Product Liability and Moral Hazard: Evidence from General Aviation
Author(s): Eric A. Helland and Alexander Tabarrok
Source: *Journal of Law and Economics*, Vol. 55, No. 3 (August 2012), pp. 593-630
Published by: The University of Chicago Press for The Booth School of Business of the University of Chicago and The University of Chicago Law School
Stable URL: http://www.jstor.org/stable/10.1086/666363

# Product Liability and Moral Hazard: Evidence from General Aviation

Eric A. Helland *Claremont-McKenna College*
Alexander Tabarrok *George Mason University*

## Abstract

Product liability law reduces the costs of accidents to consumers, thus reducing their incentives 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 manufacturers of small aircraft from product liability claims when their aircraft 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. When an aircraft is exempted from tort liability, the probability that the aircraft will be involved in an accident declines. Direct evidence of pilots' and owners' behavior is also consistent with moral hazard.

## 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 proved to be difficult.[1]

We wish to thank Jens Hennig of the General Aviation Manufacturers Association for providing us with production data and Aviation Data Services for their assistance with the registry data. We also wish to thank Bill Dickens, Jonah Gelbach, Michael Heise, Jon Klick, Darius Lakdawalla, and Seth Seabury for helpful comments and Amanda Agan and Elissa Gysi for research assistance.

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

[*Journal of Law and Economics,* vol. 55 (August 2012)]

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, it has moved from a negligence standard to strict liability—but so have many other factors influencing accidents. In addition, difficulty is caused by the bilateral nature of accidents. Since manufacturers and consumers both typically make safety investments, the problem becomes one of a double moral hazard. As the incentives of one party change, the incentives of the other parties typically change in the opposite direction. An ideal experiment would randomly assign to each party potentially involved in an accident its 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 manufacturers who were liable even though consumers were not compensated.

We address many of the difficulties in estimating the importance of moral hazard 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 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 (GARA) in 1994. The act 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, p. 583). It runs from the date the aircraft was delivered to the first purchaser or, for components, when the component was installed.[2,3]

Although liability ends only after 18 years, 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 before GARA they could be sued for any aircraft that they had ever produced. The average age of the general aviation fleet is older than 24 years, and thousands of 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

---

[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] The General Aviation Revitalization Act 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 the General Aviation Revitalization Act (GARA) ban was in place.

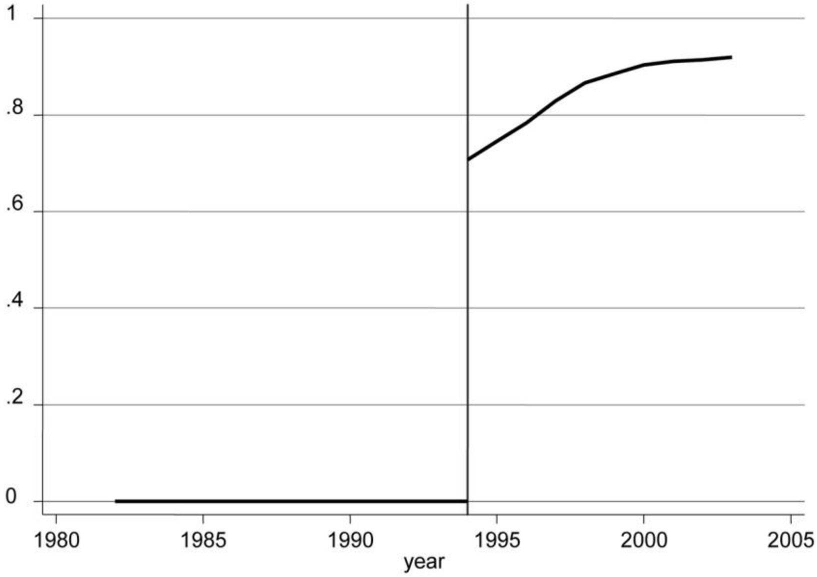

**Figure 1.** The proportion of aircraft without liability in 1982–2003

on an aircraft produced decades earlier.[4] Figure 1, which is based on aircraft registry data described below, shows that owners of 70 percent of general aviation aircraft lost the right to recover damages from the aircraft's manufacturer immediately on the passage of GARA, with the percentage rising to about 90 percent over the following decade.

The GARA policy change lets us address a number of endogeneity issues inherent to a 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. It is important to note that an aircraft manufacturer's investment in safety is focused at the level of the make and model (make-model) year information—that is, every aircraft of the same make-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-model. Manufacturers can do little to change their investment in safety as an aircraft reaches 18 years of age. However, GARA imposes a hard cutoff of liability at 18 years; thus, so long as other factors vary smoothly with age, we can estimate the effect of liability changes holding constant manufacturers' investments in safety. This is important because, in general, consumers' and manufacturers' investments in safety are jointly determined (Cooper

---

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

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 increase their investments in safety relative to pilot-owners whose aircraft are not yet covered by the liability limits. These pilot-owners also decrease the use of aircraft without liability.

Section 2 provides a more extensive discussion of moral hazard and torts. In Section 3, we discuss the data. Section 4 describes the estimation strategy. The results for accidents are presented in Section 5, Section 6 looks at prices and trade volumes, and Section 7 examines evidence of the safety investments induced by GARA. Section 8 offers a welfare calculation, and Section 9 concludes.

## 2. The Framework

The theoretical trade-off between liability rules and safety is well understood. Models typically examine three liability rules: no liability, in which the manufacturer does not pay the cost of accidents; negligence, in which the manufacturer pays for the accident only if his precaution level falls below some reasonable threshold; and strict liability, in which the manufacturer is liable for all accident costs regardless of his level of care. In the simplest version of the model, only manufacturers can take precaution (the so-called unilateral care model), and the cost of accidents, including both the cost of precaution and the cost of injuries, is minimized under a strict-liability rule or a negligence rule but not under a regime of no liability (Landes and Posner 1987; Shavell 1987). The intuition of the simple model fits well with developments in product liability law. Both case law and the *Restatement* (*Second*) *of Torts* (American Law Institute 1965–79) converged on a strict-liability standard for products, including general aviation.

Strict liability is less likely to be optimal when consumers as well as manufacturers can take precaution. Durable goods in particular often require regular maintenance, and consumers, who control the product, are often in a better position to monitor and maintain. Moreover, the way in which durable goods are used can easily contribute to the likelihood and severity of injury. Models that incorporate bilateral precaution, unsurprisingly, find that increased precaution by manufacturers can reduce precaution by consumers. The liability rule that minimizes accident costs thus depends on the relative productivity of investments in safety (Cooper and Ross 1984).

Another aspect of consumers' safety investments is the activity level. The general finding is that a strict-liability standard for manufacturers encourages overactive use by consumers, while a no-liability standard encourages consumers to use the product at the efficient activity level (Shavell 1987). Thus, when activity level is an important determinant of accidents, a no-liability standard could move the equilibrium closer to efficiency.

In the case of durable goods such as general aviation aircraft, manufacturers make most of their safety investments up front in the design stage, while consumers, pilots, and owners of small aircraft make substantial safety investments and choices regarding activity level over the lifetime of the aircraft. Most lawsuits involving aircraft accidents allege design defects, and such defects typically are difficult to undo once the aircraft has been produced. Less common are lawsuits alleging that the aircraft, although properly designed, had a defect when manufactured. In either case, the manufacturer has relatively little control over the safety of the aircraft once it has left the manufacturer's doorstep. In contrast, consumers of aircraft have much better control over day-to-day safety. Indeed, according to the Federal Aviation Administration (FAA), most accidents are caused by pilot error (General Accounting Office 2001).

Pilots have substantial control over error through decisions about how much to invest in training and decisions about when and where to fly. The FAA conducts safety seminars administered by district offices, and the Airline Owners and Pilots Association's Air Safety Institute that conducts seminars. In addition, pilot continuing education classes from the FAA or other groups are extensive.

Owners and pilots also have substantial control over the activity level of aircraft—that is, over how often the aircraft is flown, how far the aircraft is flown, under what conditions the aircraft is flown (for example, whether the aircraft is flown at night or during poor weather conditions), and so forth. Pilots' and owners' control extends to areas beyond pilots' behavior. Owners can keep their aircraft equipped with the latest safety technology or not, and they have substantial control over the frequency and intensity of safety inspections and repair. As an aircraft ages, safety information is developed through inspections by private mechanics who report problems to the Service Difficulty Report System of the FAA. If the FAA notices a pattern of problems in the Service Difficulty Report System or in another database, they will issue an airworthiness directive. Airworthiness directives are issued to owners of aircraft and may require them to either fix a particular component or conduct regular inspections for cracks or corrosion, or they may simply require that pilots not perform certain maneuvers. (Airworthiness directives typically are issued for a given make-model of aircraft, a fact that motivates our choice of manufacturer and model [manufacturer-model] year information as the locus for estimation.) The FAA recommends that owners monitor the Service Difficulty Report System database for relevant information for their aircraft, but this is done on a purely voluntary basis (FAA 2003). Airworthiness directives are mandatory, but at the level of general aviation aircraft (as opposed to air carriers), there is substantial de facto room for choice.

Another source of information for general aviation pilots are type clubs. According to the FAA, "The owners of older airplanes routinely form organizations, especially when the manufacturer no longer exists or *provides little consumer* *support*. These organizations (referred to as “type clubs”) share information and are often considered the best source of continued airworthiness concerns that could be or develop into safety problems.” (FAA 2003, p. 2).[5]

The clubs are a source of expertise regarding the maintenance of a particular model and will provide members with information on service difficulties. These clubs also typically provide information on flight safety that goes beyond mechanical difficulties; for example, they may instruct members on how to safely maneuver their aircraft and provide information about potential avionics upgrades and inspection techniques. The FAA recommends that pilots and owners take advantage of the information collected by type clubs, but again this is on a voluntary basis (FAA 2003).

In sum, in addition to choosing when, where, and how much to fly, owners have substantial choice regarding safety investments. Owners can increase the frequency and quality of inspections. They can monitor or not monitor the FAA’s Service Difficulty Report System and airworthiness directives, and they can choose how strictly and quickly to follow the instructions therein; they can attend seminars on safety or not; and they can choose to join or not join type clubs. The incentive to make these investments in safety increases when manufacturers are no longer potentially liable for accidents. Thus, as GARA switches the liability rule for general aviation aircraft from strict liability to no liability, we look for changes in accident probabilities, safety investments, and activity level changes, such as retiring aircraft early or flying fewer night flights.

