An Evaluation of Legislation Designed to Improve Airline Pilots' Safety and Performance*

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Abstract

H.R. 5900, which was passed by Congress in July 2010, legislated more restrictive pilot rest requirements and increased the number of pilot training hours required to obtain an airline transport pilot license. This paper examines the effect that raising the occupational licensing standards have had on airline service quality. A priori, the effect is ambiguous since putting in place more restrictive licensing requirements reduces the available pool of replacement pilots and may cause airline pilots to behave opportunistically and put forth less effort, which suggests a detriment to on-time performance. On the other hand, well-rested and more experienced pilots may provide enhanced productivity leading to improved on-time performance. Our event study analysis surrounding the effective date of H.R. 5900 (August 2013) shows a long run improvement in traditional delays due to more effective pilots, but extended delays in the long run were exacerbated by binding work schedule restrictions.

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1 Introduction

A larger proportion of the U.S. workforce is impacted by occupational licensing than either minimum wage or unionization (Kleiner, 2000). The goal of occupational licensing is to protect the public from "incompetent, untrustworthy, or irresponsible practitioners" (Gittleman and Kleiner, 2016, p.145). Occupational licensing has grown significantly since the 1950s in the United States, with more than one-third of the U.S. workforce either licensed or certified by the government (Kleiner, 1990; Kleiner and Krueger, 2010; Kleiner and Krueger, 2013). The effect of raising occupational licensing standards on quality is ambiguous since a license requirement will eliminate some inexperienced low-quality providers; however, the remaining higher paid licensees now have less incentive to provide high-quality products or service since there are fewer competitors (Kleiner, 2000; Carroll and Gaston, 1981).

While licensing is associated with about 18 percent higher pay (Kleiner and Krueger, 2013) and has been found to reduce the wage gap between natives and immigrants (Cassidy and Dacass, 2021), less well understood is whether occupational licensing improves product quality. There is growing empirical evidence that indicates no improvement in quality from stricter licensing standards. Kleiner (2006) suggests that licensing drives up prices and overall wages compared to unlicensed occupations using cross-sectional data, yet finds no clear impact of licensing on overall quality. Farronato et al. (2020) find more stringent regulations are associated with less competition, higher prices, and no improvement in customer satisfaction when examining an online platform for home improvement services. There are two studies from the health care industry that also find no relationship between service quality and licensing standards. Kleiner and Kudrle (2000) find that states with stricter dental licensing standards do not have improved dental outcomes, yet these stricter standards are associated with higher dental wages. Kleiner et al. (2016) show that the relaxation of occupational licensing laws for nurse practitioners has led to higher wages for nurse practitioners and lower wages for physicians, while not adversely affecting the quality of patient care since neither mortality rates nor liability insurance premiums have changed. To be sure, all of these studies can only assess the impact of regulatory interventions on observed quality and it is certainly possible that there were impacts on quality dimensions that are unobserved by the econometrician. In fact, Carroll and Gaston (1981) find evidence across several occupations and trades (e.g. electrical, plumbing, real estate, dentistry, and veterinarian) that restrictive licensing requirements are detrimental to service quality. More recently, Kleiner (2013) finds more stringent licensing requirements of electricians and plumbers have little impact on worker safety. Larsen et al. (2020) suggest that more stringent teacher licensing raises the lower tail of quality for secondary school teachers while having no effect on average quality. Our paper studies how changes to occupational licensing requirements impact the quality of service provided by airline captains and first officers.

We perform an event study to analyze the ramifications of increased regulations on pilot training and work schedules in H.R. 5900, a law that was unanimously passed by both the U.S. House of Representatives and the U.S. Senate. In a similar fashion as Prince and Simon (2015, 2017) and Lee and Rupp (2007), we also use on-time performance as a proxy for quality in the airline industry by tracking two performance measures: 1) flights that arrive at least 15 minutes late (the traditional delay definition) and 2) flights that arrive at least 180 minutes late (the European Union's definition of an extended delay). Although H.R. 5900 intended to address one dimension of quality (safety), our results suggest that this regulation had unintended consequences since it affected other dimensions of quality (on-time performance). Given the multi-dimensionality of quality in the airline industry, our paper shows how regulation changes that shift effort to some dimensions of quality (safety) may affect other quality dimensions (on-time performance) positively if the two quality dimensions display complementarities or negatively if they are substitutes. We find evidence that higher occupational licensing standards for pilots improved productivity since airlines experienced a reduction in traditional delays. On the other hand, we find increases in extended delays, which may reflect the difficulty that carriers have in locating replacement crews when pilots reach their daily maximum flight time limits. Fewer traditional delays (15+ minutes) and more extended delays (180+ minutes) suggest that safety and training requirements display complementarities, whereas safety and pilot schedule restrictions could be considered as substitutes.

