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Product Liability and Moral Hazard: Evidence from General Aviation

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Abstract: Product liability law reduces the costs of accidents to consumers thus reducing their incentive to invest in safety. We estimate the impact of tort liability on a subset of consumers who have significant control over the probability of an accident, the consumers of general aviation aircraft. The General Aviation Revitalization Act of 1994 exempted small aircraft manufacturers from product-liability claims when they reached 18 years of age. We use the exemption at age 18 to estimate the impact of tort liability on accidents as well as on a wide variety of behaviors and safety investments by pilots and owners. The results are consistent with moral hazard. As an aircraft is exempted from tort liability, the probability that the aircraft is involved in an accident declines. Direct evidence on pilot and owner behavior is also consistent with moral hazard. Aircraft exempted from tort liability are flown less often and flown less often at night than similar aircraft that are covered. Pilots and owners of exempted aircraft also increase their personal investments in safety, including wearing seat belts and filing flight plans, relative to pilots and owners whose aircraft are still covered by liability.

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1. Introduction

Product liability law reduces the costs of accidents to consumers thus reducing their incentives to invest in safety. Although theoretical treatments of moral hazard are common in the literature on torts (Shavell, 1987, Landes and Posner, 1987) estimating the importance of moral hazard has proven to be difficult.[1] For many products, moral hazard will be unimportant simply because consumers have few effective ways to control accidents. Even when the effect of tort law on moral hazard is important, isolating the impact of tort law from other influences is difficult. Product liability law has changed significantly in the last 30 years, broadly speaking moving from a negligence standard to strict liability, but so have many other factors influencing accidents. In addition there is the difficulty caused by the bilateral nature of accidents. Since manufacturers and consumers typically both make safety investments the problem becomes one of "double moral hazard." As one party's incentives change the other parties incentives typically change in the opposite direction. An ideal experiment would randomly assign each party potentially involved in an accident their own liability rule. In such an ideal experiment, for example, we would observe consumers who were compensated for product related accidents even though manufacturers were not liable and manufactures who were liable even though consumers were not compensated.

We address many of the difficulties in estimating the importance of moral hazard by using a significant change in the application of liability to general aviation aircraft. General aviation is the segment of the aviation industry composed of all civil aircraft not flown by commercial airlines or the military. General aviation manufacturers were the targets of a large volume of litigation

[1] Shavell's (2004) comprehensive survey of the literature lists four empirical studies of product liability since 1978 none of which deal with the problem of moral hazard directly. A survey of accident law more generally, Dewees (1996) notes few studies of the impact of moral hazard. Recently Rubin and Shepherd (2007) have examined the role of moral hazard indirectly by looking at the impact of limits on liability on all accident rates including accidents resulting from product use. Kessler and McClellan (1996, 2002) find that tort liability substantially increases the amount of defensive medicine which can be considered a type of moral hazard. Some of the earliest estimates of moral hazard in tort come from auto cases (see Landes (1982), Cummins et al (2001) and Loughran (2001)).

beginning in the 1970s. In response to the perception of a liability induced decline in the general aviation industry, Congress passed the General Aviation Revitalization Act in 1994 (GARA). GARA exempted aircraft from product-liability claims if they were older than 18 years and had fewer than 20 seats. The 18-year statute of repose created by GARA is quite broad. The limitation is defined as "18 years with respect to general aviation aircraft and the components, systems, subassemblies, and other parts of such aircraft." (Rodriguez 2005). It runs from the date the aircraft was delivered to the first purchaser or for components when the component was installed.[2,3]

Most observers suggest that GARA was very effective in reducing manufacturers' litigation exposure. In 1997 Cessna's general counsel estimated that the annual number of new lawsuits was less than half that of the 5 years prior to GARA (Rodriguez 2005, p. 601). The GAO reported that typical manufacturers saw an even bigger drop from a high of 900 lawsuits a year in the early 1980s to 80 a year in 2001. Increased production by general aviation manufacturers also suggests that GARA was effective. Cessna and Beach exited the general aviation industry due to liability concerns but began producing general aviation aircraft again soon after GARA was passed. Piper, reorganized after bankruptcy as New Piper, also reentered the market in 1995. Figure 1 shows that industry-wide production increased substantially after GARA was passed.[4]

One reason that GARA was effective is that airplane manufacturers face a very long liability tail. The major manufacturers, Cessna, Beech and Piper, have been producing planes since 1927, 1932 and 1927 respectively and prior to GARA they could be sued for *any* aircraft that they had *ever* produced. The average age of the general aviation fleet is over 24 years and thousands of

[2] We do not know the exact date of delivery to the first purchaser so we mark the end of liability as 18 years from the date of manufacture. The first purchaser includes dealers and lessors as well as primary consumers so planes are almost always delivered to the first purchaser soon after manufacture (Schwartz and Lorber 2002).

[3] GARA also had the effect of banning recovery of damages from most other sources. A distributor or lessor, for example, can typically assert all defenses available to the manufacturer. Given this bar it is unlikely that injured consumers were able to recover their damages from other sources once GARA's ban was in place.

[4] Figure 1 is based on data for the types of aircraft covered by GARA and which we use in our estimates. As such it differs slightly from General Aviation Manufacturers' Association (GAMA) data on shipments as that data includes some aircraft over 20 seats. Nevertheless the GAMA data and our sample show the same pattern but somewhat higher production levels in the GAMA data.

aircraft built in the 1930s and 1940s are actively flown today. Thus it was neither infeasible nor uncommon for a manufacturer to be sued for a production defect on an aircraft produced decades earlier.[5] Figure 2, based on aircraft registry data described below, shows that 65% of general aviation aircraft lost the right to recover damages from the aircraft's manufacturer immediately upon GARA's passage with the percentage rising to about 85% over the following decade.

GARA's impact on safety is less clear. Figure 3 shows perhaps a slight decline in the number of accidents per 100,000 flight miles, a standard safety measure, for planes over 18 after GARA (relative to younger non-affected planes). But the change isn't obvious and doesn't occur until a few years after GARA. There are several problems, however, with looking at accident rates. The number of hours flown, for example, is endogenous. An implication of the standard theory of liability is that individuals without the ability to sue will reduce their activity level, i.e. fly fewer hours. In addition, Figure 3 does not control for the fact that aircraft are moving from under 18 years of age to over 18 years thus the two lines in Figure 3 are measuring different types of aircraft over time.

To get at some of these effects, Table 1 presents a "back of the envelope" regression of the probability of an accident, arguably a composite measure of both use and safety. We run the regression as a difference-in-difference model with year fixed effects. The log results suggest that the probability of an accident for aircraft over 18 years of age dropped by 38% following GARA's passage (note that this is relative to aircraft under 18 years of age and is equivalent to a .4% reduction in the accident rate). While suggestive there are clearly a number of problems with this "back of the envelope" regression which we will be addressing with micro-data and more appropriate econometric models.

[5] Moreover, Craig (1991) finds that about one third of all accidents ended up in litigation with variation depending on the manufacturer involved.

The GARA policy change lets us address a number of endogeneity issues inherent in the time trend test of moral hazard and tort. In particular, we exploit the fact that models of aircraft, like models of cars, have production runs over several years. Importantly, an aircraft manufacturer's investment in safety is focused at the level of the make and model, i.e. every aircraft of the same make and model will have the same safety features. When we see a product recall, for example, the decision typically applies to all aircraft of a particular make and model. Manufacturers can do little to change their investment in safety as an aircraft reaches its 18th birthday. But GARA imposes a hard cutoff of liability at the 18th birthday thus, so long as other factors vary smoothly with age, we can estimate the effect of liability changes holding manufacturer investments in safety constant. This is important because in general consumer and manufacturer investments in safety are jointly determined (e.g. Cooper and Ross 1984). Thus our "quasi-experiment" has characteristics similar to the ideal experiment described above – manufacturers' investments in safety are held constant even as consumers lose the ability to sue.

The results indicate that for aircraft no longer covered by tort liability the likelihood of an accident declines. Furthermore pilots and owners of aircraft without liability increased their investments in safety relative to pilot/owners whose aircraft are not yet covered by the liability limits. These pilot/owners also decreased the use of aircraft without liability.

The following section presents a simple model of double moral hazard and torts. In section 3 we discuss the data. Section 4 describes the estimation strategy. The results are presented in section 5 and section 6 examines evidence on the safety investments induced by GARA. Section 7 concludes.

2. The Framework

Consider a simple double moral hazard model similar to the warranty model formalized in Cooper and Ross (1984).[6] In this model a consumer owns a single unit of a commodity that may or may not fail at some point during the life of the product. The probability that there is no product related accident is $\prod$ and the probability of an accident is $(1-\prod)$. $\prod$ is a function of the safety investments of the consumer, *e*, and the manufacturer, *q*. In the context of general aviation safety investments by consumers (specifically pilots and/or owners) take a variety of forms, including pilot training and aircraft maintenance. In addition, product upgrades and additions such as improvements to avionics are the responsibility of the owner and not the manufacturer.

Following the convention in the double moral hazard literature, we assume that safety investments reduce accidents at a decreasing rate: $\prod_e > 0$, $\prod_q > 0$, $\prod_{ee} \leq 0$, and $\prod_{qq} \leq 0$. We follow Copper and Ross in leaving the sign of $\prod_{eq}$ unspecified.[7] It is not obvious in our context whether safety investments by aircraft consumers and manufacturers are complements, substitutes or unrelated.[8] Further we assume that the loss, *L*, resulting from an accident is not related to safety investments by either party. In other words, safety investments reduce the probability of a crash but if the aircraft crashes they do not reduce damages. Each aircraft owner's utility is given by

$$U(e,\ q,\ s) = y-(1-\prod)(1-s)L-g(e)$$

[6] Cooper and Ross (1984) build a model of warranties in which the price of a good and the level of warrantee are endogenous. By contrast the model presented here does not allow price to function as a decision variable and takes the liability rule to be exogenous. In this sense it is closer to the model presented in Spence's (1977) famous paper on liability rules.