Our primary interest is in estimating the strength of moral hazard on the consumer’s side as well as the routes by which it is made manifest. In addition, we also examine the effect of the GARA switch on the price of used aircraft and the quantity traded. In essence, GARA removed an insurance product from the aircraft bundle; thus, we would expect to see price declines among affected aircraft. Moreover, since some consumers place a high value on insurance and others a low value, we would expect to see increased trade. In particular, as GARA came into play, consumers who place a high value on insurance would want to sell aircraft to consumers who place a low(er) value on insurance. As with other durable goods, consumers who value high quality (in this case, insurance) will sell aircraft that are 18 or older and will buy new or newer aircraft (Hendel and Lizzeri 1999; Gilligan 2004).

## 3. Data

### 3.1. *Data Sources*

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

---

[5] Emphasis added; we expect less manufacturer support for older aircraft after GARA.

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 it from a private source for 1987, 1991, and 1994–2003.[6] 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 that destroyed the aircraft before 1987, we were able to fill in the panel using the accident data discussed below. The registry contains information on the year that the aircraft was manufactured, the approved uses of the aircraft, a code for the manufacturer and model of the aircraft, and aircraft identification. The registry also contains information on whether the aircraft changed owners and, indirectly, via the aircraft's absence from the registry, whether it was retired or sold to a new owner in a foreign country.

The data on accidents come from the FAA and the National Transportation Safety Board accident data from 1982 to 2003. The data are linked to registry data via the aircraft identifier. Because the FAA recycles aircraft identifiers, the data are also merged using a serial number. Because some of the accidents are self-reported, it is important to understand the process that generates the accident data. Under federal law, any accident or incident involving a general aviation aircraft must be reported to the National Transportation Safety Board (NTSB) immediately. Although the NTSB delegates some investigations to the FAA, notification must go to the NTSB.[7] The notification must include the type of aircraft, the name of the owner-operator, the name of the pilot, the points of departure and destination of the aircraft, the location of the accident, the number of persons involved, any injuries or deaths, and details on the nature of the accident, the extent of damage to the aircraft, and the weather at the time of the accident. Within 10 days, written reports with further details must also be filed.

The specific definitions of accident and incident are fairly all-encompassing. An accident is defined as "an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damages."[8] Substantial damages are defined as any damage that affects the structural strength, performance, or flight of the aircraft. Essentially, if the damage must be repaired, it is substantial damage. Serious injury is defined as any injury requiring hospitalization, fractures, hemorrhages, internal organ damage, or serious burns.

Incidents that need to be reported do not involve damage or injury to the aircraft or crew but involve an aircraft malfunction, the inability of a crew member to perform his or her duties, a fire, a collision between two aircraft that

---

[6] Data for previous years 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.

[7] The statute is typically referred to as National Transportation Safety Board (NTSB) rule 830.

[8] See the National Business Aviation Association, NTSB Accident and Incident Reporting Requirements (http://www.nbaa.org/ops/safety/ntsb/).

does not meet the definition of an accident, or damage to any property other than the aircraft.

There are serious penalties for failing to report an accident or incident. Currently, the fines are $1,000 per day and up to 10 years in jail. In addition, an operator's license can be suspended for failure to report.[9] Moreover, airport operators are also required to report accidents or incidents if they are aware of them, and most airports impose additional fines for failure to report. While there are possible penalties for actions that may have caused an accident, these generally occur in accidents that would be difficult to conceal because they typically involve substantial damage or injuries.[10] Finally, aircraft manufacturers are also required to report an accident. Given that GARA's statute of repose is void in the case of fraud, aircraft and parts manufacturers also have incentives to report accidents of which they become aware, particularly if those accidents have not been previously reported.

The comprehensiveness of the registry 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 with data from the General Aviation and Air Taxi Activity (GAATA) survey from the FAA. The GAATA survey contains data on the number of hours flown and the percentage of aircraft regularly flown according to manufacturer and model, although this is not broken down by aircraft age. After 1996, the FAA published these data only in six broad categories rather than by manufacturer and model, as it had done previously.

The data on prices come from the *Aircraft Bluebook: Historical Value Reference* (1982–2003), which contains quarterly data on the price of a make-model for a specific model year of aircraft from 1982 to 2003. One issue is that the *Bluebook* data have a more detailed set of make-model classifications than the registry data. This more detailed classification system describes additional features of the aircraft that influence the price. For this reason, we estimate the price data using the make-model classification in the *Bluebook* rather than the classification from the registry data.

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 because these are significantly less common than fixed-wing aircraft and involve substantially different safety issues (General Accounting Office 2001). We estimate the models using only make-models with more than 7,000 aircraft produced over all model years. Because there are a large number of make-models with very limited production runs,

---

[9] See the National Transportation Safety Board, United States Code, Title 49 (http://www.ntsb.gov/legal/ntsb_statute.html#1155).

[10] An examination of FAA civil penalties since 1998 suggests that most involve regulatory noncompliance discovered during an FAA or NTSB investigation of an accident. The exception is the illegal transportation of hazardous materials.

Table 1

Descriptive Statistics for the Registry Data

| | Mean | SD | Min | Max |
|---|---|---|---|---|
| Accident in year *t* | .007103 | .083977 | 0 | 1 |
| Post-GARA × Over 18 | .379015 | .485142 | 0 | 1 |
| Over 18 | .666783 | .471363 | 0 | 1 |
| Age | 25.876786 | 13.766735 | 1 | 67 |
| Approved: | | | | |
| For commuter use | .018042 | .133105 | 0 | 1 |
| For utility use | .095810 | .294330 | 0 | 1 |
| For agriculture | .033439 | .179781 | 0 | 1 |
| For surveying | .001616 | .040170 | 0 | 1 |
| For advertising | .002908 | .053848 | 0 | 1 |
| For weather monitoring | .000940 | .030649 | 0 | 1 |
| For research and development | .002700 | .051887 | 0 | 1 |
| For exhibition | .004122 | .064068 | 0 | 1 |
| Commercial flight | .160166 | .366760 | 0 | 1 |
| Partnership | .037414 | .189774 | 0 | 1 |
| Corporate ownership | .270677 | .444310 | 0 | 1 |
| Co-owned | .135683 | .342452 | 0 | 1 |
| Government owned | .011629 | .107209 | 0 | 1 |

**Note.** $N = 5{,}351{,}949$.

this restriction reduces the number of make-model fixed effects without substantially reducing the sample size. To check the robustness of the restriction, we also estimate the accident regressions using the five largest make-models.

The means and standard deviations of the data are included in Tables 1–4. Table 1 presents the registry data for 1982–2003; Table 2, the GAATA data for 1984, 1985, and 1989–1996; and Table 3, the combined accident data from the NTSB and the FAA for 1982–2004. Table 4 presents the *Bluebook* price data and the sales and retirement data.

### 3.2. Difference in Means

The accident rate is the result of the safety investments of manufacturers and of owners and pilots. As noted above, much of the manufacturers' safety investment takes place in the design of the aircraft and the level of quality control during its production. Because these investments are predetermined when GARA takes effect, we can focus attention on the incentives of owners and pilots. Thus, our prediction is that the end of liability for aircraft older than 18 years will result in a decrease in the probability of an accident as owners and pilots increase safety investment. Figure 2 presents a simple difference in means.[11] We divide aircraft into four groups: those older than 18 after GARA (Over 18 × Post-

---

[11] In Figure 2, the left panel shows the change in accident probabilities before and after the General Aviation Revitalization Act for the treatment (Over 18) and control (Under 18) groups of planes by make-model number. The right panel shows the difference in the difference, suggesting that after GARA the probability of an accident decreased in the treatment group relative to the control group.

## Table 2

## Descriptive Statistics for General Aviation and Air Taxi Activity Survey Data

| Variable | Observations | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Log hours flown for manufacturer-model cohort | 9,080 | 4.108206 | 1.206289 | 2.41906 | 7.740664 |
| Actively used (%) | 9,231 | .6850883 | .2458056 | 0 | 1 |
| Hours flown at night (%) | 8,826 | .1294468 | .1572456 | 0 | .9985716 |
| Manufacturer-model in cohort (1,000s) | 9,231 | 3.124753 | 5.648578 | .001 | 26.855 |
| Without manufacturer liability (%) | 9,231 | .2031816 | .3692677 | 0 | 1 |
| Older than 18 (%) | 9,231 | .6389117 | .3716459 | 0 | 1 |
| Approved (%): | | | | | |
| For commuter use | 9,231 | .000158 | .0018781 | 0 | .0285551 |
| For utility use | 9,231 | .0299363 | .1387689 | 0 | .8774527 |
| For agriculture | 9,231 | .0480593 | .171968 | 0 | .9655532 |
| For surveying | 9,231 | .0034016 | .0165608 | 0 | .2916667 |
| For advertising | 9,231 | .0022398 | .0063982 | 0 | .125 |
| For weather monitoring | 9,231 | .0011281 | .0030586 | 0 | .0416667 |
| For research and development | 9,231 | .004842 | .0082397 | 0 | .08 |
| For exhibition | 9,231 | .0063513 | .0491081 | 0 | 1 |
| Commercial flight (%) | 9,231 | .1377616 | .2656354 | 0 | 1 |
| Partnership (%) | 9,231 | .0325939 | .0201089 | 0 | .1794872 |
| Corporate ownership (%) | 9,231 | .2776998 | .2332139 | 0 | 1 |
| Co-owned (%) | 9,231 | .1025523 | .0893378 | 0 | 1 |
| Government owned (%) | 9,231 | .0125677 | .0319892 | 0 | 1 |

