincentives should be taken into account in the formulation of safety regulations. The empirical analysis of economic factors influencing accidents will determine to what extent these incentives could be used effectively. Particularly, it will verify whether financial variables are statistically significant in explaining accident rates of individual firms[7].

To formalize the allocation problem of a carrier, we extend the Brander and Spencer (1989) model. We consider a risk neutral carrier with limited liability (Sappington, 1983 and Karni, 1984) and a compulsory insurance contract covering all bodily injuries and all other injuries below an upper bound and above a deductible. Given the nature of our data (small carriers represent 85% of the population), we assume that the decision maker controls the majority of the airline equity. In other words, we abstract from agency problems between outside equity holders and managers[8] and we emphasize the *ex-ante* moral hazard problem between the manager and the banks or bondholders who finance a fraction of the investments in aircrafts and other projects. We assume that the realized profits are not perfectly observable (costly state verification) by the outside investor. The investment projects (I) are financed by debt (D) and by equity (E)

$$I = D + E. \tag{1}$$

The face value of the debt is denoted by $F \geq 0$ and is determined simultaneously with D on the bond market (or by the banks). In fact, the competitive bond market defines F as an

7 See Ravid (1988) for a review on the interactions of production and financial decisions.

8 Consequently, we do not consider debt as an investor's disciplinary device to obtain more cooperation from the managers (see Harris and Raviv (1992) and Dewatripont and Tirole (1994), for more details on this role of debt)

explicit function of D and E:

$$F = F(D, E). \tag{2}$$

Even in the presence of insurance, airline accidents are costly. We assume that the total number of passengers is a decreasing function of the total number of accidents (y) in a given period. However, more investments (I) in airplanes and airport facilities increase the airlines' output. We can set the revenue function $R(I, y)$ as a function of I and y, and assume that $R_I > 0$ and $R_y < 0$ with $R_{II} < 0$ and $R_{yy} < 0$. The manager (and his employees) affects the accident distribution $G(y/e)$ (with density $g(y/e)$) by his (their) effort (e) which is costly ($C(e)$ with $C_e > 0$, $C_{ee} > 0$)[9] and undesirable. We assume that more effort generates lower accidents distributions in the sense of the monotone likelihood property which implies that $\frac{\partial}{\partial y}\left(\frac{g_e(y/e)}{g(y/e)}\right) < 0$ for all $e \in [\underline{e}, \overline{e}]$ and all $y \geq 0$. In other words, more effort implies first-order stochastic dominance ($G_e(y/e) \geq 0$ for all y) or reduces the expected number of accidents.

The debt contract[10] defines a critical number of accidents (y^*) such that

$$R(I, y^*) - F = 0. \tag{3}$$

y^* is a function of I and F, the face value of the debt. By total differentiation of (3) we verify that:$y_I^* = -\frac{R_I}{R_y} > 0$ and $y_F^* = \frac{1}{R_y} < 0$ which means that more investments increase both the profits and the critical level of accidents for bankruptcy, while an increase in the face value of debt decreases that critical level.

For a given financial structure, the optimal level of effort in safety (e^*) solves the following problem:

$$\max_e V(e; I, F) = \int_0^{y^*} (R(I, y) - F)\, g(y/e)dy - C(e) - v(E)$$

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9 We limit our interpretation of the effort cost to its monetary value.

10 It was shown recently in the literature on security design that the optimal financial contract is generally a debt contract when *ex-ante* and *ex-post* (costly state verification) moral hazard problems are present (Dionne and Viala (1992, 1994)). See Harris and Raviv (1992) and Allen and Winton (1992) for recent surveys on security design.

where $v(E)$ is the owner's opportunity cost of equity.

The first-order condition is equal to

$$V_e = \int_0^{y^*} (R(I, y) - F)\, g_e(y/e)\, dy - C_e = 0.$$

The second-order condition (V_{ee}) is assumed to be strictly negative.

From Innes (1990) and Dionne and Viala (1992) it is known that e^* is lower than the socially optimal level of effort (e^{**}) corresponding to the full information situation. Since the effort of the carrier cannot be monitored without costs by the investors and since the carrier does not receive all the benefits associated with more effort, the latter has less incentive for safety.

For our purpose, the following comparative statics results are of interest:

$$\frac{de}{dF} = \frac{1}{V_{ee}} \int_0^{y^*} g_e(y/e)dy \leq 0, \tag{4}$$

which is always true since by assumption $G_e\,(y/e) \geq 0$ for all y. An important interpretation of this result is that moral hazard is more significant when the face value of debt is higher. In other words, for a given level of investment, a higher F means more accidents since it reduces the range of benefits where the owner receives a return from his effort.

Moreover,

$$\frac{de}{dI} = \frac{-1}{V_{ee}} \left[\int_0^{y^*} R_I(I, y)\, g_e(y/e)dy \right] > 0, \tag{5}$$

if $g_e(y/e) > 0$ for all $y \leq y^*$, which is a stronger assumption[11] than the one used to sign (4). This means that higher investments increase the efficiency of effort for a given level of debt.