2 H.R. 5900 Legislation

The crash of Colgan Air flight 3407 on February 12, 2009 in Buffalo, New York tragically took the lives of all 49 passengers and crew on board in addition to a person whose house was struck by the plane.[1] The ensuing NTSB Accident Report (AAR-10/01) indicated that pilot error was the likely culprit, while pilot fatigue may have also contributed since the cockpit voice recorder indicated a yawn by the co-pilot minutes prior to the crash.[2]

As a consequence of this Colgan Air crash, legislation H.R. 5900 was approved in July 2010, which increased the minimum number of hours for a prospective first officer to obtain an airline transport pilot (ATP) license from 250 hours to 1,500 hours. This legislation also implemented a 9-hour minimum rest period prior to the flight duty period while mandating that a pilot must have an opportunity for eight hours of uninterrupted sleep during the rest period.[3] This change constitutes a one hour increase in rest compared to the previous pilot rest rule, while the uninterrupted eight hours of sleep opportunity represents a new initiative. Maximum flight time limits were also set to either eight or nine hours depending on when the pilot is scheduled to begin their initial shift. Finally, the new rule implements maximum flight duty period limits based on the number of flight segments, while the previous rest rule did not consider the number of flight segments.

2.1 Enhanced Training Requirements

Increasing the minimum number hours of training before a pilot can obtain an ATP license should improve pilot safety and competence. These enhanced training requirements are likely to have a larger impact on regional airlines since these carriers are more likely to hire inexperienced pilots. It is common for experienced regional airline pilots to eventually move to higher paying

[1] Borenstein and Zimmerman (1988) find the total social cost of a fatal aviation accident is considerably larger than the average firm reduction in equity value of 1 percent (or $4.5 million).

[2] According to its official accident report, the National Transportation Safety Board determined that "the probable cause of this accident was the captain's inappropriate response to the activation of the stick shaker, which led to an aerodynamic stall from which the airplane did not recover." (National Transportation Safety Board Accident Report/AAR-10/01, PB2010-91401. February 2, 2010).

[3] For more details see the FAA Fact Sheet - Pilot Fatigue Rule Comparison, 21 December 2011, `https://www.faa.gov/news/fact_sheets/news_story.cfm?newsKey=12445`.

jobs with major airlines and low-cost carriers. A possible consequence of having better trained pilots is a potential boost in pilot productivity (especially for regional airlines) and hence improved service quality through better on-time performance. Therefore, we test this hypothesis that enhanced training requirements had a larger quality impact on the regional airlines by comparing the on-time performance across three carrier types (regionals, majors, and low-cost carriers) in both the short-term and long-term following H.R. 5900 implementation.

An unintended consequence of mandating enhanced training requirements is a short-term pilot shortage since this legislation poses a higher hurdle for prospective pilots before becoming a first officer. In fact, Great Lakes Airlines[4] and Republic Airways[5] declared bankruptcy after the implementation of H.R. 5900 and both regional airlines cited the lack of available pilots as the primary reason for their bankruptcy filing.

This paper investigates the effect of the H.R. 5900 legislation on on-time performance and not safety since there have not been any fatal accidents due to pilot error since the Colgan Air crash in 2009. Indeed, industry insiders we interviewed proudly lauded the recent safety record in the U.S. airline industry. Therefore, we cannot use accidents as a measure to estimate the effect of H.R. 5900 on safety.

The FAA, however, does collect data on "incidents" which occur more frequently than accidents yet still do not occur with enough frequency for meaningful analysis. The FAA distinguishes an accident from a safety incident as follows: an accident occurs when there is a serious injury (hospitalization of greater than 48 hours and/or death) or damage to the aircraft which exceeds \$500.[6] On the other hand, an incident is something much more minor that "affects or could affect the safety of operations."[7] Table 1 reports the number of incidents by airline during our sample time period. Given the lack of variation in incidents while keeping in mind that there is an aver-

[4]https://www.prnewswire.com/news-releases/great-lakes-airlines-shuts-down-operations-indefinitely-300620781.html, last accessed 27 May 2020.