[7] More typical is Kambhu (1982) who specifies safety investments by consumers and manufacturers are substitutes $\prod_{eq} \leq 0$.

[8] Both cases have been discussed in the literature on product safety. For example, in the case of aircraft one might think that aircraft with more extensive safety features and regular safety updates by manufacturers increase the effectiveness of consumer's investment in safety. If the manufacturer regularly provides information failure points in the aircraft, then inspections can focus on these areas and increase the likelihood that a give inspection finds a problem. By contrast if warnings are excessive, providing information to consumers that are not valuable they may reduce the effectiveness of consumer expenditures.

where $s \in [0,1]$ is share of damages born by the manufacturer and *(1-s)* is the consumer's share.[9] g(e) is the cost to the consumer of providing a given safety investment and we assume $g'(\bullet) \geq 0$, $g'(0) = 0$, and $g''(\bullet) > 0$.

Since all of the aircraft covered by GARA are at least 18 years old we ignore the role of price as a choice variable (see Higgins 1981). The logic is that any contracts or warrantees have typically expired so tort law cannot be privately overridden by contracting over price and liability terms. In this context manufacturer's minimize their losses associated with a given liability rule *s*.

$$V(e,q,s) = -C(q) - (1-\Pi)sL$$

Where *C(q)* is the cost function of providing *q* safety investment and $C'(\bullet) \geq 0$, $C'(0) = 0$, and $C''(\bullet) > 0$. The socially optimal solution maximizes total surplus *U+V* so the cost sharing variable, *s* drops out and the maximization satisfies:

$$\Pi_e L = g'(e) \qquad (1)$$

$$\Pi_q L = C'(q) \qquad (2)$$

The solution to (1) and (2) for a given *q* and *e* are denoted by *e*(q)* and *q*(e)*.

The non-cooperative q and e are easy to understand from the manufacturer and buyer's reaction functions. For a given liability rule buyers maximize *U* with respect to *e*, given their conjecture about *q* and manufacturers maximize *V* with respect to *q* given their conjectures about *e*. The solution to this problem satisfies:

$$\Pi_e (1-s) L = g'(e) \qquad (3)$$

$$\Pi_q sL = C'(q) \qquad (4)$$

[9] See Miceli (1997) for a discussion of treating liability rules as a continuous variable.

With solutions $\hat{e}(q;s)$ and $\hat{q}(e;s)$. Comparing (1) and (2) with (3) and (4) produces the well known result that no liability rule, $0<s<1$, will produce the first best level of safety investments as both parties receive less than the full benefits of their investment in safety; that is for any $0<s<1$, $\hat{q}(e;s) < q^*(e)$ and $\hat{e}(q;s) < e^*(q)$. When $s=1$, strict liability, manufacturers behave optimally ($q^*(e) = \hat{q}(e;1)$) but when $s=0$, no liability, buyers behave optimally, ($e^*(q) = \hat{e}(q;0)$).

A change in liability rules has the expected comparative statics in that the partial effect of s on e and q are given by

$$\hat{e}_s = -\Pi_e L / [(1-s)\Pi_{ee} L - g''] < 0$$

$$\hat{q}_s = \Pi_q L / [\Pi_{qq} sL - C''] > 0 .$$

Cooper and Ross (1984) also demonstrate the existence of a Nash equilibrium e and q which satisfy (3) and (4). The slope of the reaction functions depends on Π_{eq}, whose sign we have left ambiguous. Assuming it is positive the reaction functions have the shapes shown in Figure 4. Point A is the non-cooperative Nash equilibrium in Cooper and Ross (1984) while K is the socially optimal solution. A decrease in s increases safety investments by consumers and decreases safety investments by manufacturers. Thus, in general with a reduction in s we would predict an increase in e, a decrease in q and an indeterminate effect on the accident rate making moral hazard difficult to identify. In our experiment, however, q is fixed because manufacturer investment in safety occurs 18 years before consumers lose the right to sue.

One aspect of consumers' safety investments we have not modeled explicitly but will deal with in the empirical section of the paper is the activity level. There is an extensive literature on the impact of liability rules on the activity level of a product (Shavell 1987) with the general finding that a strict liability standard on injurers encourages over-active use by victims while a no-liability standard encourages victims to use the product at the efficient activity level. Thus we will look for activity level changes as well as changes in safety investment as the liability rule for general aviation aircraft moves from strict liability to no liability.

3. Data

Our primary data source is the annual Aircraft Registration Master File which contains detailed records on all U.S. Civil Aircraft registered with the FAA. It includes commercial air carrier and general aviation aircraft. The registry is essentially the universe of aircraft operated in the United States. The FAA updates but does not store the registry but we were able to obtain copies of the registry from a private source for 1987, 1991 and 1994-2003.[10] Because the registry contains information on when the aircraft first entered the database we are able to construct a panel back to 1982. For aircraft that were involved in accidents which destroyed the aircraft prior to 1987 we were able fill in the panel using the accident data discussed below. The registry contains information on the year the aircraft was manufactured; the aircraft's approved uses, a code for the manufacturer and model of the aircraft as well as an aircraft id.

The data on accidents come from the FAA and NTSB accident data 1982-2003. The data are linked to the Registry data via the aircraft identifier. Because the FAA recycles aircraft identifiers the data is also merged on serial number.

The Registry's comprehensiveness is beneficial for constructing the population of general aviation aircraft but it contains no information on how often or how intensively aircraft are flown. To measure use we merge the Registry data to the General Aviation and Air Taxi Activity Survey (GAATA) from the FAA. The GAATA survey contains data on the number of hours flown and percent of aircraft regularly flown by manufacturer and model although this is not broken down by

[10] Previous years of the data do not seem to be available from any of the private companies supplying the information. Only Aviation Data Services had data back to the 1980s.

aircraft age. Also, after 1996, the FAA published this data only in six broad categories rather than by manufacturer and model as it had done previously.

To construction the sample we examine only those aircraft covered by GARA. In addition we limit the analysis to aircraft built after 1936 since the manufacturer model codes do not accurately differentiate many of the aircraft manufactured before that date. We also do not include helicopters in the sample as these are significantly less common than fixed wing aircraft and involve substantially different safety issues (GAO 2001).

Our data encompasses the universe of general aviation aircraft between 1982 and 2003. This gives us over 210,000 aircraft and over 4 million aircraft years. Given the difficulty in analyzing such a large panel we draw a random sample of 20,000 aircraft giving us 367,176 aircraft years. A second issue is that aircraft accidents are rare events. Since we are interested in the impact of safety we oversample accidents. To correct for the bias due to oversampling we use Manski and McFadden's (1981) method of choice based sampling. We divide our sample into aircraft that are not involved in an accident between 1982 and 2003 and aircraft that had at least one accident during the period. We then draw 10,000 aircraft from each subset making the sample proportion 50% for each group. Since we have the population of aircraft we know the true proportion of the sample is 13% for accidents and 87% for non-accident aircraft thus we can construct a weight that scales down accident aircraft and scales up non-accident aircraft.

$$\text{Weight}=(.13/.5)*\text{accident sample}+(.87/.5)*(\text{non-accident sample})$$

The means and standard deviations of the weighted data are included in Table 2. Panel A is from the registry data for years 1982-2003, panel B the GAATA data for 1984, 1985, 1989-1996, and panel C is the NTSB and FAA combined accident data from 1982-2004.

4. Estimation

Identification of the impact of liability status on the probability of an accident comes from variation in liability status across age cells and the 1994 law change. Specifically let

$$y_{ijtk} = X_{ijt}\beta + f_k(a) + C_{tk}\delta + D_{tk}\alpha + \vartheta_t + \lambda_j + \phi_k + u_{itjk} \qquad (5)$$

where y_{ijtk} is an indicator variable equal to one if aircraft *i,* in year *t*, of manufacturer model group *j*, and year manufactured cohort *k*, had an accident. X_{itj} are characteristics of the aircraft with manufacturer-model specific coefficients β. The controls include the approved uses of the aircraft including approved for commuting, utility, agriculture, surveying, advertising, weather monitoring, research and development and exhibition. We also include whether the aircraft was owned by a business, a partnership or government. (The omitted default category is individual ownership). We include a control for aircraft operated commercially. Given the sample restrictions this does not include aircraft that provide regular commercial transport of passengers but does include charter flights and aircraft rented for sight seeing. We also include the number of aircraft of a particular model and the number not covered by liability because in Helland and Tabarrok (2007) we find that there is a consumption externality associated with larger cohort sizes. We also include year fixed effects, ϑ_t, to capture the time trend in Figure 3, fixed effects for the year in which the aircraft was built, ϕ_k, to capture the technology available at the time the aircraft was constructed and manufacturer-model fixed effects, λ_j, to capture differences in the safety of different models.

Given a possible nonlinear relationship between age and accident probability we include $f_k(a)$, a smooth function (a low order polynomial) representing the age profile of the aircraft. We estimate polynomials of various lengths. C_{tk} is an indicator variable for aircraft without the option of suing the manufacturer; i.e. those over 18 after GARA. We also include D_{tk}, a control for aircraft over 18 (i.e. both pre and post GARA) to capture any impact of an aircraft turning 18 that might be independent of the liability regime. Finally u_{itjk} is an unobserved error term. In addition, we also run a specification of the model in which we interact the polynomials with an indicator variable for aircraft 18 and over. This specification allows for the possibility that the safety profile of an aircraft not only varies non-linearly in age but also allows for the possibility that 18 years of age is in some way important in aircraft safety independent of the policy experiment induced by GARA.