The preceding results define a relationship between the optimal level of effort and both the investment and the face value of the debt:

$$e = h\,(I,\, F)\,. \tag{6}$$

11 However, we can show that $g_e\,(y/e)$ is always positive in the interval $[0, y^*]$ if F is sufficiently high and $e \in [\underline{e}, \overline{e}]$. This result uses the fact that $y^*_F < 0$.

We are now ready to study the effects of borrowed funds and equity on safety. Since investment and face value of the debt are themselves determined by the choices of borrowing and equity, we can substitute (1) and (2) in equation (6) and obtain

$$e = h(D + E,\, F(D,\, E)) \equiv e(D, E), \tag{7}$$

which implies that $\dfrac{de}{dD} = \dfrac{de}{dI} + \dfrac{de}{dF}\dfrac{dF}{dD}$ and $\dfrac{de}{dE} = \dfrac{de}{dI} + \dfrac{de}{dF}\dfrac{dF}{dE}$.

Under general conditions[12], we can show that $\dfrac{dF}{dD} > 0$ while $\dfrac{dF}{dE} < 0$. It follows that the effect of borrowing (D) on safety is ambiguous since the two effects have opposite signs. Borrowing increases investment and consequently increases the efficiency of effort $\left(\frac{de}{dI}\right) > 0$. This increase in effort can be reversed by the potential increase in the face value of the debt (F) since the owner becomes the residual beneficiary of profits over a smaller set of states of nature which reduces the incentives of effort $\left(\frac{de}{dF}\,\frac{dF}{dD} < 0\right)$. In other words, there is a trade-off between efficiency in safety and moral hazard. However, an increase in equity (E) unambiguously increases effort or safety $\left(\frac{de}{dE}\right) > 0$ since there is no moral hazard effect. *Therefore, an increase in the debt-equity ratio* $\left(\frac{D}{E}\right)$ *is ambiguous on effort and consequently on the number of accidents.* In the empirical section of the paper, we will test directly the relationship between debt-equity ratios and accidents.

Under private information, it is clear that debt will be used only if the owner is wealth constrained. In fact, this seems to be the case in the airline industry since the purchase's of new aircrafts are mainly financed by bonds or more generally by debt. Therefore, those firms that finance the investments by debt really face the above trade-off between investment efficiency and moral hazard. New aircrafts increase efficiency in safety while their financing by debt reduces the entrepreneurs' incentives for safety since it keeps profits over a smaller set of states of nature than equity does.

12 The detailed derivation is available upon request from the authors.

Up to now we have assumed that debt is used only for variations in investment projects. In some circumstances, the entrepreneur may have to substitute borrowed funds for equity because the opportunity costs of equity have increased. This is particularly true for firms near bankruptcy which have to borrow money in order to survive or to pay their current expenditures or current claims. Moreover, banks can renegotiate the debt with equity holders in periods of financial crisis in order to alter the terms of the loans instead of forcing bankruptcy. This type of renegotiation is particularly observed when bankruptcy costs are high or when the market value of aircrafts is higher than their book value.

These changes in the capital structure for a given level of investment can be formalized by differentiating the profit constraint of the bondholder (or the bank):

$$D(1+i) = F \cdot G(y^*/e) + \int_{y^*}^{\infty} R(I,y)g(y/e)dy - (1 - G(y^*/e))A \tag{8}$$

where A is the auditing cost. The total differentiation of (8) with respect to D and E for a given I yields:

$$\frac{dF}{dD} - \frac{dF}{dE} = (1+i)/H \tag{9}$$

where $H \equiv G(y^*/e) + \int_{y^*}^{\infty} R(I,y)\, g_e(y/e)\, dy$, which has to be positive to obtain a positive marginal opportunity cost of equity at equilibrium since this opportunity cost is equal to

$$v'(E) = (1+i)(G(y^*/e))/H \ . \tag{10}$$

Now differentiating (6) holding I constant and substituting borrowed funds to equity yields from (9)

$$\frac{de}{dD} - \frac{de}{dE} = \frac{de}{dF}\left(\frac{(1+i)}{H}\right) < 0 \ . \tag{11}$$

This means that when firms borrow money only to refund equity or to pay current claims when they are in financial difficulties, they reduce effort or safety and should have more accidents than firms who use borrowed funds to make investment. This behavior will also be tested in the empirical section of the article. We will, in fact, verify whether near bankruptcy airlines have more accidents than those in a better financial situation.

3. Econometric Model

The choice of the econometric model must be guided by the nature of the data and the hypothesized underlying process generating it. In the following econometric analysis, the dependent variable (the number of accidents in a given period) is a count, taking only non-negative integer values. In the analysis of such variables, it is natural to use econometric models based on discrete distributions. Much of the econometric research and applications in that field introduced the Poisson regression model as a starting point[13].

If Y_{it} is the number of accidents for the ith firm at time t, and X_{it} is a vector of observed exogenous variables for firm i at time t, the probability of having y accidents is equal to

$$P(Y_{it} = y | X_{it}) = \frac{e^{-\lambda_{it}} \lambda_{it}^{y}}{y!} \quad , \tag{12}$$

where $\lambda_{it} = \exp(X_{it}\beta)$. It follows that $E(Y_{it}|X_{it}) = V(Y_{it}|X_{it}) = \exp(X_{it}\beta)$. Under usual conditions, one can obtain maximum likelihood estimates of the β vector of parameters. However, the basic Poisson assumption that the conditional mean and variance of Y_{it} (given X_{it}) are equal may not be supported by the data. Inappropriate imposition of this restrictive assumption (termed equidispersion) may produce estimators without the desired properties[14].