[5]https://money.cnn.com/2016/02/26/news/companies/pilot-shortage-bankruptcy/index.html, last accessed 27 May 2020.

[6]http://www.faraim.org/faa/far/CFR-2015-title49-vol7-part830.pdf/

[7]According to a conversation with a United captain, an incident is "something that is 'just embarrassing' for pilots, such as the plane slipping off the taxiway."

age of nearly 5.5 million flights per year by our sample airlines combined, we do not believe that incidents are a feasible outcome variable to study the effect of H.R. 5900. Instead, the objective of this paper is to focus on a different dimension of quality that is also important for passengers: timeliness.

Table 1: Number of Incidents

	Airline	2010	2011	2012	2013	2014	2015	2016	2017	2018	TOTAL
Major Airlines	Alaska Airlines	0	3	0	0	0	2	0	2	1	8
	American Airlines	4	6	6	3	5	1	3	2	0	30
	Continental Airlines	0	2	2	0	1	0	0	0	0	5
	Delta Air Lines	13	13	12	8	7	2	2	2	3	62
	United Airlines	15	5	4	3	10	3	3	5	7	55
	US Airways	9	5	6	2	3	0	0	0	0	25
Low-Cost Carriers	AirTran Airways	2	3	0	0	0	0	0	0	0	5
	Allegiant Air	4	1	4	1	1	3	7	4	10	35
	Frontier Airlines	2	1	0	2	1	3	0	1	1	11
	JetBlue Airways	2	0	1	3	4	0	1	1	1	13
	Southwest Airlines	9	13	8	3	5	1	2	5	3	49
	Spirit Airlines	2	0	1	0	1	0	1	1	0	6
	Virgin America	0	1	0	0	0	1	1	1	0	4
Regional Airlines	Endeavor Air	0	0	0	0	1	0	0	0	1	2
	Envoy Air/ American Eagle	4	6	5	6	4	2	4	1	1	33
	ExpressJet	12	8	9	6	4	2	0	1	0	42
	Mesa Airlines	3	2	1	0	1	0	0	5	0	12
	Midwest Airlines	0	0	0	0	0	0	0	0	0	0
	PSA Airlines	3	5	3	3	1	0	4	3	0	22
	Republic Airlines	6	2	1	5	4	4	3	3	2	30
	SkyWest Airlines	9	5	5	3	1	1	3	4	0	31
	TOTAL	99	81	68	48	54	25	34	41	30	480

Source: FAA Accident and Incident Data System (AIDS). `https://www.asias.faa.gov/apex/f?p=100:12:::NO:::`

In summary, pilots seeking to become first officers on commercial aircraft must now meet the following training conditions:

1. Have at least 1,500 hours total time as a pilot.

2. Complete an Airline Transport Pilot Certification Training Program (ATP CTP) with expanded training in risk-assessment and responding to emergency situations, including how to recover from a stall that led to the crash of Colgan Air flight 3407.

3. Additionally, first officers must have at least 1,000 hours as SIC ("second in command") before becoming a captain.

2.2 Increased Employee Rest Requirements

In addition to increasing the number of flight hours required for training before a pilot can be licensed as a commercial airline pilot, H.R. 5900 also increased employee rest restrictions for pilots and limited the number of daily flight segments that pilots can fly. Since the rest requirements applied to all pilots, these restrictions make it more difficult for airlines to find last minute replacements for pilots and flight crews. Hence, minor flight delays that cause a pilot to time-out can now ultimately lead to extended flight delays. The impact of longer employee rest requirements will likely be felt across all carrier types since this legislation reduces crew availability and flexibility for all airlines. To maintain historical on-time performance, carriers will need more stand-by replacement crews to be on call as pilots reach duty time limits due to flight delays. Prior to stepping foot on the aircraft, every pilot must certify that they are not too fatigued to fly. The H.R. 5900 legislation changed the stigma attached to pilot fatigue since it is now non-punitive for a pilot to call in fatigued, whereas pilots previously would have their pay docked for missing flights due to fatigue.