Since we are interested in the probability of an accident in each year we estimate survival model. Since our age variable is observed only at yearly intervals we estimate a discrete time version of the proportional hazard model. These models are typically estimated using a complementary log-log (cloglog) regression (See Meyer, 1990 and Jenkins, 2005). Thus constructed, the probability of an accident is given by

$$\Pr(accident \mid X) = 1 - \exp\left\{-\exp(X\beta)\right\},$$

where X are the independent variables discussed above. The model allows us to easily deal with three features of the data. First, although our sample period begins in 1982 many of the aircraft have been flying for considerably longer and hence, in the terminology of survival models, have been in the risk set for a considerable time period before 1982. Similarly the model allows us to easily model new entrants to the sample. Second an accident usually does not result in the destruction of the aircraft. Thus an aircraft is likely to remain in the risk set even after an accident. Finally the model allows us to deal with the truncation created by the fact that we do not observe accidents after 2003.

One remaining issue is that age is measured annually in the aircraft registry data which introduces the problem that the standard errors have group structure and so conventional standard errors will overstate precision. Lee and Card (2006) show that in cases where the treatment determining variable is discrete the observation should be clustered on the right hand side variable. The difficulty is that it is likely that the manufacturer-model cell, which is not nested within age, also contains unobserved and correlated random components. Cameron, Gelbach and Miller (2006) suggest two-way clustering as a solution to this problem. They demonstrate that if there are $j \in \{1,...,J\}$ manufacturer model clusters and $k \in \{1,...,K\}$ age clusters, then an estimate of the variance-covariance matrix that accounts for the correlation within both cluster groups is $V^{JA} = V^{J} + V^{A} - V^{J \cap K}$. The first term captures the unspecified correlation between aircraft of the same manufacturer-model group while the second captures the unspecified correlation between aircraft of the same age. Since both the manufacturer-model and age clustered variance-covariance matrix include the diagonal of the variance-covariance matrix the manufacturer-model-age cluster is subtracted off to avoid double counting (see Cameron, et al. 2006).

This problem is particularly important in the regression on hours flown, the proportion actively flown and night hours regressions discussed below. Because the survey data only provides these variables for the manufacture model group by year we are forced to use the average age of the cluster to determine liability treatment. The quasi-experiment still has a policy change for accidents, because all aircraft in a particular manufacturer model cluster can fall on either side of the cutoff. For those manufacturer model combinations produced both before and after 1976 (i.e. 18 years before GARA's implementation in 1994) the quasi-experiment is "fuzzy" as there will be a gradual increase in those aircraft of that manufacturer model combination without liability as the cluster moves across the 18 year boundary.

5. Results: Accidents

The results for equation (5) are presented in Table 3, Panel A. Columns 1, 2 and 3 present polynomials in age of order 1, 2 and 3.[11] In column 4 we estimate the model including a 3rd order polynomial interacted with an indicator variable for aircraft over the age of 18.

The effect of GARA on the accident rate is measured by the coefficient on the post-GARA*over-18 variable – in all specifications the coefficient is negative. That is, we find that the accident rate for aircraft which are no longer subject to tort declines in all specifications. The effect is largest, a 19% decline in accidents, when we restrict the accident rate to be a linear function of aircraft age. The effect almost halves to an 11% decline in accidents when we allow for a second order polynomial in age but the coefficient does not change applicably when we allow for additional flexibility in the age polynomial. Thus, we will focus on the results from column 2 because we think the second order polynomial gives the best tradeoff between flexibility of estimation and efficiency. In that specification, the marginal effect is to reduce the accident probability by approximately .00084 from a base probability of an accident of .0074. This indicates that the removal of liability coverage resulting from GARA produced an 11.23% decline in the probability of an accident.

In 1994, 70% of aircraft were already over 18 years of age so the moment that GARA came into effect it moved a majority of the general aviation fleet to a no-liability regime. The model in Table A is primarily identified from this one-time change. The influence of GARA, however, can be estimated in a second way. Aircraft younger then 18 in 1994 moved from a strict liability regime to a no-liability regime during different years following the 1994 passage of GARA. We

[11] We also ran regressions with polynomials of order 4 and 5 but in no case were the results on the variables of interest substantially different.

can thus ask, what happens to the probability of an accident when an aircraft loses liability in the post-GARA era?

Our second experiment has some advantages over the first. Instead of the universe of all general aviation aircraft, which includes airplanes built in 1935 as well as 1975 our second experiment focuses attention on aircraft cohorts in which some members were younger than 18 in 1994 and thus on aircraft from the same technological era. Our second experiment also draws its variation from changes in liability status that happen over many different years, as an aircraft reaches its 18th birthday, rather than from the single year, 1994.

In Table 3, Panel B we estimate the effect of moving to a no-liability regime based only on post 1994 data and only on those aircraft in which some portion of the manufacturer model group turned 18 during the period 1995-2003. The model thus becomes

$$y_{ijtk} = X_{ijt}\beta + f_k(a) + D_{tk}\alpha + \vartheta_t + \lambda_j + \phi_k + u_{itjk} \qquad (6)$$

In this experiment there is no independent effect of an aircraft turning 18 and thus the over 18 coefficient, D_{tk}, reflects the impact of GARA.

In all specifications the elimination on liability on aircraft that turn 18 is negative (and in 3 of the 4 specifications the coefficient is statistically significant at the 10% level or greater). Furthermore, the impact of GARA is economically significant and the effect is consistent with the results found from the first experiment. As an aircraft turns 18 the probability of an accident falls by about 9-12% with our base specification showing a decline in accidents of 11.55%. Thus, our estimate of the decline in accidents caused by GARA from two very different experiments is almost identical.

The similarity between the reduction in accidents following GARA's abrupt passage in 1994 and the reduction in accidents that occurs as planes reach the age of 18 after GARA's passage has implications for the causal mechanism. The changes in Panel A were likely to be mostly unanticipated. The changes in Panel B, however, are anticipated because the law change is known before these pilots make their safety investments. Since aircraft are durable goods investments in maintenance are unlikely to vary discretely at the cutoff. That is, since planes are durable and the cutoff of liability is known in advance investments in maintenance could optimally start earlier than the liability cut off. Yet because the two impacts are similar this suggests that the post GARA investments in safety are mostly behavioral. We will be investigating the causal mechanism at greater length further below.

To put this drop into perspective, in 1993, the year before GARA was enacted; there were 1778 aircraft accidents in our sample of which 339 involved fatalities claiming the lives of 689 individuals. An 11% reduction in the number of accidents in the GARA affected sample (about 70% of the aircraft stock) would indicate approximately 150 fewer accidents and 58 fewer fatalities. Over the 1994-2002 period the accident rate fell by about 22% so we estimate that half of this increase in safety was due to GARA.

5.1 Robustness from Pseudo GARA, Chow Tests, and Regression Discontinuity

In Table 3, Panel C we perform a robustness check. In this table we truncate the sample to 1984-93 and estimate the model *as if* GARA had been passed in 1987. The estimating equation is similar to equation 5 with C_{ijtk} equal to one in this case if the year is 1987 or greater rather than the actual date of GARA's passage. If the results are due to some other feature of aircraft turning 18 we should expect negative coefficients on the pseudo post-GARA over-18 variable. The results are similar regardless of what year between 1982 and 1994 we use for the "pseudo" law. In fact the impact of our "pseudo" GARA is positive, although small and not significant in any specifications, suggesting that something fundamental changed for aircraft over the age of 18 in 1994.

An alternative test is presented in Figure 5. If there was a behavior change in 1994, then a Chow test for structural breaks on pseudo laws from 1982 to 2003 should reveal a maximum at the true break. We find that the Chow test is near zero in the early years of the sample, rises to a maximum in 1994 and is lower thereafter. The Chow test suggests that a structural break occurred with 1994 being the most likely year for the break, consistent with our hypothesis that GARA was the causal factor.[12]

In Table 4, we estimate the effect of GARA on the accident rate by looking only at aircraft aged 17 and 19. Thus, this model is closer in spirit to a regression discontinuity design than our difference in difference estimates above. In this case we use the population of general aviation aircraft which are 17 and 19 in a given year. Because of this we do not use choice based sampling. The model is similar to before except now the coefficient on Post GARA * Over 18 is based solely on the accident rate of 19 year old aircraft relative to 17 year old aircraft. The coefficient is not statistically significant at conventional levels but it is negative and of similar magnitude to that shown earlier, suggesting a decline in the accident rate of about 15%.

6. Safety Investments

Ideally we would like to have a model of the production of safety. What sort of safety investments by manufacturers does tort encourage and what is the optimal response of pilots to the end of this liability? We do not have a model this specific but Peltzman's (1975) classic treatment of seatbelts provides us some intuition. Suppose that pilots are at a safety optimum consistent with safety investments by manufacturers, their own safety investments and expected recovery from tort. A reduction in tort compensation should increase safety investments in those areas with the lowest

[12] One issue is the significance level to attach to the Chow test. There is considerable debate the macroeconomics literature about the proper significance levels when the exact date of the break is not known. Zivot and Andrews (1992) provide proper significance levels for time series data but we know of no similar discussion for panel data. For this reason we bootstrap the Chow test using a pair cluster bootstrap. See Godfrey and Orme (2002) for a discussion of bootstrapping Chow tests.

marginal cost. For this reason we would not necessarily expect to see increases in safety on the same dimensions as tort induces in manufacturers, e.g. product design changes are too costly for an individual pilot to control. But pilots do have control over other aspects of safety such as what aircraft they fly, when and how they fly, the frequency of mechanical inspections and so forth. In the next 3 sections we investigate safety investments along these dimensions to get a better understanding of the margins on which moral hazard operates.