Deviation from the equidispersion hypothesis can be the consequence of numerous different factors. Most of them can be related to unobserved or unmodelled heterogeneity. Gouriéroux,

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13 See Boyer, Dionne and Vanasse (1992), Dionne and Vanasse (1992) and Rose (1990) for applications on accidents and Gurmu and Trivedi (1992) for a survey of other applications.

14 See Gouriéroux, Monfort and Trognon (1984a and b) and Cameron and Trivedi (1986) for a discussion of the effect of inappropriate restrictions in Poisson models on standard errors of estimators.

Monfort and Trognon (1984b) introduced a specification error in the regression component of the Poisson distribution where the error term is the consequence of unobserved or omitted explanatory variables independent from the exogenous variables. Conveniently assuming the error term to be gamma distributed, they obtained a negative binomial distribution allowing for overdispersion where the conditional variance is greater than the conditional mean[15].

With panel data, it is common to suspect the presence of unobserved individual or firm specific effects. Hausman, Hall and Griliches (1984) presented count data models with both fixed and random effects. They obtained models allowing for overdispersion.

Using the relation between duration models and count data models, Gouriéroux and Visser (1992) also showed that unobserved spell specific factors in the duration model can lead to overdispersion or underdispersion (conditional variance smaller than conditional mean) in the related count data model[16].

Since neglecting dispersion can affect our conclusions about the statistical significance of the effects of the explanatory variables on the distribution of accidents, it is important to test for its presence. Our dataset is a panel (unbalanced). Therefore, the presence of dispersion may be the consequence of unmodelled heterogeneity and/or unobserved firm specific effects in addition to potential spell specific factors. Consequently, the adequacy of our Poisson regression results will be evaluated using dispersion tests proposed by Cameron and Trivedi (1985, 1986). These tests are limited to the detection of dispersion in Poisson models but they do not permit the identification of the sources of dispersion, if any. When the equidispersion hypothesis is rejected,

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15 Hausman, Hall and Griliches (1984) obtained a similar distribution by introducing intrinsic randomness. Moreover, Gouriéroux and Montfort (1989) introduced the ALDP model allowing more flexibility in the choice of the distribution of the error term. The ALDP model may have the Poisson and negative binomial models as special cases.

16 In the presence of dispersion, models based on the Katz family of distributions may also be used. These models allow for under – and overdispersion (see King (1989) and Winkelmann and Zimmermann (1991)).

the standard Poisson model is not appropriate. Instead, one must use models that explicitly take into account heterogeneity and/or firm specific effects.

4. Data and Variables

The different econometric models are estimated with data on Canadian carriers of levels 1, 2 and 3[17]. Most of the data have been provided by Statistics Canada on a quarterly basis from 1976 to 1987. The accident records of carriers were obtained from the Canadian Safety Board and the North variable was provided by Transport Canada. The sample used in this study has been constructed with four different datasets: operating statistics (departures, hours flown, etc.), revenues and expenses (unit toll and charter revenues, labor expenses, fuel, etc.), balance sheet and data on accidents. We have information in at least one of these four datasets on 5767 quarterly observations for a total of approximately 120 carriers[18]. However, there are several missing observations in each dataset except for the accident dataset which is complete. Observations are missing for several reasons. For instance, the balance sheet dataset was not computerized before 1981, so it is likely that several carriers are missing in this dataset. In addition, a carrier could have reported annually its balance sheet and failed to report quarterly other types of information (or vice-versa). Observations for which needed information was not complete were eliminated as well as some other observations because of inconsistencies[19]. We came up with a sample of 3249 observations with information on all variables. This sample represents 56 % of the potential observations and missing cases may be considered as random events.

17 Level 1 includes carriers with at least 1,000,000 passengers per year. Level 2 is for carriers transporting at least 50,000 passengers per year but no more than 1,000,000. Level 3 carriers transport at least 5,000 passengers but no more than 50,000.

18 For many carriers, information is not available over the entire period of the study (1976-1987) because some of them entered the industry after 1976 or exited the industry before 1987. Thus, for these carriers, we do not have 48 observations (4 quarters, 12 years).

19 For example, in some cases, carriers are reporting hours flown but zero departure.

Also, we have deleted *133* observations because the operating margin, debt-equity ratio, working capital or maintenance expenditures per departure were lying outside a range of 3 standard deviations each side of their mean[20]. The final sample therefore includes 3116 observations.

This is the basic sample from which most of the econometric estimations were performed. We also used another sample for the models which include lagged variables. This additional sample is much smaller (*2157* observations) because for several carriers information is not available each year or each quarter within a year. Hence, several observations were deleted because the information was not available at the preceding quarter or for the four preceding quarters. The variables retained for the econometric analysis are defined in the appendix.