Moreover, since a variety of factors can contribute to a flight being delayed beyond the control of the airline pilot, we examine the subset of morning flights (from 5:00AM to 9:00AM) since the initial morning flight eliminates one primary delay cause: late arriving aircraft. In addition, morning flights are not subjected to another prevalent flight delay cause: delays that propagate/cascade during the day (Dou et al., 2020; Rupp, 2009). While weather delays are possible in the morning, weather induced delays are less likely since both thunderstorms and heat induced delays (Adler, 2021) are afternoon phenomena. Therefore, we expect that flight delays induced by increased employee rest restrictions to be more prevalent for morning flights.

The aviation industry is not alone in adjusting its rest requirements since both the trucking industry and medical residency profession have recently imposed stricter duty hour limitations in an effort to prevent employee fatigue and improve safety. These changes were prompted due to growing evidence of the dangers posed by fatigued employees. For example, a sleep study of long-haul truck drivers revealed that truckers obtained less sleep than required for alertness on the job with the highest risk of sleeping on the job occurring late night and early morning (Mitler et al., 1997). In the medical profession, interns that have just worked shifts of extended duration (24 hours or more) have a significantly higher likelihood of being involved in a motor vehicle accident compared to non-extended shifts (Barger et al., 2005).

The benefits from reducing the number of consecutive hours working may extend beyond improving safety since less fatigued employees may also be more productive. Whether employees are working in modern day call centers (Collewet and Sauermann, 2017) or in ammunitions plants in Britain during World War I (Pencavel, 2015), both studies find a similar result − as the number of hours worked increases, employees become less productive. Beyond employee fatigue on an extended shift, Pencavel (2018) presents considerable evidence that longer hours of work have adverse effects on worker health and quality of life. Pencavel (2016) suggests that worker productivity suffers after a long working week if workers do not have adequate time off from the job to restore their physical, mental, and emotional well-being. Understanding the relationship between hours and output productivity is important because this relationship is a key determinant of future economic growth (Denison, 1962).

In summary, H.R. 5900 also stipulated the following changes to pilot scheduling/rest requirements based on flight time in the previous 24 hours:

1. 9 consecutive hours of rest for less than 8 hours of scheduled flight time.

2. 10 consecutive hours of rest for between 8 and 9 hours of scheduled flight time.

3. 11 consecutive hours of rest for more than 9 hours of scheduled flight time.

3 Empirical Analysis

3.1 Data

Our primary data set is the On-Time Performance Data, which is published monthly by the U.S. Department of Transportation. The raw data provides information on every scheduled domestic flight by carriers with at least 1% market share in the U.S. We observe the flight's carrier, origination and destination airports, as well as scheduled and actual departure and arrival times. Following Forbes et al. (2019), we exclude cancelled or diverted flights along with flights that depart or arrive more than 60 minutes early in order to resolve possible data entry issues.

The cause of a flight delay can be characterized into five broad categories (in order of frequency): 1) late aircraft (e.g. previous flight arrived late causing subsequent flights to be late); 2) carrier (e.g. maintenance or crew problems, aircraft cleaning, baggage loading, or fueling); 3) national air system (e.g. abnormally heavy traffic volume at the airport or air traffic control); 4) weather (e.g. tornado, blizzard, or hurricane); and 5) security (e.g. security breach or evacuation of a terminal).[8] We aggregate these observations to the carrier-route-year-month level in order to calculate the proportion of delays that are attributed to either the pilot or airline. To be sure, the increased regulations on pilot training and work schedules in the H.R. 5900 law potentially impact delays that are classified as either carrier or late aircraft delays. Moreover, the cause of delays are not mutually exclusive since there are cases in which a delay is attributed to multiple reasons. Delays that are attributed exclusively to the national air system (NAS), weather, and/or security issues are unaffected by the regulations established by H.R. 5900.

Although there are several measures of service quality in the airline industry, we proxy for product quality by using two measures for flight delays that have been defined by American and European aviation authorities.[9] First, we employ the industry standard delay definition of flights

[8] According to a March 2020 report by the U.S. Department of Transportation, aircraft arriving late (40%) was the most common cause of a delayed flight in 2019 followed by air carrier delay (31%), national aviation system (NAS) delay (24%), extreme weather (6%), and security delay (0%). See AhmadBeygi et al. (2008) and Dou et al. (2020) for an examination of how delays propagate in airline networks.