6.1 Hours Flown, Aircraft Actively Used and Hours Flown at Night

Some evidence of the behavioral changes can be found by looking at aircraft activity levels. The General Aviation and Air Taxi Activity Survey (GAATA) is available for 1984-1985 and 1989-1996 (thus we have only two years in the post-GARA era). The dependent variable in Table 5 Panel A is the log of the average hours flown in a year.

$$\ln(\overline{hours}_{jt}) = X_{jt}\beta + g(\overline{age}_{jt}) + P_{jt}\pi + N_{jt}\alpha + \vartheta_t + \lambda_j + v_{jt}$$

were X_{jt} are the controls discussed above for manufacturer model group j in year t, $g(\overline{age}_{jt})$ is the average of the age polynomials for members of manufacturer model group j, P_{jt} is the percentage of the manufacture model group without liability and N_{jt} is the percentage of the manufacturer model group over 18. The year fixed effects, ϑ_t, and manufacture-model fixed effects, λ_j, retain their meaning from equation 5. The model is identified using the 1994 law change and the changes in average cohort age as each manufacturer model group moves over the threshold from liability to no liability. The prediction is that as a cohort moves from liability to no liability the number of hours flown will decline.

The results are presented in Table 4 which repeats the pattern from Table 3 of including increasingly higher order polynomials and interactions with over 18. The key difference for the specification in Table 4 is that the polynomial is now the average of the age, age squared and age cubed polynomial of the aircraft make and model cohort and the interaction term is a dummy variable for the last aircraft of that make and model turning 18.

In the first panel we look at the average hours flown. The impact of GARA is negative in all specifications but is statistically significant only in the linear specification, which we discount. Thus, we find some but limited evidence that removing the right to sue decreased the aircraft activity level. As the data on hours flown is coarse and likely subject to significant measurement error the lack of evidence is perhaps not surprising.

We may find more evidence by looking at a better measured variable, the proportion of aircraft of a manufacturer model combination that are still actively flown. At the extremes a one indicates that all of the surveyed aircraft in a manufacturer model combination are still actively flown while a zero indicates none are actively flown. One difficulty with the dependent variable is that it is bounded by zero and one and hence the effect of liability, or any independent variable, cannot be constant throughout the range of the independent variable. The usually solution to this problem is to estimate the model using the logistic transformation. In this case the logistic is not ideal because it requires that observations of zero and one be deleted even though these observations may be especially informative about the effect of liability. A better approach in cases like this is the general linear model as outlined in Papke and Wooldridge (1996).

The non-linear logit quasi-maximum likelihood model is estimated as

$$E(\%Active \mid X) = G(\beta X)$$

where $G(\bullet)$ is the logistic function. Unlike the logistic this model allows estimation uses all the information in the data to make inferences.

The results are presented in Table 5 Panel B. For our second and higher order polynomial specifications we find that the end of liability decreased the percentage of active aircraft of a given make and model by about 5%. The results suggest that removal of liability insurance causes individuals to retire their aircraft more rapidly.

An interesting question is whether pilot/owners flew their aircraft differently and in particular more carefully after GARA was passed? All hours flown in an aircraft are not equally dangerous. Hours flown at night are considerably more dangerous than hours flown during the day.[13] The GAATA survey contains a measure of the percentage of hours flown by the manufacturer model at night. The average for the available years (1984-85, 1989-96) is 13% with almost a quarter of the sample flying no night hours. The impact of the removal of liability on night hours flown is shown in Panel C of Table 3. We find that GARA reduced night hours flown by 67% in our base specification and a similar figure in the more flexible specifications; in all cases the result is statistically significant. Note that this is a large decline on a small base and likely reflects the fact that after GARA many planes were simply not flown at night.

6.2 Results: Investments in Safety

The aircraft registry does not contain information on investments in safety. The aircraft accident file does contain information on investments in safety but aircraft in accidents are unlikely to be a random sample of all aircraft: one would hope that aircraft with more safety investments are less likely to be in the accident file. Some types of accidents, however, are less influenced by safety investments than others and for these accidents the information on safety investments in the accident file are more likely to be a random sample of safety investments in the population.

[13] For example of the accidents occurring during the day 15% involved a fatality while for those at night 28% involved a fatality. Similarly nighttime crashes resulted in the destruction of the aircraft in 38% of the cases while in daytime crashes only 22% of the aircraft were destroyed.

For this reason we estimate the model using all accidents in our sample and a subset of accidents in which the FAA determined that weather was the sole causal factor in the accident. Although weather is a contributing factor in about 30% of general aviation accidents it is labeled the sole cause of the accident in only about 10% of all accidents. These are typically accidents in which the pilot encounters poor weather after having begun his or her flight. The most well known example would be wind sheer accidents in which sudden wind variability forces an aircraft into an uncontrolled dive. More typical are severe weather conditions encountered mid-flight but which were not foreseen before takeoff, as flying into dangerous weather that is forecast would typically be classified as a pilot error. Note that for weather to be ruled the sole causal factor the FAA must determine not only that weather was the proximate cause of the accident but – importantly for our interpretation - that the presence or absence of a particular safety investment was *not* causal. Thus, at least according to the FAA, the subset of weather caused accidents is random, an act of "Mother Nature."

The FAA's classification is unlikely to be perfect, of course, the absence of some safety investments may have prevented the weather related accident and this is simply misclassified by the FAA. Nevertheless the distribution of aircraft in weather-caused accidents should more closely approximate the distribution in the population of general aviation aircraft so we can better use this distribution to estimate investments in safety pre and post-GARA – this will be especially true, as we discuss further below, for safety investments that *a priori* have little chance of influencing whether an accident occurs such as the wearing of a seatbelt.

The data contains seven safety efforts or investments by aircraft owners/pilots that are available for most of the sample period. These are whether the aircraft and pilot had a biennial flight review, whether the crew was instrument rated, whether the flight was during daylight hours, whether the crew was wearing their seatbelt at the time of accident, whether the flight's airport of origin was different from its destination airport, whether the pilot had filed a flight plan, whether the aircraft had undergone an inspection in the last year and finally if the aircraft had a functioning Emergency Locator Transmitter (ELT).

The biennial flight review, or simply the flight review, is required of every holder of a pilot' license at least every two years and consists of at least 1 hour of ground instruction and 1 hour of flight with a certified instructor. The indicator variable measures whether the pilot of the aircraft had met this requirement. The day variable is equal to one if the flight occurred during daylight hours. The indicator for seatbelt equals one if the crew were wearing their seatbelt and/or shoulder restraints at the time of the accident. The variable long flight equals one if the airport the plane departed from is different from the destination airport. General aviation flights are at the greatest risk of an accident during takeoff and landing. An increase in long flights among aircraft without liability coverage suggests that recreational flights are less common.

The variable flight plan equals one if the aircraft involved in the accident had filed a flight plan. Flight plans are filed by pilots with the local branches of the FAA prior to takeoff. They contain basic information on departure and arrival points, estimated flying time, alternate landing airports in case of bad weather, whether the flight has an instrument rated crew, and personal information on the passengers and crew. Flight plans are not required for all flights, excluding those crossing national borders, but highly recommended by the FAA since they provide a way of alerting authorities if a flight is overdue. The indicator variable for inspected within the last year is equal to one if the aircraft has received an inspection within the last year. The FAA requires that general aviation aircraft are inspected at least every 100-hours of flight time, which typically occurs once a year. Finally the indicator variable functioning ELT equals one if the aircraft's ELT was operational at the time of the crash. The ELT is designed to emit an Emergency signal on impact so that search and rescue teams can more easily locate a downed aircraft.

The probability of each of these safety investments being in place is estimated using a logit model. Due to small cell sizes for a number of these variables we do not include manufacturer model, model year, year or use of aircraft fixed effects. Thus the regression reported in Table 6 include only an indicator variable for over 18, the over 18 indicator interacted with post GARA, which is the variable we show in the table, and the 3rd order polynomial in age. The left columns contain information on all crashes while the right columns contain information only on weather related crashes. We have approximately 30-40 thousand observations in the all accident data regressions and 4-5 thousand observations in the weather-caused data. The data covers the period from approximately 1982 to 2003 with some variation depending on the specific investment.

The results from both the all accident data and the weather-caused accident data suggest that GARA increased a number of different safety investments. Importantly, in almost all cases the estimated increase in safety is as large or larger in the weather-caused sample which is what we would expect if selection biases the all accident results downward (e.g. imagine that accidents only occur when the plane is not inspected in the last year then in a sample of *accidents* there would be no variation in safety investments pre and post-GARA even if GARA caused many pilots to have their planes inspected). For example, we estimate that GARA increased inspections by 5.5% using the all accident sample but by 14.5% using the weather-caused sample.

Focusing on the weather-caused sample we find increases in the probability that the crew wears seatbelts, takes a long flight (i.e. fewer short flights), files a flight plan, and had the plane inspected in the last year.

Interestingly, the coefficient on seat belt usage is almost identical in the all accident and weather-caused accident sample. This is what one would expect if our argument about the random nature of weather-caused accidents is correct and if wearing a seatbelt does not contribute to whether or not an accident occurs but only affects the extent of injury conditional on an accident.