## Table 3

## Descriptive Statistics for Federal Aviation Administration and National Transportation Safety Board Accident Data

| | All Accidents | | | | | Weather-Related Accidents | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Observations | Mean | SD | Min | Max | Observations | Mean | SD | Min | Max |
| Fatal Accident | 43,820 | .1877 | .390477 | 0 | 1 | 5,772 | .25797 | .437555 | 0 | 1 |
| Substantial Damage | 43,820 | .720105 | .448953 | 0 | 1 | 5,772 | .659563 | .473897 | 0 | 1 |
| Destroyed Aircraft | 43,820 | .248996 | .432436 | 0 | 1 | 5,772 | .325337 | .468616 | 0 | 1 |
| Biennial Flight Review | 39,013 | .769308 | .421281 | 0 | 1 | 5,207 | .783561 | .411857 | 0 | 1 |
| Crew Instrument Related | 39,013 | .112809 | .316363 | 0 | 1 | 5,207 | .10313 | .304158 | 0 | 1 |
| Daytime Flight | 43,517 | .835375 | .370846 | 0 | 1 | 5,745 | .813229 | .389762 | 0 | 1 |
| Crew Wearing Seat Belt | 40,736 | .907355 | .289938 | 0 | 1 | 5,325 | .898028 | .30264 | 0 | 1 |
| Long Flight | 30,155 | .463107 | .498645 | 0 | 1 | 4,206 | .500238 | .500059 | 0 | 1 |
| Filed Flight Plan | 43,813 | .233766 | .42323 | 0 | 1 | 5,770 | .322357 | .467419 | 0 | 1 |
| Inspected in Past Year | 33,470 | .665671 | .471763 | 0 | 1 | 4,363 | .655054 | .475405 | 0 | 1 |
| ELT Functional | 41,051 | .292222 | .454789 | 0 | 1 | 5,488 | .329628 | .470121 | 0 | 1 |
| Aircraft Age (years) | 43,036 | 21.3096 | 12.92367 | 0 | 66 | 5,378 | 20.75046 | 12.69763 | 0 | 66 |
| Aerial Application | 43,820 | .063533 | .243921 | 0 | 1 | 5,772 | .04158 | .199645 | 0 | 1 |
| Air Drop | 43,820 | .000342 | .018499 | 0 | 1 | 5,772 | .000347 | .018613 | 0 | 1 |
| Aerial Observation | 43,820 | .005431 | .073498 | 0 | 1 | 5,772 | .006584 | .080878 | 0 | 1 |
| Air Race or Show | 43,820 | .000297 | .017222 | 0 | 1 | 5,772 | .000173 | .013613 | 0 | 1 |
| Business, Executive, or Corporate | 43,820 | .070904 | .256667 | 0 | 1 | 5,772 | .092169 | .28929 | 0 | 1 |
| Ferry | 43,820 | .010885 | .103765 | 0 | 1 | 5,772 | .008143 | .089877 | 0 | 1 |
| Flight Test | 43,820 | .000844 | .029046 | 0 | 1 | 5,772 | .000173 | .013163 | 0 | 1 |
| Instructional | 43,820 | .138749 | .345689 | 0 | 1 | 5,772 | .101178 | .301591 | 0 | 1 |
| Personal | 43,820 | .595938 | .490715 | 0 | 1 | 5,772 | .637734 | .480697 | 0 | 1 |
| Positioning | 43,820 | .015358 | .122975 | 0 | 1 | 5,772 | .016286 | .126582 | 0 | 1 |
| Public Use | 43,820 | .006025 | .077385 | 0 | 1 | 5,772 | .005024 | .07071 | 0 | 1 |
| Commercially Certified | 43,820 | .238864 | .426394 | 0 | 1 | 5,772 | .236487 | .424961 | 0 | 1 |

**Note.** ELT = emergency locator transmitter.

Table 4

Descriptive Statistics for the Price, Sales, and Retirement Data

| | Mean | SD | Min | Max |
|---|---|---|---|---|
| Quarterly price data ($n$ = 56,203): | | | | |
| Price in constant year 2000 $U.S. | 101,183.24 | 99,279.64 | 8,287.8 | 1,003,385 |
| Post-GARA × Over 18 | .29 | .45 | 0 | 1 |
| Over 18 | .49 | .50 | 0 | 1 |
| Annual sales and retirement data ($n$ = 124,251): | | | | |
| Number of aircraft sold in current year | 3.39 | 12.47 | 0 | 277 |
| Number of aircraft retired in current year | .31 | 1.88 | 0 | 109 |
| Post-GARA × Over 18 | .34 | .48 | 0 | 1 |
| Over 18 | .63 | .48 | 0 | 1 |
| Age | 25.90 | 15.90 | 0 | 67 |
| Number of aircraft in model-model-year cohort | 46.92 | 156.86 | 1 | 2,937 |

**Note.** GARA = General Aviation Revitalization Act.

GARA), those older than 18 before GARA (Over 18 × Pre-GARA), those younger than 18 before GARA (Under 18 × Pre-GARA), and those younger than 18 after GARA (Under 18 × Post-GARA). Thus constructed, our difference in difference is

$$(\text{Over 18} \times \text{Post-GARA} - \text{Over 18} \times \text{Pre-GARA})$$

$$- (\text{Under 18} \times \text{Post-GARA} - \text{Under 18} \times \text{Pre-GARA}).$$

We refer to aircraft older than 18 as the treatment group and aircraft younger than 18 as the control group.

The results in Figure 2 show that when we average over the total number of aircraft in our sample, accident probability increases slightly for control aircraft and decreases for those in the treatment group. This pattern is borne out with four of the five largest make-models of aircraft, with only one experiencing an increase in the accident rate. The decrease is slightly more than .001, or a tenth of 1 percent, suggesting a 10 percent decline in the accident rate. While this effect may appear quite large, it should be noted that most accidents involve damage to the aircraft only and no injury to the pilot (see Table 3).

While the results are consistent with the model, they also suggest heterogeneity of effects. It may also be important to control more carefully for the exact aircraft being compared. In Section 4, we turn to a more in-depth estimation.

## 4. Estimation

### 4.1. *Identification*

For the majority of the responses to changes in liability, we utilize a common estimation strategy. For example, 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. Let

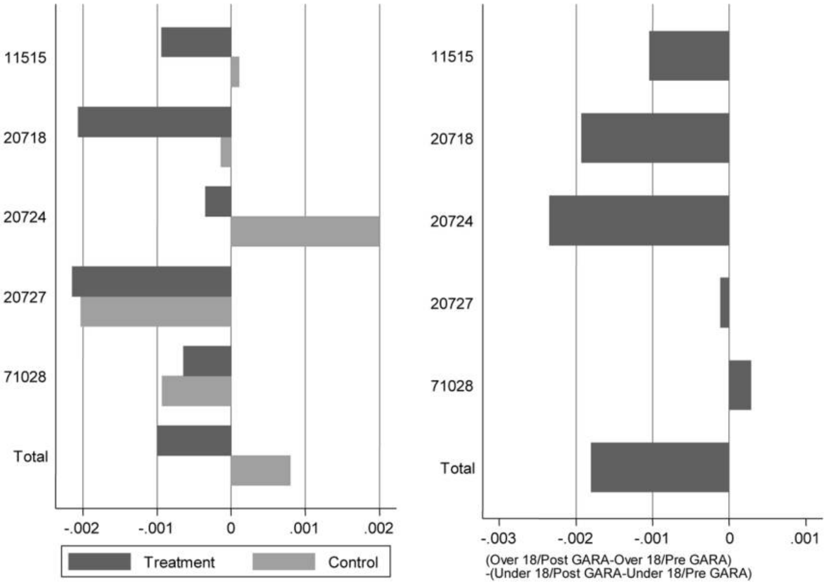

**Figure 2.** Accident difference in difference

$$\boldsymbol{y}_{ijtk} = \boldsymbol{X}_{ijt}\beta + f_k(a) + \boldsymbol{C}_{tk}\delta + \boldsymbol{D}_{tk}\alpha + \vartheta_t + \lambda_j + \phi_k + \boldsymbol{u}_{itjk}, \tag{1}$$

where $\boldsymbol{y}_{ijtk}$ is an indicator variable equal to one if aircraft $i$, in year $t$, of manufacturer-model group $j$, and in year-manufactured cohort $k$ had an accident. The term $\boldsymbol{X}_{itj}$ denotes characteristics of the aircraft with manufacturer-model-specific coefficient $\beta$. The controls include the approved uses of the aircraft, including commuting, utility, agriculture, surveying, advertising, weather monitoring, research and development, and exhibition. We also include information on whether the aircraft was owned by a business, a partnership, or a 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 sightseeing. We also include year fixed effects, $\vartheta_t$, to capture the time trend; fixed effects for the year in which the aircraft was built, $\phi_k$, to capture the technology available at the time the aircraft was constructed; and manufacturer-model fixed effects, $\lambda_j$, to capture differences in the safety of different models.

Because aircraft age determines our treatment—that is, the end of liability—but may also have an independent effect on accidents due to wear and tear on the aircraft, controlling for age independent of liability is important. The standard approach of including a linear age term could be insufficient if accident probabilities vary nonlinearly with age. Given the 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. The polynomial lets accident quality vary smoothly with age. We estimate polynomials of various lengths.[12]

The term $\boldsymbol{C}_{tk}$ is an indicator variable for aircraft without the option of suing the manufacturer—namely, aircraft older than 18 after GARA. Inclusion of the age polynomial means that our assessment of the effect of GARA's liability cutoff at age 18 is estimating a break in the relationship between expected age and accidents. We also include $\boldsymbol{D}_{tk}$, a control for aircraft older than 18 (that is, both before and after GARA), to capture any impact of an aircraft turning 18 that might be independent of the liability regime and a smooth polynomial. Finally, $\boldsymbol{u}_{itjk}$ 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 older. This specification not only allows for the possibility that the safety profile of an aircraft varies nonlinearly in age but also allows for the possibility that being age 18 is in some way important in aircraft safety, independent of the policy experiment induced by GARA. We utilize this identification strategy to estimate the probability of an accident, whether an aircraft is sold or retired, and the residual value of the aircraft.

### *4.2. Estimating the Probability of an Accident*

Since we are interested in the probability of an accident occurring in each year, we estimate a 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 that is functionally equivalent to a Cox proportional hazard model (Meyer 1990; Jenkins 2005). This semiparametric model is flexible and imposes fewer restrictions than do models that force duration times to follow a Weibull or other fixed distribution.