[9] Forbes et al. (2015), Prince and Simon (2017), and Rupp and Tan (2019) use flight delays as their proxy for product quality.

that arrive 15+ minutes after their scheduled arrival time. Moreover, flight delays are based on arrival time since airline passengers (especially those making connections) are more concerned about arrival delays than departure delays. Second, since neither the U.S. Department of Transportation nor the Federal Aviation Administration specify guidelines for an extended delay, we adopt the European Union's measure of an extended delay: flights that arrive 180+ minutes after their scheduled arrival time.[10]

We append the data on delays with the T-100 data set, which is also published monthly by the U.S. Department of Transportation. This data set is used to calculate the total number of scheduled flights at both the origin and destination airports for a given route (defined as a directional airport-pair). We also collect relevant dates for airlines who have filed for Chapter 11 bankruptcy protection from various public sources.

Table 2: Summary Statistics

Variable	Definition	Mean (Std. Dev.)
$Delay15_{ijt}$	Proportion of flights with arrival delays (15+ minutes) due to the pilots or airline for airline i on route j in time period t	0.1289 (0.0891)
$Delay180_{ijt}$	Proportion of flights with extended arrival delays (180+ minutes) due to the pilots or airline for airline i on route j in time period t	0.0063 (0.0128)
$Delay15\_Control_{ijt}$	Proportion of flights with arrival delays (15+ minutes) due to non-aircraft and non-carrier factors for airline i on route j in time period t	0.0616 (0.0604)
$Delay180\_Control_{ijt}$	Proportion of flights with extended arrival delays (180+ minutes) due to non-aircraft and non-airline factors for airline i on route j in time period t	0.0026 (0.0084)
$OriginFlights_{jt}$	Number of flights at origin airport of route j in time period t Note: $OriginFlights\_small = \frac{originflights}{10,000}$	9,223.689 (8,282.559)
$DestFlights_{jt}$	Number of flights at destination airport of route j in time period t Note: $DestFlights\_small = \frac{destflights}{10,000}$	9,218.532 (8,268.055)
$Bankrupt_{it}$	Dummy variable indicating if airline i is bankrupt in time period t	0.035 (0.1840)
Majors	Proportion of observations associated with major airlines	0.318
LCCs	Proportion of observations associated with low-cost carriers	0.326
Regionals	Proportion of observations associated with regional airlines	0.356
Routes	Number of routes in the sample	5,566
N	Number of observations	509,643

Table 2 reports the summary statistics for the variables used in our empirical analysis. Our final data set covers 21 airlines servicing 5,566 routes in 96 time periods (August 2010 - July 2018) and

[10]The European Union's Air Passenger Rights stipulates that passengers be compensated if their flight is delayed by more than three hours. `https://europa.eu/youreurope/citizens/travel/passenger-rights/air/index_en.htm`

contains 509,643 observations at the airline-route-year-month level. We find that 12.89% of flights in our full sample experience arrival delays due to the airline and/or pilot ($Delay15$), whereas 0.63% of flights are extended delays ($Delay180$). These values are smaller than the means reported in the existing literature (e.g. Forbes et al., 2015; Prince and Simon, 2017; Rupp and Tan, 2019) since we restrict our attention to the subset of "treatment" delays which are attributed to either the airline or late arriving aircraft.

3.2 Estimation Model

To quantify the impact of raising the occupational licensing requirement from H.R. 5900 on product quality provided in the U.S. airline industry, we implement a fixed effects regression model in which on-time performance serves as the dependent variable. The key variables of interest in our empirical analysis are the dummy variables that identify the short run and long run effects of the implementation of the H.R. 5900 law. There are three relevant time periods in our analysis based on the passing of H.R. 5900 by the U.S. House of Representatives and the U.S. Senate on July 29, 2010 and July 30, 2010, respectively, and the law becoming effective on August 1, 2013:

1. Post-legislation and pre-enforcement ($HR5900\_baseline$: August 2010 - July 2013)
2. Short run effect of legislation ($HR5900\_shortrun$: August 2013 - July 2015)
3. Long run effect of legislation ($HR5900\_longrun$: August 2015 - July 2018)