The variables used to explain the distribution of accidents first control for risk exposure and operating conditions. The total number of hours flown (HOURS) accounts for risk exposure while the variable SPEED is used to approximate the average type of aircraft used by a carrier. A positive sign is predicted for HOURS while a negative sign is predicted for SPEED since jets are safer than other types of aircraft. A dummy variable (NORTH) captures the effect of particular weather conditions and a time trend (TIME) controls for the evolution of technology over time. A negative sign is predicted for TIME while a positive one should be observed for the NORTH variable. Finally, a dummy variable (SMALL) controls for the size of the airline.

The analysis of financial effects on safety output starts with the introduction of revenue and expense variables (FE, the total maintenance expenditures per departure; OMARG, operating margin) and financial variables (DERATIO, debt over equity; WC, working capital). Operating margin was used by Rose (1990) as a profitability measure and its predicted sign for the current period is ambiguous since more profits may also indicate less expenditures on safety. The FE

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20 See below for the exact definitions of these variables.

variable is more accurate to measure safety activity. A negative sign is predicted. WC reflects liquidity differences between airlines. This variable is a complement to operating margin.

From the theoretical model presented in Section 2, we have a trade-off between efficiency in the investment effect and the moral hazard effect on safety for those airlines that use borrowed funds to finance investment projects like the purchase of new aircrafts. If the investment effect dominates the moral hazard effect, a negative sign should be obtained for DERATIO. We also obtained that, for firms near bankruptcy that substitute debt for equity at a given level of investment, the moral hazard effect should dominate. Therefore more accidents are predicted for airlines experiencing financial difficulties.

In our dataset we have access only to accounting equity which can be negative when a carrier experienced recurrent financial losses. We used two DERATIO variables (positive, DERATIOP; and negative DERATION) and we predict that the near bankruptcy effect should be more important with DERATION.

In addition to current values of OMARG, DERATIO and WC, we also introduced one quarter lags for these variables. In the case of annual data (DERATIO and WC), we used the average value of the four preceding quarters. Lags help to capture the effect of persistent financial conditions on accidents. It also helps to smooth annual data to quarterly figures. However, since our sample is an incomplete panel dataset, lagging is limited to one quarter because too much observations would have to be dropped with higher order lags.

Table 1 presents the means and standard deviations of the variables for both samples used in the econometric analysis.

(Table 1)

A close look at Table 1 reveals two interesting facts. First, the frequency of accidents may seem quite high at around 10%. This is explained by the fact that in this study we consider all types of accidents regardless of their gravity and also carriers of all sizes and types[21]. Second, in both samples, the means of operating margin and working capital are negative. These figures illustrate the precarious positions of airlines, even under economic regulation. Moreover, a breakdown of OMARG and WC shows that it is mostly small carriers which experienced financial difficulties.

5. Econometric results

All the following results are based on Poisson regressions. As pointed out in Sections 3 and 4, our sample is an incomplete panel and one may suspect the presence of unobserved firm specific effects. It is then important to test for misspecification of the Poisson model. For each estimated models of Tables 2 and 3, we computed the score test statistic of Cameron and Trivedi (1986). Under the equidispersion hypothesis, this statistic is asymptotically normal (N(0,1)). We do not reject the equidispersion hypothesis for all of the estimated models. Consequently, neglecting the panel aspect of the data does not affect the results.

Tables 2 and 3 present the maximum likelihood estimates of the parameters for six econometric specifications. The χ^2 goodness of fit statistics indicate that all six models fit the data at any reasonable confidence levels[22]. Models 1, 2, 4 and 5 were also estimated with the restricted sample of *2157* observations and the results[23] are almost identical to those presented in Tables 2 and 3.

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21 We used the definition of accident of the Canadian Safety Board. This definition encompasses all kinds of accidents from crashes with many deaths to a broken landing gear following landing on an icy runway in the arctic region. It excludes of course near mid-air collision and other types of incidents. Furthermore, for level I and II carriers our sample's rate of accidents per thousand departures is .0111 which is identical to the rate computed by Rose (1990) for the U.S. However, the rate for level III carriers in our sample is .107.

22 However, since the goodness of fit statistic has no upper bound, it cannot be used to compare the models.

23 The complete results are available upon request from the authors.

(Table 2)

(Table 3)

The results of Models 1 and 4 can be compared to those of Table 2 in Rose's article (1990) where the operating margin coefficients for small firms range from –2.04 to –2.77 and are statistically different from zero at a 10 percent level or better. Her coefficient for medium firms is significant only for her fixed effect specification which is the most comparable to that of our Model 4 in Table 3. In Rose's study, the estimated coefficients are not significant for large firms, a result that we obtain for big airlines in our study. However, our coefficient of OMARG·S is *positive* and statistically significant which means that increased profitability for small carriers (about 85% of our two samples) is associated with more accidents. Although this result can be useful for the administration of public safety, it does not necessarily indicate that carriers with large operating margins spend less resources on safety since different levels of operating margins can be explained by many variables other than maintenance expenditures. Moreover, the interpretation of this variable is not straightforward. Do higher operating margins mean that airlines have more funds for safety or do they mean that airlines reduce their maintenance expenditures during the period under study? Since, in Model 4, we used operating margins of the current period only, both interpretations are equally valid. We did reestimate Model 4 by adding LOMARG·S and LOMARG·B and the results were not affected (Model 4.a in Table 4). They are similar to those of Model 6 which is Model 4.a with additional explanatory variables:

(Table 4)

A more precise variable to measure the correspondence between the number of accidents in a given period and the different airlines' safety efforts is the level of maintenance expenditures per departure (FE). This variable is included in Models 2, 3, 5 and 6. We observe from Tables 2 and 3 that its coefficient is negative in Model 2, regardless of the carriers' sizes and negative only for small airlines in Model 5. This result is very important, and, to our knowledge, was not published in any other study where many exposure and financial variables were considered together. It first shows precisely that the operating margin variable is a questionable proxy for safety expenses. It also indicates that if safety is regulated in such a manner that accidents are supposed to be independent of economic considerations, small Canadian carriers do affect their level of accidents by modifying their level of maintenance expenditures. In other words, even under strict safety regulation, carriers seem to trade-off *ex-ante* profits with *ex-post* costs of accidents. We also observe that the addition of other financial variables in Model 6 does not affect the result obtained in Model 5.

Another important result concerns the debt/equity ratio variables. We first observe from Model 2 that the coefficient of the positive DERATIO variable is statistically different from zero and negative, while the coefficient of the negative definition is not different from zero. The associate dummy variable (DUM) is also not significantly different from zero. This means that the two variables have different slopes but the same intercept. Below we present a graphical interpretation of these results[24]:

(Figure I)

Figure I shows that the investment effect $\left(\frac{de}{dI}\right)$ associated to an increase in the positive current debt/equity ratios dominates the moral hazard effect $\left(\frac{de}{dF}\frac{dF}{dD}\right)$. More debt, for a given level of equity, increases the efficiency of the safety effort by permitting more investments in aircrafts, for example. Model 5 indicates, however, that this result is significant for small airlines only. It seems that the current debt/equity ratio affects only the managers' behavior of

24 The estimated slope of a given explanatory variable (x_j) is equal to $\exp\,(x\beta)\cdot\beta_j$ and its variation is given by $(\beta_j)^2\exp\,(x\beta)$. Note that the calculated values are a function of all other variables in the regression component $(x\beta)$.

small firms under asymmetrical information. One interpretation is that these carriers may be less scrutinized by the safety authority since many of them do not use large airport facilities.

Models 3 and 6 introduce other important results. They show a negative coefficient for the negative lagged debt/equity variable (LMDEN)[25]. Recall that this ratio is average debt over average equity of the four previous quarters. A negative ratio means that the average value of equity during the previous four quarters was negative, which can be interpreted as a situation of near-bankruptcy. Figure II below is useful for more interpretation.

(Figure II)

We see that those airlines with large debt and negative equity have more accidents which is consistent with the interpretation that the moral hazard effect dominates the investment effect for airlines that are nearbankruptcy. Recall that the moral hazard effect is due to the fact that the owner-manager is interested only in the non-bankruptcy states. We want to emphasize here that our interpretation differs from that of Golbe's (1988). Here, the near-bankruptcy effect is a first-order dominance effect on the expected number of accidents while Golbe focused on mean preserving spread effects. Since our statistical results do not reject the Poisson assumption, it can be convenient, however, to use both interpretations if we restrict the definition of increasing risk to that of a greater variance.

All of the above results were obtained when appropriate control variables were introduced. We used some proxy variables for risk exposure such as HOURS and NORTH and other control variables such as SPEED and TIME. The TIME variable took into account the evolution of the safety technology over time and the change in the composition of the sample. As we can see, its coefficient is significant at a 1% confidence level with a negative sign. The coefficients are

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[25] Since we did not have many observations with negative values, we were not able to separate the bigger airlines from the smaller ones.

very stable from one model to the other. The same comment applies to the variable NORTH which takes into account the particular operating conditions in the Northern region designated in 1987. Since accidents are rare, random events, many other factors (that we find on accident reports, for example) other than those used in the above econometric analysis may have been the real causes of the events. However, this information on accident reports cannot be used in the different models of Tables 2 and 3 since we do not have information on the average conditions when there is no accident.

Two other significant variables were introduced as control variables, namely HOURS and SPEED. The variable SPEED was a proxy for the different types of airplanes and the variable HOURS approximated risk exposure. Both variables have the appropriate significant effects on the number of accidents.

6. Conclusion

In this article, Poisson models of airline accidents have been estimated and their adequacy evaluated with dispersion tests. We have shown that some financial variables are significant when explaining the distribution of airline accidents in Canada during the period 1976–1987. Particularly, the econometric results indicate that both maintenance expenditures per departure (FE) and debt/equity ratio variables have statistically significant effects on the accident frequency. More importantly, the statistical results indicate that the moral hazard effect on safety is dominated by the investment effect for positive values of debt/equity, while the moral hazard effect dominates for negative values (when firms have more financial difficulties). This means that airlines' financial conditions affected their safety choices during that period. These results seem to indicate that Canadian carriers trade off safety with other activities in a period characterized by both a strong regulation of aviation safety and an economic regulation of the industry. The statistical results also clearly indicate that the designated northern area (identified by the variable NORTH) represents a more dangerous region for flying and that the type of aircrafts (measured by the proxy SPEED) is a significant explanatory factor in airline accidents. Other control variables in the models such as time and hours flown are also significant.