The model allows us to easily deal with three features of the accident 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 period before 1982. Similarly, the model allows us to easily model entrants to the sample. Second, an accident usually does not result in the destruction of the aircraft. Using the Meyer framework, it is also easy to accommodate the fact that aircraft typically return to active use after an accident, which means that aircraft can have multiple accidents over their life span. Finally, the model allows us to deal with the truncation created by the fact that we do not observe accidents after 2003.

We parameterize the hazard rate using the age polynomials described above

---

[12] For a further discussion of the use of polynomials to control for nonlinear effects and treatment variables, see Lee and Card (2006).

## Table 5

## Discrete Time Proportional Hazard Regressions of Accidents, 1982–2003

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Full-model accidents, 1982–2003: ($n$ = 5,351,949): | | | | | |
| Post-GARA × Over 18 | −.123** | −.162** | −.155** | −.144** | −.134** |
| | (.0300) | (.0345) | (.0355) | (.0360) | (.0316) |
| Over 18 | .0363+ | .0671** | .0692** | .0390 | .0910** |
| | (.0202) | (.0244) | (.0245) | (.0350) | (.0225) |
| Marginal effect of Post-GARA × Over 18 | −.000737 | −.000968 | −.000929 | −.000863 | −.000793 |
| % Change in accident rate | −10.4 | −13.6 | −13.1 | −12.2 | −11.2 |
| Post-GARA-only model ($n$ = 556,166): | | | | | |
| Over 18 | −.0672 | −.151* | −.129* | −.127 | −.0674 |
| | (.0604) | (.0641) | (.0654) | (.0870) | (.0610) |
| Marginal effect of Post-GARA × Over 18 | −.000445 | −.00102 | −.000868 | −.000849 | −.000440 |
| % Change in accident rate | −6.02 | −13.7 | −11.7 | −11.5 | −5.95 |
| Pseudo-GARA model (1987) ($n$ = 5,351,949): | | | | | |
| Post-GARA × Over 18 | .00377 | .00717 | .0272 | −.000499 | −.0341 |
| | (.0255) | (.0306) | (.0321) | (.0323) | (.0277) |
| Over 18 | .00398 | $-1.48 \times 10^{-6}$ | −.00339 | −.0223 | .0732** |
| | (.0240) | (.0313) | (.0311) | (.0388) | (.0279) |
| Marginal effect of Post-GARA × Over 18 | $2.29e \times 10^{-5}$ | $4.36 \times 10^{-5}$ | .000165 | $-3.03 \times 10^{-6}$ | −.000206 |
| % Change in accident rate | .32 | .61 | 2.32 | −.043 | −2.9 |
| Age polynomial of order | 1 | 2 | 3 | 3 | 3 |
| Age polynomial interacted with Over 18 | No | No | No | Yes | No |
| Make-model-specific age polynomial | No | No | No | No | Yes |

**Note.** Standard errors clustered on aircraft are in parentheses. The number of make-models is as follows: for full-model accidents and for the pseudo-GARA model (General Aviation Revitalization Act) model, $n$ = 272,207; and for the Post-GARA only model, $n$ = 60,761. All estimates include year fixed effects and controls for approved usage, manufacturer-model, and year of manufacture.

+ Significant at the 10% level.

* Significant at the 5% level.

** Significant at the 1% level.

and estimate the model using up to 21 periods (1982–2003), depending on whether the aircraft was built after 1982 or left the sample before 2003. Thus constructed, the probability of an accident in a given year is

$$\Pr(\text{accident}|\boldsymbol{X}) = 1 - \exp\{-\exp(\boldsymbol{X}\beta)\},$$

where $\boldsymbol{X}$ is the independent variable discussed above. The standard errors are clustered on the individual aircraft.

## 5. Results: Accidents

The results for equation (1) are presented in the Post-GARA-only model in Table 5. Columns 1–3 present first-, second-, and third-order age polynomials.[13] In column 4, we estimate the model including a third-order polynomial interacted with an indicator variable for aircraft older than 18. Column 5 estimates the model using a third-order make-model-specific age polynomial.

The effect of GARA on the accident rate is measured by the coefficient on the variable Post-GARA × Over 18; in all specifications, the coefficient is negative and significant. In other words, we find that the accident rate for aircraft that are no longer subject to tort declines in all specifications. The effect is smallest—a 10 percent decline in accidents—when we restrict the accident rate to be a linear function of aircraft age. The effect rises to a 14 percent 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 focus on the results from column 2, because we think that the second-order polynomial gives the best trade-off between flexibility of estimation and efficiency. In that specification, the marginal effect is to reduce the accident probability by approximately .000968 from a base probability of an accident of .0071. This indicates that the removal of liability coverage resulting from GARA produced a 13.6 percent decline in the probability of an accident.

To put this drop into perspective, in 1993, the year before GARA was enacted, there were 1,778 aircraft accidents in our sample; 339 of these accidents involved fatalities, claiming the lives of 689 individuals. A 13 percent reduction in the number of accidents in the GARA-affected sample (about 70 percent of the aircraft stock) would indicate approximately 162 fewer accidents and 62 fewer fatalities. Over 1994–2002, the accident rate fell by about 22 percent, so we estimate that just more than half of this increase in safety was due to GARA.

In 1994, about 70 percent of aircraft were already older than 18, so the moment that GARA came into effect, it moved a majority of the general aviation fleet to a no-liability regime. The specification for full-model accidents in Table 5 is primarily identified from this one-time change. The influence of GARA, however,

---

[13] We also ran regressions with polynomials of the fourth and fifth order, but in no case were the results associated with the variables of interest substantially different.

can be estimated in a second way. Aircraft younger than 18 in 1994 moved from a strict-liability regime to a no-liability regime during different years after the passage of GARA in 1994. We 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 eighteenth birthday, rather than from the single year 1994. The disadvantage is that the sample size had only about 10 percent of the number of aircraft years of our full sample.

In the post-GARA-only model in Table 5, we estimate the effect of moving to a no-liability regime solely on the basis of post-1994 data and data on those aircraft in which some portion of the manufacturer-model group turned 18 during 1995–2003. The model thus becomes

$$\boldsymbol{y}_{ijtk} = \boldsymbol{X}_{ijt}\beta + f_k(a) + \boldsymbol{D}_{tk}\alpha + \vartheta_t + \lambda_j + \phi_k + \boldsymbol{u}_{itjk}. \tag{2}$$

In this experiment there is no independent effect of an aircraft turning 18 and thus the coefficient for Over 18, $\boldsymbol{D}_{tk}$, reflects the impact of GARA.

In all specifications the elimination of liability on aircraft that turn 18 is negative (and in two of the three specifications, the coefficient is statistically significant at the 10 percent level or greater). Furthermore, the impact of GARA is economically significant, and the effect is consistent with the results from the first experiment. As an aircraft turns 18, the probability of an accident decreases by about 9–12 percent, with our base specification showing a 13 percent decline in accidents. Thus, our estimate of the decline in accidents caused by GARA, as determined in two very different experiments, is almost identical.

The similarity between the reduction in accidents after the abrupt passage of GARA in 1994 and the reduction in accidents that occurs as planes reach the age of 18 after passage of GARA has implications for the causal mechanism. The changes in full-model accidents in Table 5 were likely to be mostly unanticipated. The changes in the Post-GARA-only model in Table 5, however, are anticipated because the law change was known before these pilots made 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 was known in advance, investments in maintenance could optimally start earlier than the liability cutoff. Yet because the two impacts are similar, this suggests that the post-GARA investments in safety are mostly behavioral. Below, we discuss more evidence for behavioral changes as the primary causal mechanism for lower accident rates.

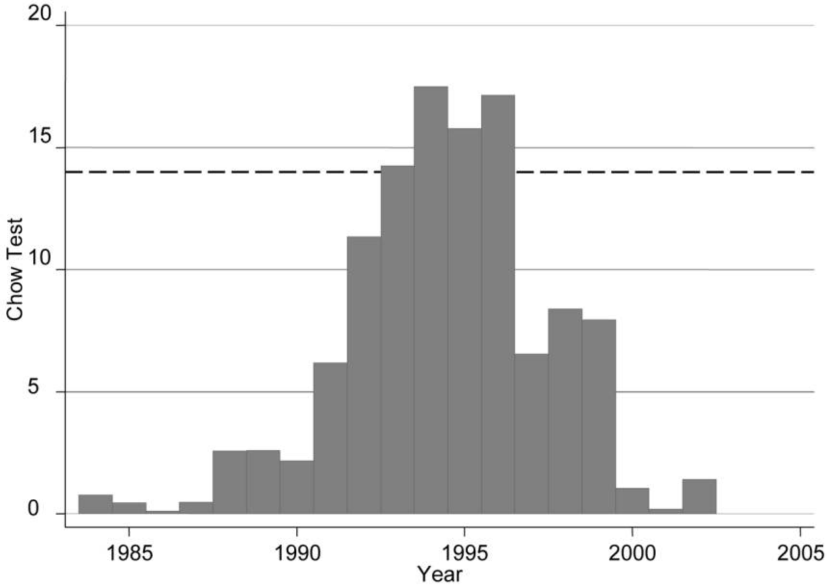

**Figure 3.** Chow test for a structural break in 1994

### *5.1. Robustness from the Pseudo–General Aviation Revitalization Act Model, Chow Tests, and Regression Discontinuity*

In the pseudo-GARA model in Table 5, we perform a robustness check. Here we truncate the data sample to 1984–93 and estimate the model as if GARA had been passed in 1987. The estimating equation is similar to equation (1), with $C_{ijtk}$ equal to one in this case if the year is 1987 or greater rather than the actual date of the passage of GARA. 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 which year between 1982 and 1994 we use for the pseudo-GARA law. In fact, the impact of our pseudo-GARA model is positive, although small and not significant in any specifications, which suggests that something fundamental changed for aircraft older than 18 in 1994.

An alternative test is presented in Figure 3. If there was a behavior change in 1994, then a Chow test for structural breaks on pseudolaws 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, increases to a maximum in 1994, and is lower thereafter. The Chow test suggests that a structural break occurred, with

Table 6

Limited Age Regressions

| | Ages 17 and 19 Only |
|---|---|
| Over 18 | .0313 |
| | (.0519) |
| Post-GARA × Over 18 | −.166* |
| | (.0842) |
| Marginal effect of Post-GARA × Over 18 | −.00112 |
| % Change in the accident rate | −13.5 |
| Age polynomial of order | None |
| Age polynomial interacted with Over 18 | No |

**Note.** Robust standard errors, in parentheses, are clustered on the manufacturer-model cohort. All regressions include year fixed effects and control for approved usage, manufacturer-model, and year of manufacture. $N = 301{,}729$.