Following Prince and Simon (2017), our basic regression specification is

$$y_{ijt} = \alpha + \delta_{ij} + \nu_{it} + \beta_1 HR5900\_shortrun_t + \beta_2 HR5900\_longrun_t + \beta_3 Controls_{ijt} + \varepsilon_{ijt}, \quad (1)$$

where y_{ijt} is the on-time performance product quality proxy ($Delay15_{ijt}$ or $Delay180_{ijt}$) for airline i servicing route j in time t. Since the baseline time period ($HR5900\_baseline$) is excluded from the regression, the coefficients for both the short run and long run time periods are interpreted with respect to the three years immediately prior to the implementation of the law.[11] *Controls* represent a variety of potential delay factors, including airport congestion measured by the number of flights at both the origin airport and destination airport of a route in a given time period ($OriginFlights\_small$ and $DestFlights\_small$)[12] and three dummy variables based on the bankruptcy status of an airline: 1) $Bankrupt\_before$ = 1 if the airline files for bankruptcy protection in the following year, 2) $Bankrupt$ = 1 if the airline is currently bankrupt, and 3) $Bankrupt\_after$ = 1 if the airline exits bankruptcy in the previous year. Finally, we include carrier-route fixed effects (δ_{ij}) and carrier-month fixed effects (ν_{it}), implement two-way cluster-robust standard errors by carrier-route and carrier-month, and weight our regressions by the number of flights operated by a particular airline on a specific route in a given time period.

3.3 Before and After Comparison

In an effort to improve aviation safety, the H.R. 5900 legislation raised the occupational licensing requirements for airline transport pilots and reduced the maximum possible pilot duty time from nine to eight hours. The primary objective of H.R. 5900 appears to have been achieved given that there have been no fatal aviation crashes due to pilot error since the Colgan Air crash in February 2009.[13] In fact, approximately 5.46 billion domestic U.S. airline passengers were safely transported between August 2010 to July 2018.[14]

An unintended consequence of the H.R. 5900 legislated changes is that employee productivity may change after raising the occupational licensing standards from 250 to 1,500 pilot training hours. Given that the occupational licensing hurdle has been raised which resulted in fewer qualified airline pilots, the remaining pilots may be less diligent in providing on-time performance since

[11] As in Prince and Simon (2017), our short run effect time period spans two years, whereas our long run effect time period covers three years.

[12] Mayer and Sinai (2003), Rupp (2009), and Molnar (2013) investigate the role of congestion on flight delays.

[13] We are aware of a single aviation fatality between February 2009 and July 2018, which occurred when a Southwest Airlines passenger was struck by a fan blade that broke off mid-flight on April 17, 2018. https://time.com/5243733/southwest-passenger-commercial-airline-death/, last accessed 28 May 2020.

[14] Domestic passenger counts come from https://www.transtats.bts.gov/Data_Elements.aspx?Data=1, last accessed 27 December 2022.

there is a thinner pool of replacement pilots. Such a scenario would result in positive estimated coefficients for the time dummies for the 15+ minute arrival delays in Equation (1) and would also be consistent with Carroll and Gaston (1981) who finds that occupational restrictions lower the quality of service received. On the other hand, better trained pilots may be more diligent in their provision of on-time arrivals and hence improve product quality. In this scenario, there would be negative estimated coefficients for the time dummies for the 15+ minute arrival delays.

H.R. 5900 also legislated increased pilot rest requirements and imposed stricter duty time limits (a reduction from nine to eight hours) which could create a binding constraint for airlines since flight crews could time out with no replacement crews available. As such, an increase in extended flight delays might have nothing to do with employee effort and instead reflect a shortage of qualified replacement pilots. Hence, the binding constraint of a pilot shortage issue can be identified if there are positive estimated time coefficients for 180+ minute arrival delays in Equation (1).

Table 3: The Effect of H.R. 5900 on Delays

	(1) Pooled	(2) Majors	(3) LCCs	(4) Regionals
$HR5900\_shortrun$	0.0191**	0.0057	0.0467**	0.0061
	(0.0041)	(0.0039)	(0.0064)	(0.0048)
$HR5900\_longrun$	-0.0065*	-0.0099**	0.0100*	-0.0260**
	(0.0028)	(0.0032)	(0.0046)	(0.0052)
$OriginFlights\_small$	0.0171**	0.0110*	0.0400**	0.0093
	(0.0044)	(0.0054)	(0.0092)	(0.0086)
$DestFlights\_small$	-0.0009	-0.0058	0.0121	-0.0063
	(0.0032)	(0.0035)	(0.0098)	(0.0073)
$Bankrupt\_before$	-0.0042	-0.0094		-0.0160
	(0.0069)	(0.0087)		(0.0105)
$Bankrupt$	-0.0026	0.0013		-0.0191
	(0.0075)	(0.0106)		(0.0124)
$Bankrupt\_after$	0.0064	0.0104	-0.0009	0.0126
	(0.0059)	(0.0073)	(0.0039)	(0.0098)
N	508,942	161,907	166,040	180,995

Note: *Delay*15, the industry standard definition for a delayed flight (arrival at least 15 minutes late), is the dependent variable. Carrier-route fixed effects and carrier-month fixed effects suppressed. Two-way cluster-robust standard errors by carrier-route and carrier-month are reported in parentheses. * and ** indicate statistical significance at the 5% and 1% levels, respectively.