One problem with these measures of safety investments is that they may be complementary or serve as substitutes. For example if one is flying during the day it may be less important to be instrument rated. If an aircraft has regular inspections these inspections likely increases the chances that the aircraft's ELT is functional. We do not have a theory about how these safety investments interact. For this reason we also estimate the model using the proportion of all the possible safety investments in our data that were undertaken by the aircraft pilot/owner. Although this is a crude measure of total safety investments, this procedure has two advantages. First it lets us include more control variables such as the fixed effects for manufacturer model and model year and it lets us estimate the effect of moral hazard on an overall measure of safety investments. The model is again estimated using the Papke and Wooldridge technique. The standard errors are again clustered on both the manufacturer model and the index.

The results are presented in Table 7. We find only small effects, on the order of an increase of 1%, in the all accident sample but large and statistically significant effects in the weather-related sample. We find that GARA caused an increase in the proportion of safety investments undertaken by about 10% (a marginal effect of 5% relative to an average investment proportion of 57%).[14]

The results suggest that the dynamics of safety investments are complex but, as predicted by the model, the move from strict liability to no liability increases safety investments by consumers.

[14] The results are robust to different methods of accounting for missing observations on safety investments. Above we assume that the denominator is the number of non-missing fields for that observation. Thus if five of the eight safety investments were recorded for an observation the denominator is five. We have also estimated the model including all safety investments recorded in the data for that year, i.e. eight if the year is between 1982 and 2000, and assumed missing values were zero. Finally we estimated have also estimated the model treating missing observations as one. In each case the results are substantively identical.

Thus far we have found that the removal of liability decreases the use of the product and results in the products being used in less dangerous ways. These safety investments have the effect of reducing the probability of an accident.

6.3 Decomposing the accident rate

We have discovered that a reduction in tort compensation is associated with a reduction in accidents and an increase in safety behavior such as taking fewer short flights and having more mechanical inspections. In this section we investigate moral hazard further by decomposing accidents along two dimensions. Was the accident minor or major (a substantially damaged or destroyed aircraft) and did a mechanical failure contribute to the accident, yes or no. Together these provide us with four categories of accidents that we estimate using a competing hazard model.

The decomposition helps to capture an important aspect of accidents and safety investments. Pilots already have strong incentives to prevent serious accidents, thus we would not expect to see large reductions in major/serious accidents. To the extent that pilots have less control over mechanical failure than pilot error we might also expect to see a smaller reduction in accidents involving mechanical failure than those involving pilot error.

Following Jenkins (2005) we use a competing risks model estimated with age polynomials specific to accident type, over 18 and post GARA over 18 indicators, and year fixed effects. Because of the small number of accidents of each type we constrain the other variables in the model to be identical across accident types.[15]

[15] This amounts to estimating the model using a multinomial logit and allows us to test hypotheses about accident specific hazards.

The results are presented in Table 8.[16] The decomposition indicates that only minor accidents, both those with and without mechanical failure, appear to fall with GARA. The coefficients on both types of major accidents are statistically insignificant from zero and are of the wrong sign. Minor accidents make up only 12% of all accidents in our sample but the marginal impact of GARA is very large. In fact, the combined effect of these two reductions is consistent with the 11% reduction in accidents that we estimated above.

A nearly 100% reduction in minor accidents appears to be too large. Accidents, however, are rare events and decomposing them into types makes the types rarer still. Thus, we do not put great weight on this finding. Nevertheless, our results are consistent with the hypothesis that most of the reduction in accidents occurred through a reduction in minor accidents.

7. Discussion and Conclusion

GARA eliminated the right of general aviation pilots and owners to sue manufacturers for losses resulting from an accident in aircraft 18 years of age or older. GARA meant that general aviation aircraft of the same make and model had different liability status depending on their age. We used this quasi-experimental variation to estimate the impact of liability rules on consumer moral hazard. Our technique isolates the impact of consumer moral hazard because manufacturers' investment in aircraft safety occurs during the design phase and for much of the general aviation fleet these investments were made during a regime of strict liability. Thus, we are able to provide one of the first estimates of moral hazard in the context of liability law.

Our estimates show that the end of manufacturer liability for aircraft was associated with a significant reduction in the probability of an accident on the order of 11.5%. The evidence suggests that modest decreases in the amount and nature of flying were largely responsible. Following

[16] In Table 8 we present the results from the second order polynomial in age only although other results are similar.

GARA, for example, aircraft owners and pilots retired older aircraft, took fewer night flights, and invested more in a variety of safety procedures and precautions such as wearing seat belts and filing flight plans. Minor accidents especially declined.

Although we cannot estimate the cost of the safety investments made by pilots and/or owners to generate these gains, GARA appears to have been very effective in reinvigorating the U.S. aircraft industry. A telling feature of the GARA experiment is that GARA passed only because of very substantially lobbying by *pilot's associations,* i.e. the very people who would lose the right to sue in the case of an accident. The pilot's associations were concerned at the exit of airplane manufacturers from the industry and evidently calculated that the inefficiency of the pre-GARA system was such that eliminating their right to sue was beneficial for themselves and *a fortiori* for the aircraft manufacturers.

There are several important features of our quasi-experiment that limit how far we can generalize the results to other product related accidents or tort liability generally. Aviation is heavily regulated and a great deal of safety information is available to consumers. It is not clear that reducing manufacturer liability in other contexts would lead consumers to increase their safety investments. Interestingly, because GARA changed consumer incentives long after manufacturers had made their investment decisions, the law may well have induced the socially optimal level of precaution for a large fraction of the stock of general aviation aircraft.

References

Cameron, A. Colin, Jonah Gelbach and Douglas Miller (2006) "Robust Inference with Multi-Way Clustering" NBER Working Paper No. T0327.

Cooper, Russell and Thomas Ross (1984) "Product Warranties and Double Moral Hazard," *RAND Journal of Economics*, 16(1):103-113

Craig, Andrew (1991) "Product Liability and Safety in General Aviation," in *The Liability Maze: The Impact of Liability Law on Safety and Innovation*, ed. Peter Huber and Robert Litan.

Cummins, David, Richard D. Phillips, and Mary A. Weiss (2001) "The Incentive Effects of No-Fault Automobile Insurance" *Journal of Law and Economics*, 44:427–464

Trebilcock, Michael J., Don Dewees, and David Duff. (1996). *Exploring the domain of accident law: Taking the facts seriously*. New York: Oxford University Press.

General Accounting Office (2001) *General Aviation: Status of the Industry, Related Infrastructure and Safety Issues.*

Godfrey, Leslie G. and Chris D. Orme, (2002) "Using bootstrap methods to obtain nonnormality robust Chow prediction tests," *Economics Letters* 76(3): 429-436.

Helland, Eric and Alexander Tabarrok (2007) "Crash and Learn: Consumption Externalities and the Reduction of Aircraft Accidents," memo.

Higgins, Richard (1981) "Products Liability Insurance, Moral Hazard, and Contributory Negligence," *Journal of Legal Studies*, 10(1):111-130.

Jenkins, Stephen P (2005) *Survival Analysis*, memo.

Kambhu, J (1982) "Optimal Product Quality under Asymmetric Information and Moral Hazard." *Bell Journal of Economics*, 13:483-492.

Kessler, Daniel and Mark McClellan (2002) "Do Doctors Practice Defensive Medicine," *Quarterly Journal of Economics*, 111(2):353-390

Kessler, Daniel and Mark McClellan (2002) "Malpractice law and health care reform: optimal liability policy in an era of managed care" *Journal of Public Economics*, 84:175–197.

Landes, Elizabeth (1982) "Insurance, Liability, and Accidents: A Theoretical and Empirical Investigation of the Effect of No-Fault Accidents" *Journal of Law and Economics*, 25(1):49-65.

Landes, William M. and Richard A. Posner (1987). *The Economic Structure of Tort Law*. Cambridge, MA: Harvard University Press.

Lee, D.S. and D. Card. (2006) "Regression Discontinuity Inference with Specification Error." NBER Technical Working Paper #T0322.

Loughran, David, (2001) *The Effect of No-Fault Automobile Insurance on Driver Behavior and Automobile Accidents in the United States*, RAND Santa Monica

Miceli, Thomas (1997) *Economics of the Law: Torts, Contracts, Property and Litigation*, Oxford University Press.

Papke and Wooldridge (1996) "Econometric methods for fractional response variables with an application to 401(k) plan participation rates." *Journal of Applied Econometrics* 11: 619–632

Peltzman, Sam (1975) "The Effects of Automobile Safety Regulation," *Journal of Political Economy*, 83(4): 677-726

Rodriguez, James F. (2005) "Tort Reform & GARA: Is Repose Incompatible with Safety?" *University of Arizona Law Review* 47: 577-606.

Rubin, Paul and Joanna Shepherd (2007) "Tort Reform and Accidental Deaths," *Journal of Law and Economics*, 50:221–238

Schwartz, Victor E. and Leah Lorber (2002) "The General Aviation Revitalization Act: How Rational Civil Justice Reform Revitalized An Industry." *Journal of Air Law and Commerce* 67:1267-1341

Shavell, Steven (1987) *Economic Analysis of Accident Law*. Cambridge, MA: Harvard University Press.

Shavell, Steven (2004) *Foundations of Economic Analysis of Law*, Belknap Press of Harvard University Press

Spence, Michael. (1977) "Consumer Misperceptions, Product Failure and Producer Liability" *Review of Economic Studies*, 44(3):561-572.