* Significant at the 5% level.

1994 being the most likely year for the break, consistent with our hypothesis that GARA was the causal factor.[14]

In Table 6, we estimate the effect of GARA on the accident rate by looking only at aircraft ages 17 and 19. Thus, this model is closer in spirit to a regression discontinuity design than our difference-in-differences estimates above. In this case, we use the population of general aviation aircraft that are 17 and 19 in a given year. The model is similar to that used previously, except that 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 statistically significant and negative and is of similar magnitude to that shown earlier, suggesting an approximately 13 percent decline in the accident rate. The fact that the accident rate decreases quickly after GARA becomes relevant also suggests a behavioral explanation.

### *5.2. Decomposing the Accident by Make-Model*

In Table 7, we run the model separately on each of the five largest make-model combinations. The specifications are identical to those mentioned above, but they are without the make-model fixed effects since there is now only one make-model in each regression. We provide only the estimates obtained using the third-order polynomial, although all of the estimates are similar. In each case, we find a negative and significant coefficient. The marginal effects are similar to those estimated previously. Thus, the effects that we find appear to be robust across different make-models of aircraft.

---

[14] One issue is the significance level to attach to the Chow test. There is considerable debate in 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.

Table 7

Regressions on the Five Largest Make-Models

| Type of Aircraft | Post-GARA × Over 18 | Observations |
|---|---|---|
| 20724 | **−.272**** | 571,615 |
| | (.078) | |
| 71028 | −.0482 | 504,096 |
| | (.101) | |
| 20718 | −.436** | 437,404 |
| | (.091) | |
| 20727 | −.357* | 266,921 |
| | (.148) | |
| 11515 | $-.641^{+}$ | 167,375 |
| | (.382) | |

**Note.** Standard errors are in parentheses.
$^{+}$ Significant at the 10% level.
* Significant at the 5% level.
** Significant at the 1% level.

## 6. Market Impact of Changing Liability Rules

### *6.1. Prices*

We estimate the impact of GARA on the residual value using Gilligan's (2004) framework. Gilligan estimates the residual value of business aircraft using the price in year-quarter $t$ of aircraft $i$ built in year-quarter $k$: $P_t^{ik}$, with a constant rate of depreciation. The term $r^{ik}$, denoting the current price, is given by $P_t^{ik} = A_t^{ik} P_k^{ik} \exp[-r^{tk}(t-k)]$, where $A_t^{ik}$ is a shift parameter depending on the make-model and model year and $t-k$ is the aircraft's age. The residual value in year-quarter $t$ is defined as $\mathrm{RV}_t^{ik} = P_t^{ik}/P_k^{ik}$. Gilligan rearranges this equation and estimates $\log(\mathrm{RV}_t^{ik}) = \log(A_t^{ik}) - r^{it}\mathrm{Age}_t^{ik}$. To the extent that liability insurance is valuable to aircraft owners, we would predict that GARA reduces the residual value when an aircraft turns 18.

One difficulty in estimating this model is that our data do not contain the initial sales price, $P_k^{ik}$. Given that the initial price is constant, we estimate the model using a difference regression. In other words, we subtract year-quarter $t - 1$ from year $t$:

$$\log(P_t^{ik}) - \log(P_{t-1}^{ik}) - [\log(P_k^{ik}) - \log(P_k^{ik})]$$

$$= \log(A_t^{ik}) - r^{it}\mathrm{Age}_t^{ik} - \log(A_{t-1}^{ik}) - r^{it}\mathrm{Age}_{t-1}^{ik}\Delta\log(P_t^{ik})$$

$$= \log(A_t^{ik}) - \log(A_{t-1}^{ik}) - r^{it}.$$

The model is estimated using *Bluebook* price data, so our unit of observation is a manufacturer-model model year in year-quarter $t$. In accordance with Gilligan (2004), we proxy the depreciation rate with trading volume and, in our context, the number of aircraft retired. In addition, we estimate the model using polynomials of the number of aircraft retired and sold. We also include year, model, and model year fixed effects. Thus, the estimating equation is

### Table 8
### Reduced-Form Estimation of Aircraft Residual Value Function

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Post-GARA × Over 18 | −.00846** | −.00818** | −.00818** | −.00816** |
| | (.000569) | (.000586) | (.000587) | (.000587) |
| Over 18 | .00203** | .00216** | .00216** | .00217** |
| | (.000470) | (.000470) | (.000470) | (.000470) |
| Number retired | | $-8.87 \times 10^{-5}$ | $-7.50 \times 10^{-5}$ | $4.27 \times 10^{-5}$ |
| | | $(6.72 \times 10^{-5})$ | (.000127) | (.000178) |
| Number sold | | −.000206** | −.000303** | −.000425** |
| | | $(3.03 \times 10^{-5})$ | $(5.13 \times 10^{-5})$ | $(7.18 \times 10^{-5})$ |
| $(\text{Number retired})^2$ | | | $-1.92 \times 10^{-7}$ | $-5.68 \times 10^{-6}$ |
| | | | $(2.10 \times 10^{-6})$ | $(7.00 \times 10^{-6})$ |
| $(\text{Number sold})^2$ | | | $5.97 \times 10^{-7}$* | $2.51 \times 10^{-6}$** |
| | | | $(2.68 \times 10^{-7})$ | $(8.55 \times 10^{-7})$ |
| $(\text{Number retired})^3$ | | | | $4.80 \times 10^{-8}$ |
| | | | | $(6.75 \times 10^{-8})$ |
| $(\text{Number sold})^3$ | | | | $-6.64 \times 10^{-9}$* |
| | | | | $(2.77 \times 10^{-9})$ |
| Observations | 56,203 | 54,370 | 54,370 | 54,370 |

**Note.** All specifications include year, model year, and model fixed effects. Standard errors are in parentheses.
* Significant at the 5% level.
** Significant at the 1% level.

$$\Delta\log(\boldsymbol{P}_{jkt}) = \boldsymbol{X}_{kt}\beta + \boldsymbol{C}_{tk}\delta + \boldsymbol{D}_{tk}\alpha + \vartheta_t + \lambda_j + \phi_k + \boldsymbol{u}_{tjk},$$

where $\boldsymbol{P}_{jkt}$ is the price of an aircraft of manufacturer-model group $j$ and year-manufactured cohort $k$ in year-quarter $t$, and $\boldsymbol{X}_{tj}$ are the polynomials in retirement and trading volume. The year fixed effects are $\vartheta_t$, fixed effects for the year in which the aircraft was built are $\phi_k$, and manufacturer-model fixed effects are $\lambda_j$. As in previous models, $\boldsymbol{C}_{tk}$ is an indicator variable for aircraft without the option of suing the manufacturer, and $\boldsymbol{D}_{tk}$ is a control for aircraft older than 18. Finally $\boldsymbol{u}_{itjk}$ is again an unobserved error term. We control for the autocorrelation introduced by differencing, using Newey-West standard errors with second-order autocorrelation (that is, the past 2 quarters).

Results are presented in Table 8. Specification (1) does not include any measure of trading volume or retirements. Specifications (2), (3), and (4) include a first-, second-, and third-order polynomial in trading volume and retirement, respectively. The coefficient on Post-GARA × Over 18 is negative and significant in all four specifications. In each estimate, when the liability insurance of an aircraft ends, the rate of deprecation increases by about .009 percent. Given that the average value of an aircraft before GARA was $101,183, this suggests that the end of liability insurance reduced the value of an aircraft by approximately $911 per year.[15]

---

[15] Given that the difference in log price ($\log[p_t] - \log[p_{t-1}]$) is approximately equal to the percentage change in price, or $(p_t - p_{t-1})/p_{t-1}$, a .009 decline is approximately $900.00.

### *6.2. Volume of Trade and Retirements*

We expect an increase in sales of used aircraft and retirements after the change in the liability regime. The increase in sales results from aircraft owners reallocating aircraft because of the sudden disappearance of insurance as the aircraft hits age 18. Individuals who value the liability coverage will sell, at a reduced price, aircraft that no longer have coverage to individuals who do not value the coverage as highly.

We also examine retirements. Retirements can be thought of as a safety investment, the logical end point of flying aircraft fewer hours. (We examine a variety of safety investments at greater length further below.) We examine sales and retirements together because we observe a sale only if the individual or company identified in the registry changes and a retirement only if the aircraft exits the registry. The difficulty is that sales to foreign buyers are not recorded in the U.S. registry. Hence, our measure of retirements includes foreign sales. From the point of view of U.S. sellers, however, an increase in retirements is a safety investment whether the aircraft is retired or sold to a foreign buyer.

For the trading volume and retirement regressions, we estimate the total number of aircraft sold or retired in year *t*. Our date does not identify the exact date of sale, so the data are measured annually rather than each year-quarter, as is the case in the price regressions. The model follows our identification strategy. As with the price data, the unit of observation is a manufacturer-model model year in year *t*. We estimate the models in levels instead and include fixed effects for each manufacturer-model combination and each model year, so

$$\boldsymbol{y}_{ijt} = \boldsymbol{X}_{ijt}\beta + \gamma\text{Age}_{ij} + \boldsymbol{C}_{tj}\delta + \boldsymbol{D}_{tj}\alpha + \vartheta_t + \lambda_i + \phi_j + \boldsymbol{u}_{ijt},$$

where $\boldsymbol{X}_{ijt}$ is the number of aircraft in manufacturer-model group $i$ and cohort $j$ in year $t$, Age is the age of manufacturer-model cohort $ij$ in year $t$, $\boldsymbol{C}_{it}$ is an indicator variable equal to one if the cohort is older than 18, and $\boldsymbol{D}_{tj}$ is a similar indicator equal to one only if the cohort is older than 18 after GARA. Thus, $\boldsymbol{D}_{tj}$ measures the impact of GARA on sales or retirements. Finally, we include year fixed effects ($\vartheta$), manufacturer and model fixed effects ($\lambda_i$), and year manufactured fixed effects ($\phi_j$).