Since the period of analysis ended in 1987 (or one year before the deregulation of the industry), it is difficult to propose any strong recommendation for public policy based on the results of this analysis, although they can be useful for the discussion of future modifications of the regulatory scheme on aviation safety. However, the results of the different models indicate that financial variables are important in order to understand the distribution of airline accidents and that they should be considered seriously in any discussion of safety regulation[26], particularly in an environment of asymmetrical information on safety activities between the regulator, the carriers and the investors.

At least, the results of this study confirm the necessity for the safety regulation agency to have access to financial data of airlines. They also stress the importance of maintaining records on financial variables even in countries where there is no more economic regulation of the airline markets.

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26 See Rochet (1992) on capital requirements and regulation of commercial banks.

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APPENDIX

Definitions of Variables

NACC	:	The total number of accidents in which the carrier is involved during a quarter. We use the definition of the Canadian Safety Board: an accident is an event in which there is material damages and/or casualties (deaths or injuries). Observations for this variable range from 0 to 4 which justifies the use of count data econometric models;
HOURS	:	The total number of hours flown. This variable accounts for risk exposure. We used HOURS instead of the total number of departures because the former was more accurate and reliable (particularly for charter activities). We want to note, however, that HOURS and departures are highly correlated (0.95) in our sample. Finally, the number of departures was introduced in the definition of FE (see below). A positive sign is predicted for the coefficient of HOURS;
NORTH	:	A dummy variable with NORTH=1, if the carrier regularly served (50% or more of the activities) the designated northern area (National Transportation Act, 1987). NORTH=0, otherwise. This variable captures the effect of particular weather conditions of this region on airline safety. A positive sign is predicted;
SPEED	:	The ratio of total number of kilometers over total number of hours flown. This variable is a proxy for the average type of aircraft used by a carrier. A negative sign is predicted since, in general, jets are safer;
SMALL	:	A dummy variable with SMALL=1 if total operating revenues (quarterly) are less than $5 000 000 (in 1986 dollars)[27]. SMALL=0, otherwise. This variable acts as a complement to SPEED and NORTH since, in general, smaller carriers fly with smaller planes and more often in the designated northern area. Since SPEED is not a perfect measure of the fleet of a carrier and NORTH cannot take into account all the effects of bad weather conditions, we expect a positive sign for SMALL;
TIME	:	A time trend with t = 1 in 1976, t = 2 in 1977, etc. This variable controls mainly the evolution of technology over time. A negative sign is predicted since technological change helped to improve safety;
FE	:	The total maintenance expenditures per departure (in 1986 dollars). Total maintenance expenditures include expenditures on flight equipment maintenance and ground and property maintenance. It is a proxy for flight equipment maintenance since both types of maintenance are not reported separately in all cases. However, when data was available, we verified that more than 80% of maintenance expenditures were for flight equipment. More maintenance expenditures per departure means more safety and therefore less accidents;

27 Variables expressed in dollars have been deflated with the GDP price index, 1986 = 100. Source: Statistics Canada, CANSIM D 20556.

OMARG : Operating margin defined as 1 – (operating expenses/operating revenues). Operating margin is a profitability measure. More profits may indicate that airlines reduced their expenditures on safety during the period under study. Therefore, OMARG may have a positive sign.

LOMARG : Operating margin of the preceding quarter. More profits in the past may indicate that airlines have more funds today for safety, therefore LOMARG should have a negative sign;

DERATIOP : Debt over equity when equity is non-negative. Since both debt and equity come from the balance sheet of the carriers, it is reported on an annual basis. Thus, for a given year, the same value of DERATIOP appears at each quarter for a carrier. Equity can be positive or negative because it corresponds to accounting equity which is financial equity plus accumulated profits. Accounting equity can be negative when a carrier experienced recurrent financial losses. From the theoretical model, the effect of DERATIOP on accidents is ambiguous. On the one hand, a higher debt-equity ratio may indicate more investments which in turn may increase the efficiency of safety activities (negative effect on accidents). On the other, a higher ratio may signal less incentive for safety under moral hazard (positive effect on accidents);

DERATION : Debt over equity when equity is strictly negative (annual values repeated quarterly). Like DERATIOP, the effect of this variable on the number of accidents is ambiguous;

LMDEP : The ratio of the average debt and the average equity of the four preceding quarters when the average equity is strictly positive. This variable serves two purposes: it permits the introduction of lags in the analysis and it offers a method for converting annual values to quarterly ones. LMDEP helps to capture the effect of persistent financial conditions on safety. It has the same interpretation as the current debt-equity ratio;

LMDEN : The ratio of the average debt and the average equity of the four preceding quarters when the average equity is strictly negative. Like LMDEP, it captures the effect of persistent financial conditions. In particular, when LMDEN is low, it may indicate that the carrier is in a near bankruptcy situation. In this case, the coefficient of LMDEN can be interpreted as the effect of near bankruptcy on accidents[28];

[28] The effect of this variable is different from those discussed in precedent analyses on near bankruptcy (see, in particular, Golbe (1988)). Traditional analyses are based on second-order stochastic dominance (mean preserving spread) while our analysis is concerned with first-order stochastic dominance.