Viscusi, W. Kip (2005) "The Value of Life" The New Palgrave Dictionary of Economics, 2nd Edition.

Zivot, E. and D. W. K. Andrews (1992) "Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis", *Journal of Business & Economic Statistics*, 10(3): 251-270.

Figure 1: Production of General Aviation Aircraft 1980 to 2004

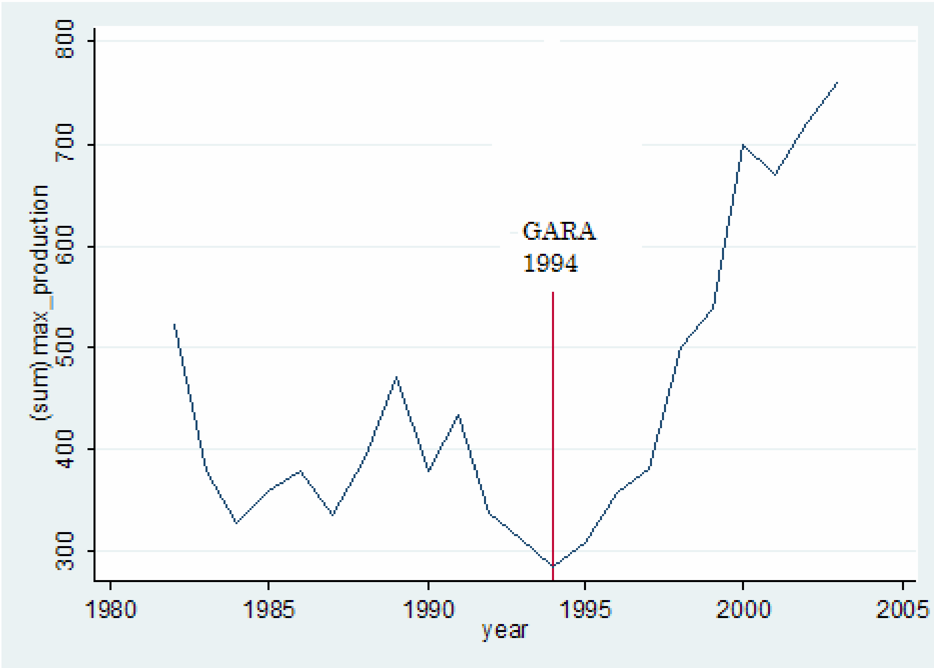

Figure 2: The proportion of aircraft without liability 1982-2003

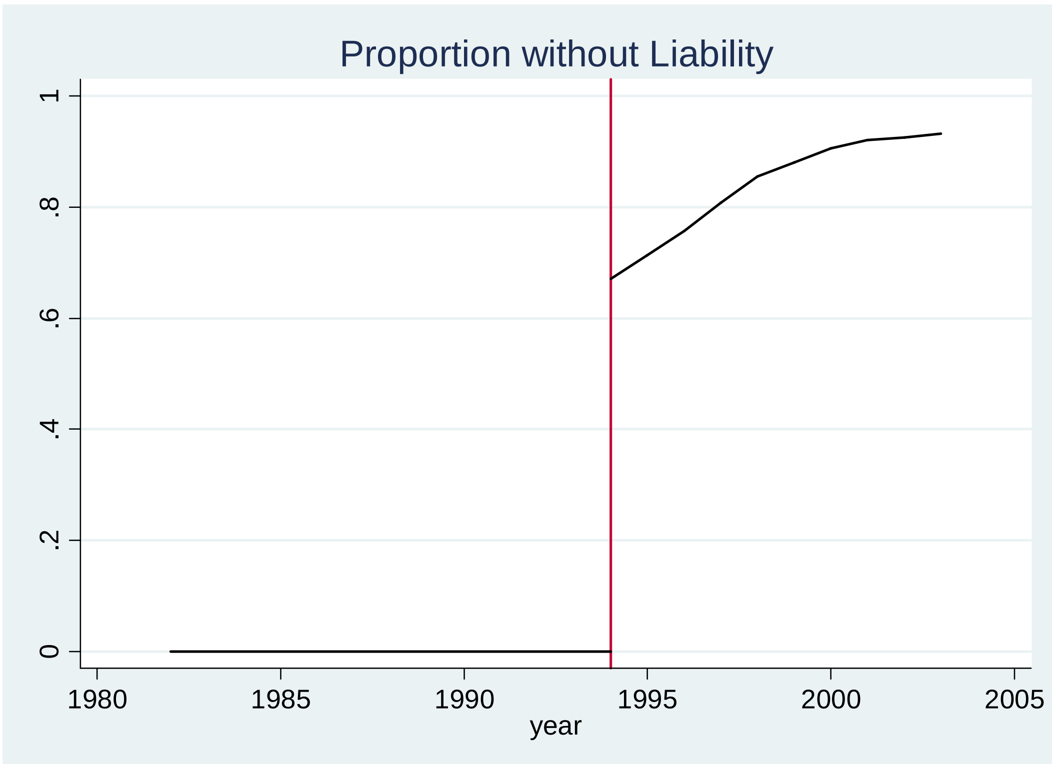

Figure 3 Accident Rate per 100,000 flight hours

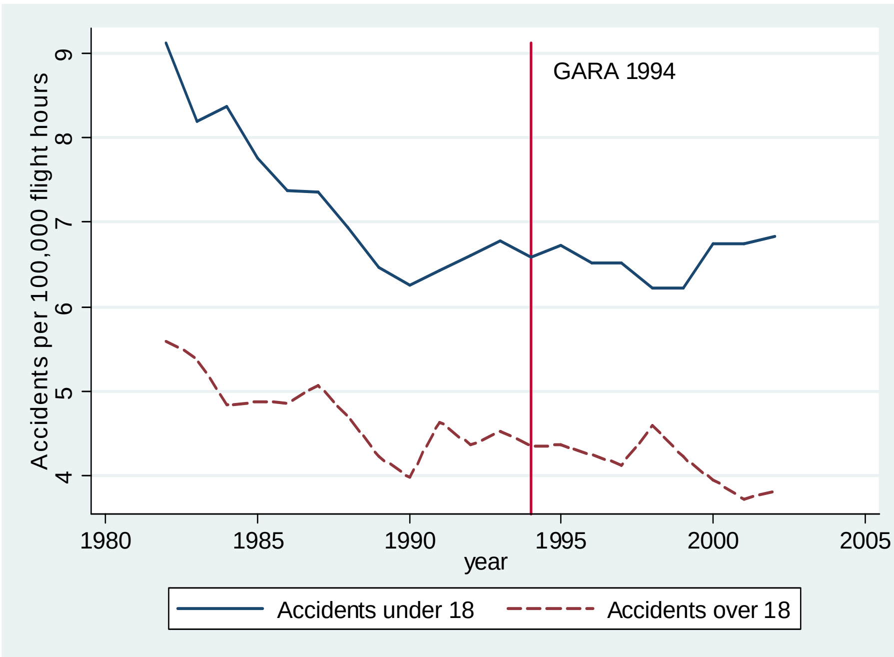

Figure 4: Reaction functions for strict and no liability assuming $\prod_{eq} > 0$