Columns 1–3 of Table 9 present the results for the total sold regression using the full sample, and columns 4–6 present the retirements. Consistent with the theory, we find that the end of liability results in an increase in sales of about 8.65 percent in the linear specification and 5.96 percent in the second-order age polynomial specification. In the third-order polynomial, the result is not significant but remains positive. Given that the average-model model year has 3.39 sales per year, this suggests about .2–.29 additional aircraft sold per year. Retirements (or sales to overseas owners) are rare in the data, with the average cohort having only about .31 retirement per year. Our estimates indicated that the number of retirements increases by 29.4 percent, or about .09 additional retirement. In the second- and third-order polynomial specifications, the impact

Table 9
Reduced-Form Estimation of Sales and Retirements

| | Total Sold, 1982–2003 ($N$ = 124,251) | | | Total Retired, 1987–2002 ($N$ = 82,217) | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Post-GARA × Over 18 | .294** | .202* | .0267 | .126** | .317** | .265** |
| | (.0638) | (.0797) | (.0867) | (.0280) | (.0349) | (.0391) |
| Over 18 | .370** | .447** | .471** | .268** | .0839* | .104** |
| | (.0535) | (.0669) | (.0670) | (.0303) | (.0364) | (.0369) |
| $R^2$ | .884 | .884 | .884 | .511 | .511 | .511 |
| % Change in number sold or retired | 8.65 | 5.96 | .79 | 29.4 | 74.1 | 61.8 |
| Age polynomial of order | 1 | 2 | 3 | 1 | 2 | 3 |

**Note.** All regressions include year, make-model, and model year fixed effects. Standard errors are in parentheses.
* Significant at the 5% level.
** Significant at the 1% level.

of GARA increases to 74 percent and 61 percent, respectively, suggesting .23 or .19 additional retirement.

Thus, the removal of liability reduces prices and increases reallocation of aircraft. We now turn to investigate safety investments in greater detail.

## 7. 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 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 marginal cost. For this reason, we would not necessarily expect to see increases in safety on the same dimensions that tort induces in manufacturers—for example, product design changes are too costly for an individual pilot to control. However, 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 Sections 7.1–7.3 we investigate safety investments along these dimensions to get a better understanding of the margins on which moral hazard operates.

### *7.1. 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: to wit, 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.

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 percent of general aviation accidents, it is labeled the sole cause of the accident in only about 10 percent 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 shear accidents in which sudden wind variability forces an aircraft into an uncontrolled dive. More typical are severe weather conditions that are encountered midflight but which were not foreseeable before takeoff. It is important to note that if an accident occurred and the pilot either did not obtain an appropriate weather briefing before flight or a fortiori flew into dangerous and forecasted weather, then such an accident would typically be classified as caused by pilot error. Thus, 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 or pilot behavior was not causal. Thus, at least according to the FAA, the subset of weather-related accidents is random, an act of Mother Nature.

The classification by the FAA is unlikely to be perfect, of course; nevertheless, the distribution of aircraft in accidents for which the weather was ruled to be the sole causal factor 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 seat belt.

The data contain seven safety efforts or investments by aircraft owners and/or pilots that are available for most of the sample period. The biennial flight review, or simply the flight review, is required of every holder of a pilot license at least every 2 years and consists of at least 1 hour of ground instruction and 1 hour of flight with a certified instructor. The Biennial Flight Review indicator variable measures whether the pilot of the aircraft had met this requirement. The Daytime Flight variable is equal to one if the flight occurred during daylight hours. The Crew Wearing Seat Belt indicator for equals one if the crew were wearing their seat belt and/or shoulder restraints at the time of the accident. The Long Flight variable equals one if the airport from which the plane departed is different from the destination airport. General aviation flights are at the greatest risk of an accident occurring during takeoff and landing. Thus, an increase in long flights among aircraft without liability coverage suggests that recreational flights are less common.

The Filed Flight Plan variable equals one if the aircraft involved in the accident

Table 10

Effect of the General Aviation Revitalization Act on Safety Investments from Accident Data: Marginal Effects

| Dependent Variable | All Accidents | Weather Related |
|---|---|---|
| Biennial flight review | −.00213 | .0182 |
| | (.00625) | (.0171) |
| Crew instrument rated | .0156** | .0158 |
| | (.00487) | (.0135) |
| Daytime flight | .000255 | .0240 |
| | (.00512) | (.0179) |
| Crew wearing seat belt | .0442** | .0482** |
| | (.00393) | (.0125) |
| Long flight | .0130 | .100** |
| | (.00821) | (.0243) |
| Filed flight plan | .0797** | .133** |
| | (.00596) | (.0196) |
| Inspected in past year | .0550** | .145** |
| | (.0119) | (.0208) |
| ELT functional | −.000502 | −.0210 |
| | (.00624) | (.0192) |

**Note.** Robust standard errors are in parentheses. The age polynomial of order is 3 for both groups. None of the regressions include year fixed effects or controls for age polynomial interacted with Over 18, approved usage, manufacturer-model, or year of manufacture.

** Significant at the 1% level.

had filed a flight plan. Flight plans are filed by pilots with the local branches of the FAA before 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 they are highly recommended by the FAA because they provide a way of alerting authorities if a flight is overdue. The Inspected in Past Year indicator variable is equal to one if the aircraft has received an inspection within the past 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 ELT Functional indicator variable equals one if the aircraft's emergency locator transmitter (ELT) was operational at the time of the crash. The ELT is designed to emit a 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. Because of the small cell sizes for a number of these variables, we do not include manufacturer-model, model year, or aircraft fixed effects. Thus, the regression reported in Table 10 includes only an indicator variable for Over 18, the Over 18 indicator interacted with Post-GARA, which is the variable that we show in Table 10 and the third-order polynomial in age. We have approximately 30,000–40,000 observations in the data regressions on all accidents and 4,000–5,000 observations in the data on weather-related accidents. The data cover the period from approximately 1982 to 2003, with some variation depending on the specific investment.

The results from both the data on all accidents and the data on weather-related accidents 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-related sample, which is what we would expect if selection biases the all accident results downward. (For example, imagine that accidents occur only when the plane is not inspected in the past 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 percent using the data for the all-accident sample but by 14.5 percent using the data for the more randomized sample of weather-related accidents. Focusing on the sample of weather-related accidents, we find increases in the probability that the crew wears seat belts, takes a long flight (that is, fewer short flights), files a flight plan, and had the plane inspected in the past year.

Interestingly, the coefficient on seat belt use is almost identical in the all-accident and weather-related accident samples. This is what one would expect if our argument about the random nature of weather-caused accidents is correct and if wearing a seat belt does not contribute to whether or not an accident occurs but, instead, affects only 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 increase the chances that the aircraft's emergency transmitter locator is functional. 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 pilot-owner of the aircraft. 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 second, it lets us estimate the effect of moral hazard on an overall measure of safety investments. The model is estimated using the technique of Papke and Wooldridge (1996). The standard errors are again clustered on both the manufacturer-model and the index.

The results are presented in Table 11. We find only small effects, on the order of an increase of 1 percent, in the all-accident sample, but we find large and statistically significant effects in the weather-related sample. We find that GARA caused an increase of about 10 percent in the proportion of safety investments undertaken (a marginal effect of 5 percent relative to an average investment proportion of 57 percent).[16]

---

[16] The results are robust to different methods of accounting for missing observations on safety investments. In Table 11 we assume that the denominator is the number of nonmissing fields for that observation. Thus, if five of the eight safety investments were recorded for an observation, the denominator is five. We also estimated the model, including all safety investments recorded in the

Table 11

Safety Investments as the Proportion of the Total Possible

| Independent Variable | (1) | (3) | (5) | (6) |
|---|---|---|---|---|
| All accidents ($N = 30{,}858$): | | | | |
| Over 18 | .00810 | −.00139 | −.00233 | .01462 |
| | (.01734) | (.01899) | (.01880) | (.02569) |
| Post-GARA × Over 18 | .02686 | .03844$^{+}$ | .02951 | .01775 |
| | (.02205) | (.01992) | (.02254) | (.02107) |
| Marginal effect | .006516 | .009325 | .0071589 | .004306 |
| % Change in overall safety investment | 1.14 | 1.63 | 1.24 | .75 |
| Weather-related accidents ($N = 3{,}717$): | | | | |
| Over 18 | −.02537 | −.04090 | −.03574 | −.08773 |
| | (.05093) | (.05958) | (.05875) | (.08048) |
| Post-GARA × Over 18 | .21980** | .24102** | .25758** | .27029** |
| | (.04660) | (.06448) | (.07690) | (.08015) |
| Marginal effect | .0518272 | .056831 | .0607354 | .063732 |
| % Change in overall safety investment | 9.03 | 9.9 | 10.59 | 11.1 |
| Age polynomial of order | 1 | 2 | 3 | 3 |
| Age polynomial interacted with Over 18 | No | No | No | Yes |

**Note.** Standard errors, in parentheses, are clustered on aircraft. All estimates include year fixed effects and controls for approved usage, manufacturer-model, and year of manufacture.

$^{+}$ Significant at the 10% level.

** Significant at the 1% level.

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. Thus far, we have found that the removal of liability increases pilots' and owners' investments in safety. We now turn to an examination of the activity level.

### *7.2. Activity Level: Hours Flown and Hours Flown at Night*

Another way that owners and pilots can respond to the removal of liability is to fly fewer hours or fly fewer hours in dangerous conditions. Some evidence of the behavioral changes on the activity level can be found by looking at the GAATA survey, which is available for 1984–85 and 1989–96 (thus, we have only 2 years in the post-GARA era). Unfortunately, the GAATA survey covers only average activity levels by make-model; thus, our evidence is somewhat weak, but we can see whether it is consistent with the increased investment in safety that we discovered above using more microdata. The dependent variable in Table 12 is the log of the average hours flown in a year:

$$\ln(\overline{\text{Hours}}_{jt}) = \boldsymbol{X}_{jt}\beta + g(\overline{\text{Age}}_{jt}) + P_{jt}\pi + N_{jt}\alpha + \vartheta_t + \lambda_j + \boldsymbol{\nu}_{jt},$$

where $\boldsymbol{X}_{jt}$ denotes the controls discussed above for manufacturer-model group $j$ in year $t$, where $g(\overline{\text{Age}}_{jt})$ is the average of the age polynomials for members of

---

data for that year (that is, eight if the year is between 1982 and 2000), and assumed that missing values are zero. Finally, we also estimated the model treating missing observations as one. In each case, the results are substantively identical.