DUM	:	A dummy variable with DUM =1 if current equity is strictly negative. DUM = 0, otherwise; this variable was introduced to take into account the intercept differences between positive and negative debt-equity ratios.
DUMLMDE	:	A dummy variable with DUMLMDE = 1 if the average equity of the four preceding quarters is strictly negative. DUMLMDE = 0, otherwise; same role as DUM.
WC	:	Working capital defined as: (total current assets - total current liabilities)/total assets (annual value repeated quarterly). This is a liquidity measure. Working capital is a complement variable to operating margin. More liquidities may mean less (or more) expenditures on safety and therefore more (less) accidents; we do not have a priori for the sign of the coefficient.
LMWC	:	Average working capital of the four preceding quarters. More liquidities in the past may allow carriers to put more funds on safety today. LMWC should therefore affect negatively the number of accidents.

Table 1. Means and Standard Deviations

Variables	3116 observations		2157 observations	
	MEAN	***STANDARD DEVIATION***	***MEAN***	***STANDARD DEVIATION***
NACC	0,1091	0,3524	0,1043	0,3470
HOURS	3747,89	10828,32	4367,71	12341,67
NORTH	0,3110	0,4630	0,3227	0,4676
SPEED	293,65	140,43	301,85	145,85
SMALL	0,8569	0,3503	0,8359	0,3705
TIME	7,819	3,475	8,166	3,300
FE	505,46	1263,28	503,63	1168,58
OMARG	-0,0190	0,4326	-0,0113	0,4094
LOMARG	—	—	-0,0098	0,4070
DERATIOP†	2,832	5,642	2,784	5,652
DERATION†	-6,235	7,685	-6,733	7,813
LMDEP‡	—	—	3,014	8,053
LMDEN‡	—	—	-8,660	15,760
DUM	0,1402	0,3473	0,1349	0,3417
DUMLMDE	—	—	0,1280	0,3341
WC	-0,0328	0,2201	-0,0298	0,2086
LMWC	—	—	-0,0383	0,1916

† Calculations based on observations for which the equity is strictly negative (DERATION) or positive (DERATIOP).

‡ Calculations based on observations for which the average equity of the preceding four quarters is strictly negative (LMDEN) or positive (LMDEP).

Table 2. Maximum Likelihood Estimates of Poisson Regression Coefficients (Asymptotic t-ratios)

	Model 1		***Model 2***		***Model 3***	
INTERCEPT	-1.1532	(-5.97)	-1.0417	(-5.12)	-1.0198	(-3.86)
HOURS	.28E-4	(6.09)	.31E-4	(6.42)	.30E-4	(5.39)
SPEED	-.33E-2	(-5.78)	-.32E-2	(-5.27)	-.31E-2	(-4.17)
TIME	-.0906	(-6.04)	-.0926	(-6.08)	-.0846	(-4.23)
NORTH	.8177	(7.18)	.7841	(6.80)	.7453	(5.20)
FE			-.17E-3	(-1.66)	-.23E-3	(-1.60)
OMARG	.7012	(3.77)	.6603	(3.51)	.6045	(2.59)
LOMARG					-.1803	(-1.39)
DERATION			-.0151	(-0.72)	.0145	(0.42)
DERATIOP			-.0291	(-1.85)	-.0522	(-1.98)
LMDEN					-.0274	(-3.92)
LMDEP					.86E-3	(0.06)
DUM			-.1401	(-0.67)	.0045	(0.01)
DUMLMDE					-.7409	(-1.65)
WC			-.0619	(-0.22)	.2650	(0.42)
LMWC					-.5950	(-0.89)
Log Likelihood	-1027.96		-1023.56		-685.77	
No. of observations	3116		3116		2157	
χ^2 Goodness of fit*	2.64		2.40		3.70	
Score test statistic for dispersion**	1.43		1.31		1.39	

* This statistic is computed as $\sum_{y=0}^{4} \frac{\left(N_y - \sum_i \widehat{p}_i(y)\right)^2}{\sum_i \widehat{p}_i(y)}$. Under Ho: predicted frequencies = observed frequencies. The statistic is distributed as a $\chi^2_{(1)}$.

** The score test statistic is computed as $\frac{1}{\sqrt{2}} \frac{\sum_{i=1}^{n}\left[(Y_i - \hat{\lambda}_i)^2 - \hat{\lambda}_i\right]}{\left[\sum_{i=1}^{n} \hat{\lambda}_i^2\right]^{1/2}}$ where $\hat{\lambda}$ is the maximum likelihood estimate of λ under Ho: equidispersion. Under Ho, this statistic is asymptotically $N(0,1)$.