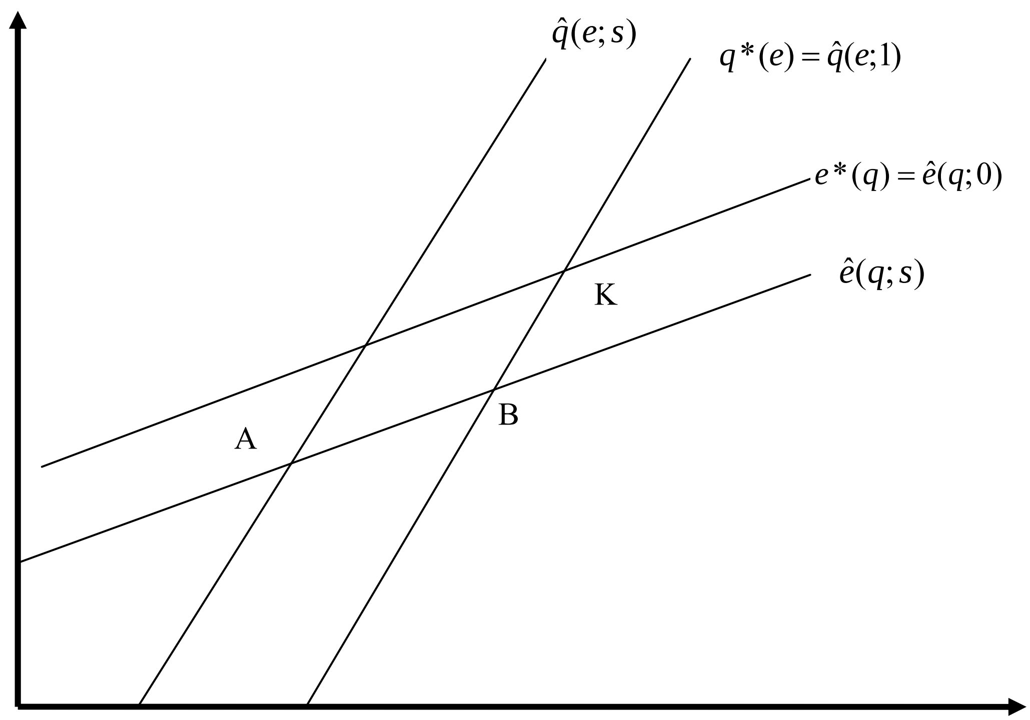

Figure 5: Chow Test for a Structural Break in 1994

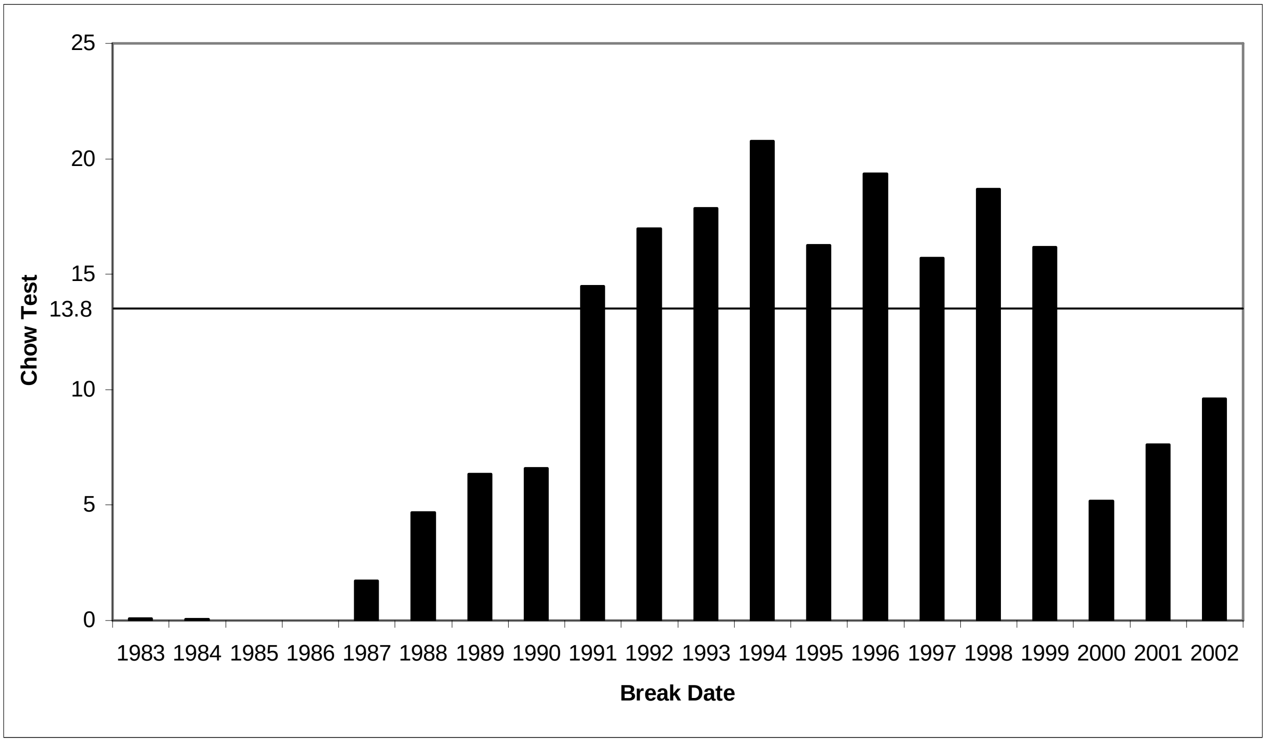

Table 1: Regression of Aggregate Accident Rates

	Log(Probability of accident)	Probability of accident
Over 18	-0.42981***	-0.00342***
	(0.07059)	(0.00084)
Over 18*Post GARA	-0.38234***	-0.00456***
	(0.11037)	(0.00132)
Year Fixed Effects	Yes	Yes
Observations	44	44
R-squared	0.88	0.84

Standard errors in parentheses
* significant at 10%;
** significant at 5%;
*** significant at 1%

Table 2, Panel A: Descriptive Statistics of the Registry Data

Variable	Observations	Mean	Std. Dev.	Min	Max
Accident in year t	367176	.0071613	.0843212	0	1
Accident with severely damaged or destroyed aircraft	367176	.0064368	.0799713	0	1
Accident with mechanical failure	367176	.0021417	.0462293	0	1
Aircraft Age	367176	25.7842	14.12467	0	67
Number Aircraft by Manufacturer /Model in 1000s*not liable	367176	3.148585	6.225977	0	23.55016
Manufacturer /Model in cohort 1000s	367176	8.533876	9.147796	0.001	27.065
Approved for commuter use	367176	.0270232	.1621513	0	1
Approved for utility use	367176	.0919186	.2889113	0	1
Approved for agriculture	367176	.0389581	.1934954	0	1
Approved for surveying	367176	.002034	.0450537	0	1
Approved for advertising	367176	.0021189	.0459823	0	1
Approved for weather monitoring	367176	.0008999	.0299844	0	1
Approved for Research and Development	367176	.0037146	.0608343	0	1
Approved for Exhibition	367176	.0095591	.0973021	0	1
Commercial Flight	367176	.1773397	.3819564	0	1
Partnership	367176	.0363893	.1872571	0	1
Corporate Ownership	367176	.2792249	.4486189	0	1
Co-Owned	367176	.1320078	.3384997	0	1
Government Owned	367176	.011122	.1048729	0	1

Table 2, Panel B: Descriptive Statistics of GAATA Survey Data

Variable	Observations	Mean	Std. Dev.	Min	Max
Log Hours Flown for Manufacturer/Model cohort	9080	4.108206	1.206289	2.41906	7.740664
Percentage actively used	9231	.6850883	.2458056	0	1
Percentage of hours flown at night	8826	.1294468	.1572456	0	.9985716
Manufacturer /Model in cohort 1000s	9231	3.124753	5.648578	.001	26.855
Percentage without manufacturer liability	9231	.2031816	.3692677	0	1
Percentage Over 18	9231	.6389117	.3716459	0	1
Percentage Approved for commuter use	9231	.000158	.0018781	0	.0285551
Percentage Approved for utility use	9231	.0299363	.1387689	0	.8774527
Percentage Approved for agriculture	9231	.0480593	.171968	0	.9655532
Percentage Approved for surveying	9231	.0034016	.0165608	0	.2916667
Percentage Approved for advertising	9231	.0022398	.0063982	0	.125
Percentage Approved for weather monitoring	9231	.0011281	.0030586	0	.0416667
Percentage Approved for Research and Development	9231	.004842	.0082397	0	.08
Percentage Approved for Exhibition	9231	.0063513	.0491081	0	1
Percentage Commercial Flight	9231	.1377616	.2656354	0	1
Percentage Partnership	9231	.0325939	.0201089	0	.1794872
Percentage Corporate Ownership	9231	.2776998	.2332139	0	1
Percentage Co-Owned	9231	.1025523	.0893378	0	1
Percentage Government Owned	9231	.0125677	.0319892	0	1

Table 2 Panel C: Descriptive Statistics of FAA and NTSB Accident Data

	All Accidents					Weather Related				
Variable	Observations	Mean	Std. Dev.	Min	Max	Observations	Mean	Std. Dev.	Min	Max
Fatal Accident	43820	0.1877	0.390477	0	1	5772	0.25797	0.437555	0	1
Substantial Damage	43820	0.720105	0.448953	0	1	5772	0.659563	0.473897	0	1
Destroyed Aircraft	43820	0.248996	0.432436	0	1	5772	0.325537	0.468616	0	1
Biennial flight review	39013	0.769308	0.421281	0	1	5207	0.783561	0.411857	0	1
Crew Instrument Rated	39013	0.112809	0.316363	0	1	5207	0.10313	0.304158	0	1
Daytime Flight	43517	0.835375	0.370846	0	1	5745	0.813229	0.389762	0	1
Crew Wearing Seatbelt	40736	0.907355	0.289938	0	1	5325	0.898028	0.30264	0	1
Long Flight	30155	0.463107	0.498645	0	1	4206	0.500238	0.500059	0	1
Field Flight Plan	43813	0.233766	0.42323	0	1	5770	0.322357	0.467419	0	1
Inspected with last year	33470	0.665671	0.471763	0	1	4363	0.655054	0.475405	0	1
ELT functional	41051	0.292222	0.454789	0	1	5488	0.329628	0.470121	0	1
Aircraft Age	43036	21.3096	12.92367	0	66	5378	20.75046	12.69763	0	66
Aerial Application	43820	0.063533	0.243921	0	1	5772	0.04158	0.199645	0	1
Air Drop	43820	0.000342	0.018499	0	1	5772	0.000347	0.018613	0	1
Aerial Observation	43820	0.005431	0.073498	0	1	5772	0.006584	0.080878	0	1
Air Race/Show	43820	0.000297	0.017222	0	1	5772	0.000173	0.013163	0	1
Business/Executive/Corporate	43820	0.070904	0.256667	0	1	5772	0.092169	0.28929	0	1
Ferry	43820	0.010885	0.103765	0	1	5772	0.008143	0.089877	0	1
Flight Test	43820	0.000844	0.029046	0	1	5772	0.000173	0.013163	0	1
Instructional	43820	0.138749	0.345689	0	1	5772	0.101178	0.301591	0	1
Personal	43820	0.595938	0.490715	0	1	5772	0.637734	0.480697	0	1
Positioning	43820	0.015358	0.122975	0	1	5772	0.016286	0.126582	0	1
Public Use	43820	0.006025	0.077385	0	1	5772	0.005024	0.07071	0	1
Commercially Certified	43820	0.238864	0.426394	0	1	5772	0.236487	0.424961	0	1