## Table 12

## Estimates from the General Aviation and Air Taxi Activity Survey Survey

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| ln(Average hours flown) ($N = 9{,}080$): | | | | |
| Over 18 (%) | −.15904** | −.22246* | −.22729* | −.41973* |
| | (.05621) | (.09229) | (.09182) | (.16897) |
| Without liability (%) | −.14220** | −.05457 | −.04908 | −.04435 |
| | (.04735) | (.04102) | (.04097) | (.04777) |
| Impact on hours flown ending liability (1-SD change) | −20.9** | −8.02 | −7.21 | −6.52 |
| % Night hours ($N = 8{,}826$): | | | | |
| Over 18 | −.38996** | .46754** | .51514** | −.04240 |
| | (.11617) | (.14390) | (.14895) | (.19435) |
| Without liability | −.54710** | −1.24474** | −1.15575** | −1.29936** |
| | (.19230) | (.25416) | (.26324) | (.28207) |
| Marginal effect of Post-GARA × Over 18 | −.042375 | −.08675 | −.089517 | −.10064 |
| % Change in % night hours | −32.74 | −67.02 | −69.15 | −77.75 |
| Age polynomial of order | 1 | 2 | 3 | 3 |
| Age polynomial interacted with Over 18 | No | No | No | Yes |

**Note.** Standard errors, clustered on manufacturer-model, are in parentheses. All estimates include year fixed effects and controls for approved usage, manufacturer-model, and year of manufacture.

* Significant at the 5% level.

** Significant at the 1% level.

manufacturer-model group $j$, $P_{jt}$ is the percentage of the manufacturer-model group without liability, and $N_{jt}$ is the percentage of the manufacturer-model group older than 18. The year fixed effects, $\vartheta_t$, and the manufacturer-model fixed effects, $\lambda_j$, retain their meaning from equation (1). 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 decrease. The results, although suggestive, are limited by the data. Unlike our other regressions, we can examine only the impact of the proportion of aircraft without liability rather than the discrete jump as an aircraft of an aircraft cohort turns 18.

The results are presented in Table 12, which repeats the pattern from Table 5 that includes increasingly higher order polynomials and interactions with the variable Over 18. The key difference for the specification in Table 12 is that the polynomial is now the average of the age, age-squared, and age-cubed polynomial of the aircraft make-model cohort, and the interaction term is a dummy variable for the last aircraft of that make-model turning 18.

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

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.[17] 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 percent, with almost a quarter of the sample flying no hours at night. The impact of the removal of liability on hours flown at night is also shown in Table 12. We find that GARA reduced the number of night hours flown by 67 percent in our base specification and by a similar value 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 many planes simply were not flown at night after GARA.

### *7.3. 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-related behavior, such as taking

---

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

fewer short flights and having more mechanical inspections. Here we further investigate moral hazard by decomposing accidents along two dimensions: Was the accident minor or major (a substantially damaged or destroyed aircraft)? Did a mechanical failure contribute to the accident (yes or no)? Together, these questions 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. To the extent that pilots have less control over mechanical failure than pilot error, we might 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, as well as 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.[18]

The results are presented in Table 13.[19] The coefficients on accidents with no mechanical failure, both minor and major, are negative and statistically significant, while the other coefficients are not statistically significant. Thus, the decomposition indicates that it is primarily accidents not involving mechanical failure that decrease as a result of GARA. Together, these two types of accidents make up 70 percent of all accidents (major accidents not involving mechanical error alone account for almost two-thirds of all accidents). The fact that it is the number of accidents not involving mechanical failure that decreases with GARA is consistent with a moral hazard effect on pilot behavior. Moreover, since pilot behavior is not under the control of the manufacturer and is not easily substituted with manufacturers' investments in safety, this suggests a net welfare increase in association with GARA.

### *7.4. Aircraft Built after the General Aviation Revitalization Act*

Our primary goal in this paper is to measure the effect of liability rules on moral hazard, taking advantage of the unique GARA experiment that changed the incentive of consumers to invest in safety only after manufacturers' safety investments had been predetermined. Of course, after GARA was implemented, manufacturers' incentives to invest in safety were also changed for new aircraft production (a very small part of the total stock). We found that GARA increased consumers' safety investments on the aircraft stock and that, as a result, the accident rate decreased. However, what is the effect on new aircraft production? Unfortunately, estimating the effect of GARA on the safety level of new aircraft is very difficult because there is no natural comparison group. Nevertheless, any

---

[18] This amounts to estimating the model using a multinomial logit regression, and it allows us to test hypotheses about accident-specific hazards.

[19] In Table 13, we present the results from the second-order polynomial in age only, although other results are similar.

Table 13

Competing-Hazard Model Decomposing Accident Risk

| Variable | Competing-Risk Model (1) | Marginal Effect (2) |
|---|---|---|
| Minor accident, no mechanical failure (8%): | | |
| Post-GARA × Over 18 | −.121** | −.0003058 |
| | (.0364) | |
| Over 18 | .0374 | |
| | (.0272) | |
| Major accident, no mechanical failure (62%): | | |
| Post-GARA × Over 18 | −.0881* | −.0002257 |
| | (.0424) | |
| Over 18 | .0990** | |
| | (.0312) | |
| Minor accident, mechanical failure (4%): | | |
| Post-GARA × Over 18 | .0693 | .0001891 |
| | (.0538) | |
| Over 18 | −.0702⁺ | |
| | (.0415) | |
| Major accident, mechanical failure (26%): | | |
| Post-GARA × Over 18 | −.0261 | −.0000686 |
| | (.0644) | |
| Over 18 | .0964* | |
| | (.0482) | |

**Note.** Standard errors are in parentheses. $N = 2.08 \times 10^7$ observations.
⁺ Significant at the 10% level.
* Significant at the 5% level.
** Significant at the 1% level.

effect is likely to be very small. Note that GARA reduces manufacturers' liability only after 18 years; therefore, manufacturers' incentives to invest in safety before and after GARA is very similar. Moreover, it would be quite difficult for a manufacturer to reduce safety investment in a way that would reduce its manufacturing costs while having an insignificant impact on the safety of planes less than 18 years old but a significant impact on planes older than 18.

As a simple test, we introduce in Table 14 a variable for aircraft built after GARA was enacted. We find that aircraft built after GARA are less likely to be involved in an accident. This is consistent with the long-term downward trend in accident probabilities. Thus, although we cannot estimate the effect of GARA per se on the safety of new aircraft, we find that there is no obvious change in accident probabilities for new aircraft. Because we find that GARA caused a decrease in accidents on the aircraft stock older than 18, and because both theory and limited evidence suggest no significant increase in accident probabilities for new aircraft, GARA will likely result in a decrease in accidents in long-term equilibrium. Few products have as long a tail of liability as aircraft production, so this result may not generalize to other products.

Table 14

Post–General Aviation Revitalization Act (GARA) Production Accidents

| | (1) | (2) | (3) |
|---|---|---|---|
| Post-GARA × Over 18 | −.141** | −.189** | −.192** |
| | (.0283) | (.0297) | (.0298) |
| Over 18 | −.000742 | .0585** | .0503* |
| | (.0191) | (.0219) | (.0226) |
| Aircraft built after GARA | −.221** | −.300** | −.320** |
| | (.0676) | (.0690) | (.0701) |
| Marginal effect of being built after GARA | −.0012 | −.0016 | −.0017 |
| % Change in accident rate | −17 | −22 | −24 |
| Age polynomial of order | 1 | 2 | 3 |
| Observations | 5,369,883 | 5,351,949 | 5,351,949 |
| Number of make-model | 276,565 | 272,207 | 272,207 |

**Note.** Standard errors are in parentheses. All estimates include year fixed effects and controls for approved usage, manufacturer-model, and year of manufacture.
* Significant at the 5% level.
** Significant at the 1% level.

## 8. The Cost of Moral Hazard

Using GARA, we found that when pilots and owners cannot sue aircraft manufacturers for an accident, the probability of an accident declines, which suggests that the right to sue creates significant moral hazard. In Table 15, we estimate the value of this decline in accidents on the basis of the value of a statistical life (VSL) and the value of damaged aircraft. The accident data tell us the number of fatalities in an accident and also whether the aircraft was destroyed, was substantially damaged, or sustained only minor damage. We take the value of a statistical life from Viscusi (2008), who summarizes a number of studies as estimating a value between $4 and $10 million, with an average value of around $7 million. The average value of an aircraft in our sample is approximately $100,000. For aircraft that sustain minor damage, we count the damage as zero. The latter calculations are somewhat arbitrary, but the value of a statistical life dominates the calculation of social value in any case.

We assume that GARA reduces the number of accidents by 13.6 percent, which is the value estimated from our preferred specification. We estimate directly from the data the proportions of accidents with fatalities or with total, substantial, or minor damage (see Table A1). In other words, we assume that GARA did not change these proportions in any significant manner.[20]

We estimate that GARA increases social value by approximately $629 million per year when the VSL is estimated at $7 million, or a value per aircraft of $2,660. The VSL dominates the calculation of social value, and thus our cal-

---

[20] To test whether this is a reasonable assumption, we estimated the model on fatal accidents and accidents with totally destroyed aircraft. Using a generalized Hausman test, we could not reject the hypothesis that GARA affected all categories of accident equally. Results are available from the authors on request.