Table 3. Maximum Likelihood Estimates of Poisson Regression Coefficients (Asymptotic t-ratios)

	Model 4		*Model 5*		*Model 6*	
INTERCEPT	-.8935	(-2.45)	-.9226	(-2.35)	-1.2017	(-2.25)
HOURS	.26E-4	(5.43)	.25E-4	(4.86)	.28E-4	(4.59)
SPEED	-.36E-2	(-5.55)	-.37E-2	(-5.46)	.35E-2	(-4.00)
TIME	-.0908	(-6.06)	-.0919	(-6.04)	-.0860	(-4.30)
NORTH	.8220	(7.21)	.7965	(6.91)	.7556	(5.24)
SMALL	-.2170	(-0.84)	.0528	(0.18)	.3356	(0.82)
FE·S*			-.54E-3	(-2.46)	-.48E-3	(-2.01)
FE·B			.17E-3	(1.55)	.15E-3	(0.96)
OMARG·S	.7180	(3.80)	.6373	(3.31)	.5943	(2.51)
OMARG·B	-.2452	(-0.19)	-.1858	(-0.15)	.4813	(0.28)
LOMARG·S					-.1675	(-1.28)
LOMARG·B					-.3547	(-0.20)
DERATION			-.0155	(-0.74)	.0136	(0.40)
DERATIOP·S			-.0333	(-1.71)	-.0561	(-1.96)
DERATIOP·B			-.0154	(-0.57)	-.0094	(-0.12)
LMDEN					-.0279	(-3.90)
LMDEP·S					.0018	(0.13)
LMDEP·B					-.0257	(-0.38)
DUM			-.1311	(-0.62)	-.0197	(-0.40)
DUMLMDE					-.7196	(-1.58)
WC·S			-.0767	(-0.27)	.1756	(0.27)
WC·B			.7369	(0.54)	2.5574	(1.14)
LMWC·S					-.4530	(-0.65)
LMWC·B					-3.2145	(-1.29)
Log Likelihood	-1027.54		-1017.98		-682.61	
No. of observations	3116		3116		2157	
χ^2 Goodness of fit	2.61		2.04		3.16	
Score test statistic for dispersion	1.42		1.11		1.26	

* S stands for SMALL and B stands for 1-SMALL.

Table 4. Partial Results for Model 4.a
(Coefficients (Asymptotic t-ratios))

OMARG·S	.70	(2.92)
OMARG·B	.09	(0.05)
LOMARG·S	-.15	(-1.10)
LOMARG·B	-.69	(-0.39)

Figure I. Airline accidents and current debt-equity ratios

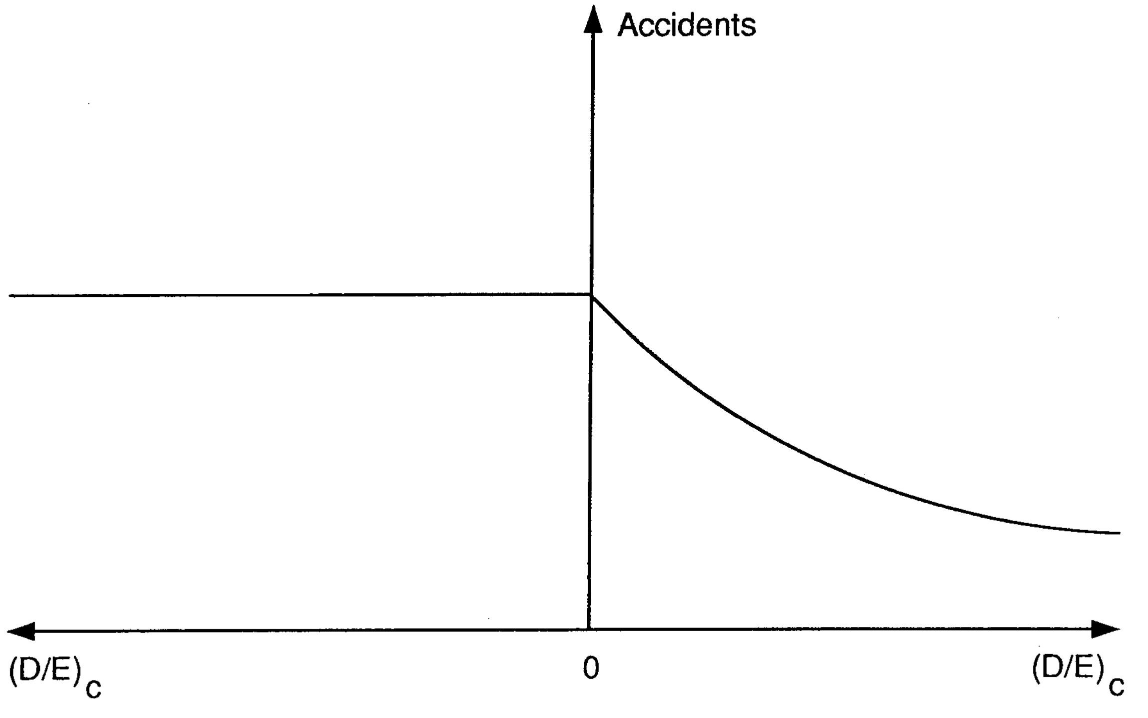

Figure II. Airline accidents and lagged debt-equity ratios