Table 3: Discrete Time Proportional Hazard Regressions of Accidents 1982-2003

	(1)	(2)	(3)	(4)
Panel A: Full Model Accidents 1982-2003				
Over 18 years	0.09565**	0.02289	0.02963	0.08011
	(0.04750)	(0.06235)	(0.05894)	(0.06505)
Post GARA * Over 18	-0.23696***	-0.13945**	-0.12364*	-0.14945**
	(0.06845)	(0.06481)	(0.07650)	(0.06719)
Marginal effect of Post GARA * Over 18	-0.00142	-0.00084	-0.00074	-0.00089
Percentage Change in the Accident Rate	**-19.11*** **	**-11.23** **	**-9.96* **	**-12.01** **
Observations: 367,176				
Panel B: Only the Post GARA sample				
Over 18 years	-0.08329*	-0.14804**	-0.11469	-0.11398**
	(0.05001)	(0.06017)	(0.08169)	(0.04714)
Marginal effect of Over 18	-0.000484	-0.00086	-0.000666	-0.00066
Percentage Change in the Accident Rate	**-6.5* **	**-11.55** **	**-8.95**	**-8.89** **
Observations: 94,403				
Age polynomial of order	1	2	3	3
Age polynomial interacted with over 18	No	No	No	Yes
Controls for Approved Usage	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Manufacturer Model controls	Yes	Yes	Yes	Yes
Year of Manufacture controls	Yes	Yes	Yes	Yes
Panel C: Pseudo GARA (1987)				
Over 18 years	0.04467	0.03794	0.07175	0.06466
	(0.09044)	(0.05721)	(0.05886)	(0.07602)
Pseudo Post GARA * Over 18	0.06064	0.07374	0.12153	0.00945
	(0.10436)	(0.08282)	(0.08943)	(0.07062)
Observations: 367,176				
Age polynomial of order	1	2	3	3
Age polynomial interacted with over 18	No	No	No	Yes
Controls for Approved Usage	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Manufacturer Model controls	Yes	Yes	Yes	Yes
Year of Manufacture controls	No	No	No	No

Standard errors clustered on manufacturer model and age in parentheses (See Text)
* significant at 10%;
** significant at 5%;
*** significant at 1%

Table 4: Limited age regressions

	Ages 17 and 19 only
Over 18 years	.1076
	(.0839)
Post GARA * Over 18	-.1958
	(.15064)
Marginal effect of Post GARA * Over 18	-0.00142
Percentage change in the accident rate	**-15.81**
Observations	313,810
Age polynomial of order	None
Age polynomial interacted with over 18	No
Controls for Approved Usage	Yes
Year Fixed Effects	Yes
Manufacturer Model controls	Yes
Year of Manufacture controls	Yes
Robust standard errors clustered on manufacturer model cohort	
* significant at 10%;	
** significant at 5%;	
*** significant at 1%	

Table 5 Estimates from the GAATA survey

	(1)	(2)	(3)	(4)
Panel A: ln(Average Hours Flown)				
% over 18	-0.15904***	-0.22246**	-0.22729**	-0.41973**
	(0.05621)	(0.09229)	(0.09182)	(0.16897)
% without liability	-0.14220***	-0.05457	-0.04908	-0.04435
	(0.04735)	(0.04102)	(0.04097)	(0.04777)
Impact on hours flown ending liability (one s.d. change)	**-20.9*****	**-8.02**	**-7.21**	**-6.52**
Observations: 9080				
Panel B: Percentage Active				
% over 18	-1.00783***	-0.31072***	-0.35042***	-0.41220***
	(0.08597)	(0.10360)	(0.10650)	(0.12441)
% without liability	0.10978	-0.16845**	-0.17253**	-0.19279**
	(0.07660)	(0.08037)	(0.08052)	(0.07596)
Marginal Effect of Post GARA * Over 18	0.0212326	-0.03263	-0.033431	-0.03729
Percentage change in the percentage active	**3.1**	**-4.76****	**-4.88****	**-5.44****
Observations: 9231				
Panel C: Percentage Night Hours				
% over 18	-0.38996***	0.46754***	0.51514***	-0.04240
	(0.11617)	(0.14390)	(0.14895)	(0.19435)
% without liability	-0.54710***	-1.24474***	-1.15575***	-1.29936***
	(0.19230)	(0.25416)	(0.26324)	(0.28207)
Marginal Effect of Post GARA * Over 18	-0.042375	-0.08675	-0.089517	-0.10064
Percentage change in the percentage of night hours	**-32.74*****	**-67.02*****	**-69.15*****	**-77.75*****
Observations: 8826				
Age polynomial of order	1	2	3	3
Age polynomial interacted with over 18	No	No	No	Yes
Controls for Approved Usage	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Manufacturer Model controls	Yes	Yes	Yes	Yes
Year of Manufacture controls	Yes	Yes	Yes	Yes

Standard errors clustered on manufacturer model in parentheses
* significant at 10%;
** significant at 5%;
*** significant at 1%

Table 6: Marginal Effects: Effect of GARA on Safety Investments from Accident Data

	All Accidents	Weather Related
Dependent Variable	Coefficient/SE	Coefficient/SE
Biennial flight review	-0.00216	0.01812
	(0.01207)	(0.01667)
Crew Instrument Rated	**0.01559***	0.01566
	(0.00800)	(0.01156)
Daytime Flight	-0.00021	0.01566
	(0.00997)	(0.01156)
Crew Wearing Seatbelt	**0.04408*****	**0.04804*****
	(0.00532)	**(0.01251)**
Long Flight	0.01330	**0.09987*****
	(0.01889)	**(0.03162)**
Field Flight Plan	**0.08010*****	**0.13435*****
	(0.01962)	**(0.02974)**
Inspected within last year	**0.05504*****	**0.14465*****
	(0.01385)	**(0.02532)**
ELT functional	-0.00049	-0.02089
	(0.00694)	(0.03170)
Age polynomial of order	3	3
Age polynomial interacted with over 18	No	No
Controls for Approved Usage	No	No
Year Fixed Effects	No	No
Manufacturer Model controls	No	No
Year of Manufacture controls	No	No

Standard errors clustered on manufacturer model and age in parentheses (See Text)
* significant at 10%;
** significant at 5%;
*** significant at 1%

Table 7: Safety Investments as Proportion of Total Possible

Independent Variable	(1)	(3)	(5)	(6)
Panel A: All Accidents				
Over 18	0.00810	-0.00139	-0.00233	0.01462
	(0.01734)	(0.01899)	(0.01880)	(0.02569)
Post GARA * Over 18	0.02686	0.03844*	0.02951	0.01775
	(0.02205)	(0.01992)	(0.02254)	(0.02107)
Marginal Effect	0.006516	0.009325	0.0071589	0.004306
% change in overall safety investment	**1.14**	**1.63***	**1.24**	**0.75**
Observations: 30858				
Panel B: Weather Related				
Over 18	-0.02537	-0.04090	-0.03574	-0.08773
	(0.05093)	(0.05958)	(0.05875)	(0.08048)
Post GARA * Over 18	0.21980***	0.24102***	0.25758***	0.27029***
	(0.04660)	(0.06448)	(0.07690)	(0.08015)
Marginal Effect	0.0518272	0.056831	0.0607354	0.063732
% change in overall safety investment	**9.03*** **	**9.9*** **	**10.59*** **	**11.11*** **
Observations: 3717				
Age polynomial of order	1	2	3	3
Age polynomial interacted with over 18	No	No	No	Yes
Controls for Approved Usage	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Manufacturer Model controls	Yes	Yes	Yes	Yes
Year of Manufacture controls	Yes	Yes	Yes	Yes

Standard errors clustered on manufacturer model and age in parentheses (See Text)
* significant at 10%;
** significant at 5%;
*** significant at 1%

Table 8: Competing Hazard Model Decomposing Accident Risk

	Competing Risk Model	Marginal Effect
	(1) Minor Accident-No Mechanical Failure (8%)	
Post GARA * Over 18	**-2.07390*** **	**-0.00080012**
	(0.54138)	
Over 18 years	0.38869**	
	(0.16956)	
	(2) Major Accident-No Mechanical Failure (62%)	
Post GARA * Over 18	0.19245	0.000809499
	(0.25754)	
Over 18 years	-0.02007	
	(0.07373)	
	(3) Minor Accident Mechanical Failure (4%)	
Post GARA * Over 18	**-1.19782** **	**-0.00021428**
	(0.57561)	
Over 18 years	0.10816	
	(0.21713)	
	(4) Major Accident Mechanical Failure (26%)	
Post GARA * Over 18	0.15693	0.000267097
	(0.27699)	
Over 18 years	-0.10030	
	(0.08870)	
χ^2 test Post GARA*Over 18 (1)= Post GARA*Over 18 (3)	3.69*	
χ^2 test Post GARA*Over 18 (1)-(4)= 0	50.48***	
Observations: 367,176	.	
Robust standard errors clustered on manufacturer model cohort		
* significant at 10%; ** significant at 5%; *** significant at 1%		

Table A1: Accidents, Fatalities and Damaged Aircraft 1982-2002

year	Total Accidents	Fatalities	Destroyed Aircraft	Substantially Damaged Aircraft
1982	3083	1281	872	2077
1983	2816	1064	760	1953
1984	2798	1113	798	1897
1985	2578	1022	716	1782
1986	2325	1010	631	1627
1987	2329	892	616	1640
1988	2201	775	593	1512
1989	2059	815	516	1476
1990	1968	756	538	1386
1991	1968	891	511	1399
1992	1814	797	465	1305
1993	1778	686	448	1282
1994	1708	692	429	1228
1995	1742	668	453	1246
1996	1631	536	379	1217
1997	1578	622	383	1155
1998	1568	536	363	1177
1999	1588	519	306	1236
2000	1482	572	290	1143
2001	1394	451	272	1079
2002	1326	425	236	1051