Table 15

The Social Value of the General Aviation Revitalization Act (GARA)

| Year | Total Aircraft | Total Accidents | Accidents Avoided | Fatalities Avoided | Destroyed Aircraft Avoided | Substantially Damaged Aircraft Avoided | Social Value of GARA ($) | Social Value Per Aircraft ($) |
|---|---|---|---|---|---|---|---|---|
| 1994 | 239,101 | 1,708 | 215 | 87 | 54 | 155 | 779,644,643 | 3,261 |
| 1995 | 239,190 | 1,742 | 220 | 84 | 57 | 157 | 752,099,968 | 3,144 |
| 1996 | 239,571 | 1,631 | 206 | 68 | 48 | 153 | 603,784,585 | 2,520 |
| 1997 | 237,841 | 1,578 | 199 | 78 | 48 | 146 | 701,278,669 | 2,949 |
| 1998 | 236,689 | 1,568 | 198 | 68 | 46 | 148 | 603,126,894 | 2,548 |
| 1999 | 235,259 | 1,588 | 200 | 65 | 39 | 156 | 588,722,161 | 2,502 |
| 2000 | 234,285 | 1,482 | 187 | 72 | 37 | 144 | 643,760,921 | 2,748 |
| 2001 | 233,001 | 1,394 | 176 | 57 | 34 | 136 | 509,951,455 | 2,189 |
| 2002 | 231,241 | 1,326 | 167 | 54 | 30 | 133 | 481,091,397 | 2,080 |

**Note.** Social value of GARA was estimated using a value of statistical life of $7 million. Average social value of GARA is $629,273,410, and average social value per aircraft is $2,660.

culations of social value are robust to changes in the value of aircraft, such as using the median value of aircraft in accidents.

Although we cannot estimate the cost of the safety investments made by pilots and/or owners to generate these gains, it is likely that these costs were low. A telling feature of the GARA experiment is that GARA passed only because of very substantial lobbying by pilot's associations—that is, the very people who would lose the right to sue in the case of an accident. Thus, not only did GARA result in a social gain, it appears to have resulted in a gain to both of the primary parties: pilot-owners and manufacturers. The pilots' associations were concerned by 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.

The evidence supports the pilots, and most observers credit GARA with greatly reducing lawsuits and reviving the American general aviation industry. In 1997, Cessna's general counsel estimated that the annual number of new lawsuits was less than half that noted during the 5 years before GARA (Rodriguez 2005, p. 601). The General Accounting Office reported that typical manufacturers saw an even bigger decrease, from a high of 900 lawsuits per year in the early 1980s to 80 lawsuits per year in 2001. Increased production by general aviation manufacturers also suggests that GARA was effective. Cessna and Beech both exited the general aviation industry because of liability concerns, but they 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 4 shows that industry-wide production increased substantially after GARA was passed.[21]

## 9. Discussion and Conclusion

The General Aviation Revitalization Act eliminated the right of general aviation pilots and owners to sue manufacturers for losses resulting from an accident in aircraft 18 or older. The General Aviation Revitalization Act indicated that general aviation aircraft of the same make-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 consumers' 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.

---

[21] Figure 4 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 those data include some aircraft with more than 20 seats. Nevertheless, the GAMA data and our sample show the same pattern but somewhat higher production levels in the GAMA data.

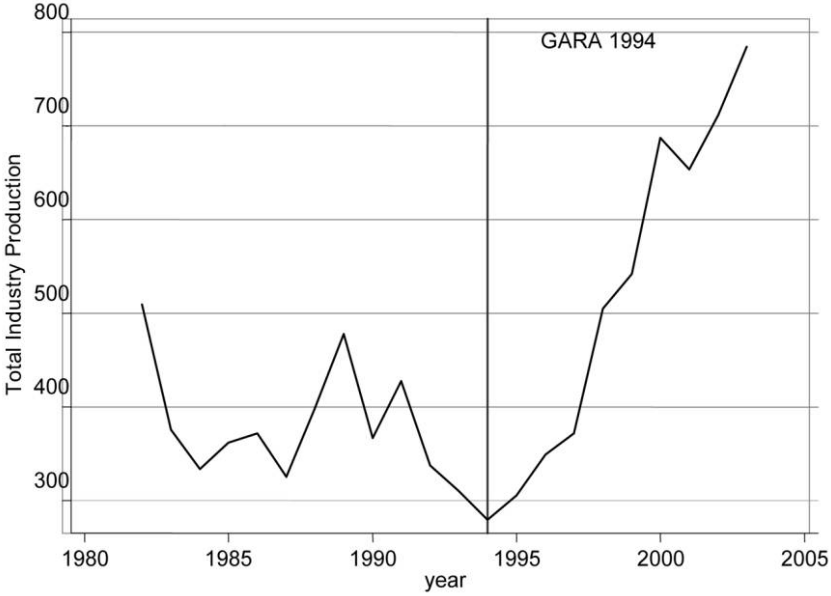

**Figure 4.** Production of general aviation aircraft, 1980–2004

Our estimates show that the end of manufacturers' liability for aircraft was associated with a significant (on the order of 13.6 percent) reduction in the probability of an accident. The evidence suggests that modest decreases in the amount and nature of flying were largely responsible. After 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 and major accidents not involving mechanical failure—those more likely to be under the control of the pilot—declined notably.

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.

# Appendix

Table A1
Accidents, Fatalities, and Damaged Aircraft, 1982–2002

| Year | Total Accidents | Fatalities | Destroyed Aircraft | Substantially Damaged Aircraft |
|---|---|---|---|---|
| 1982 | 3,083 | 1,281 | 872 | 2,077 |
| 1983 | 2,816 | 1,064 | 760 | 1,953 |
| 1984 | 2,798 | 1,113 | 798 | 1,897 |
| 1985 | 2,578 | 1,022 | 716 | 1,782 |
| 1986 | 2,325 | 1,010 | 631 | 1,627 |
| 1987 | 2,329 | 892 | 616 | 1,640 |
| 1988 | 2,201 | 775 | 593 | 1,512 |
| 1989 | 2,059 | 815 | 516 | 1,476 |
| 1990 | 1,968 | 756 | 538 | 1,386 |
| 1991 | 1,968 | 891 | 511 | 1,399 |
| 1992 | 1,814 | 797 | 465 | 1,305 |
| 1993 | 1,778 | 686 | 448 | 1,282 |
| 1994 | 1,708 | 692 | 429 | 1,228 |
| 1995 | 1,742 | 668 | 453 | 1,246 |
| 1996 | 1,631 | 536 | 379 | 1,217 |
| 1997 | 1,578 | 622 | 383 | 1,155 |
| 1998 | 1,568 | 536 | 363 | 1,177 |
| 1999 | 1,588 | 519 | 306 | 1,236 |
| 2000 | 1,482 | 572 | 290 | 1,143 |
| 2001 | 1,394 | 451 | 272 | 1,079 |
| 2002 | 1,326 | 425 | 236 | 1,051 |

# References

*Aircraft Bluebook: Historical Value Reference.* 1982–2003. Overland, Kan.: Penton Media. http://www.aircraftbluebook.com/Marketing.do?section=Marketing&page=HISTORICAL_VALUE_REFERENCE.

American Law Institute. 1965–75. *Restatement* (*Second*) *of Torts.* Philadelphia: American Law Institute.

Cooper, Russell, and Thomas Ross. 1984. Product Warranties and Double Moral Hazard. *RAND Journal of Economics* 16:103–13.

Craig, Andrew. 1991. Product Liability and Safety in General Aviation. Pp. 456–77 in *The Liability Maze: The Impact of Liability Law on Safety and Innovation,* edited by Peter W. Huber and Robert E. Litan. Washington, D.C.: Brookings Institution Press.

Cummins, David, Richard D. Phillips, and Mary A. Weiss. 2001. The Incentive Effects of No-Fault Automobile Insurance. *Journal of Law and Economics* 44:427–64.

Dewees, Don, David Duff, and Michael J. Trebilcock. 1996. *Exploring the Domain of Accident Law: Taking the Facts Seriously.* New York: Oxford University Press.

FAA (Federal Aviation Administration). 2003. *Best Practices Guide for Maintaining Aging General Aviation Airplanes.* Washington, D.C.: FAA.

General Accounting Office. 2001. *General Aviation: Status of the Industry, Related Infrastructure and Safety Issues.* Report to congressional requesters. GAO-01-916. Washington, D.C.: General Accounting Office.

Gilligan, Thomas W. 2004. Lemons and Leases in the Used Business Aircraft Market. *Journal of Political Economy* 112:1157–80.

Godfrey, Leslie G., and Chris D. Orme. 2002. Using Bootstrap Methods to Obtain Nonnormality Robust Chow Prediction Tests. *Economics Letters* 76:429–36.

Hendel, Igal, and Alessandro Lizzeri. 1999. Adverse Selection in Durable Goods Markets. *American Economic Review* 89(5):1097–1115.

Higgins, Richard. 1981. Products Liability Insurance, Moral Hazard, and Contributory Negligence. *Journal of Legal Studies* 10:111–30.

Jenkins, Stephen P. 2005. *Survival Analysis.* Working paper. University of Essex, Institute for Social and Economic Research, Colchester.

Kessler, Daniel, and Mark McClellan. 1996. Do Doctors Practice Defensive Medicine? *Quarterly Journal of Economics* 111:353–90.

———. 2002. Malpractice Law and Health Care Reform: Optimal Liability Policy in an Era of Managed Care. *Journal of Public Economics* 84:175–97.

Landes, Elisabeth M. 1982. Insurance, Liability, and Accidents: A Theoretical and Empirical Investigation of the Effect of No-Fault Accidents. *Journal of Law and Economics* 25:49–65.

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

Lee, David S., and David Card. 2006. Regression Discontinuity Inference with Specification Error. Technical Working Paper No. T0322. National Bureau of Economic Research, Cambridge, Mass.

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

Meyer, Bruce. 1990. Unemployment Insurance and Unemployment Spells. *Econometrica* 58:757–82.

Papke, L. E., and J. M. Wooldridge. 1996 Econometric Methods for Fractional Response Variables with an Application to 401(k) Plan Participation Rates. *Journal of Applied Econometrics* 11:619–32.

Peltzman, Sam. 1975. The Effects of Automobile Safety Regulation. *Journal of Political Economy* 83:677–726.

Rodriguez, James F. 2005. Tort Reform and 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* 50:221–38.

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, Mass.: Harvard University Press.

———. 2004. *Foundations of Economic Analysis of Law.* Cambridge, Mass.: Belknap Press of Harvard University Press.

Viscusi, W. Kip. 2008. The Value of Life. Pp. 586–90 in vol. 8 of *The New Palgrave Dictionary of Economics,* edited by Steven N. Durlauf and Lawrence E. Blume. 2d ed. Basingstoke: Palgrave Macmillan.

Zivot, Eric, and Donald W. K. Andrews. 1992. Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis. *Journal of Business and Economic Statistics* 10(3):251–70.