Table 3 reports the regression results using $Delay15$, the industry standard definition for a delayed flight, as the dependent variable. Column (1) includes the full sample of 21 airlines, whereas Columns (2), (3), and (4) represents subsamples for major airlines, low-cost carriers (LCCs), and regional airlines, respectively.[15]

The negative and statistically significant estimate for $HR5900\_longrun$ in Column (1) suggest that there were fewer treatment delays in the two to five years after the law took effect compared to the baseline time period (three year time period between the passing of the law and its implementation). Given that 12.89% of flights are treatment delays attributed to the pilot or airline (Table 2), these results are economically significant. For example, an estimate of -0.0065 for $HR5900\_longrun$ implies that delays fell by 5.04% in the long run compared to the baseline time period. Thus, the increased training requirements imposed by H.R. 5900 are associated with more productive pilots, eventually leading to an industry-wide improvement in on-time performance in the long run.

Luttman and Nehiba (2020) find that regional airlines and low-cost carriers both reduced their flight frequency due to H.R. 5900, whereas major carriers maintained their capacity. By segmenting our data based on the three types of carriers, we find that our industry wide results are robust for both major airlines and regional airlines. In other words, the estimated coefficients for the long run in Columns (2) and (4) remain negative and significant. These results are also economically significant since the average value of $Delay15$ for major airlines and regional airlines is 10.21% and 13.68%, respectively. Indeed, H.R. 5900 decreased delays in the long run by 9.70% and 19.01% for major and regional airlines, respectively.[16] However, low-cost carriers experienced a statistically significant increase in delays in the long run. As with Luttman and Nehiba (2020), we find that not all types of airlines experienced the same operational effect from H.R. 5900.

[15] Six major airlines include Alaska Airlines, American Airlines, Continental Airlines, Delta Air Lines, United Airlines, and US Airways. Seven low-cost carriers include AirTran Airways, Allegiant Air, Frontier Airlines, JetBlue Airways, Southwest Airlines, Spirit Airlines, and Virgin America. Eight regional airlines include Endeavor Air, Envoy Air/American Eagle, ExpressJet, Mesa Airlines, Midwest Airlines, PSA Airlines, Republic Airlines, and SkyWest Airlines. Tan (2018) discusses the differences between these three types of airlines.

[16] It is worth noting that several mergers occurred within our sample time period, including United-Continental and U.S. Airways-American. As a robustness check, we keep the acquiring airline while omitting the acquired airlines from our sample and obtain qualitatively similar regression results.

Regional airlines understandably experienced an improvement in traditional delays since newly licensed ATP pilots are most likely to be employed by this type of airline. It is interesting, however, to consider the beneficial spillover effect on major airlines since regional airlines are contracted by major airlines to transport passengers between the major airlines' hub airports and smaller spoke airports.[17] If flights operated by a regional airline are more likely to be on time, then subsequent flights operated by the major airlines might be more likely to be on time. On the other hand, low-cost carriers do not typically hire newly licensed ATP pilots so their product quality in the long run may not necessarily be impacted by the H.R. 5900 law.

To be sure, estimated coefficients for the $Bankrupt\_before$ and $Bankrupt$ variables are omitted in Column (3) since $Bankrupt\_before = 0$ and $Bankrupt = 0$ for all observations pertaining to low-cost carriers. During our sample period, Frontier Airlines was the only low-cost carrier to experience a bankruptcy. Since it emerged from that condition in the year prior to our sample, we are able to estimate the coefficient for $Bankrupt\_after$ in Column (3). On the other hand, one major airline (American Airlines) and three regional airlines (American Eagle, Pinnacle Airlines, and Republic Airways) underwent bankruptcy during our sample period so we are able to estimate all three bankruptcy variables in Columns (2) and (4).

Table 4 presents the regression results for extended delays which last 180+ minutes ($Delay180$). As with Table 3, regression results for the pooled sample and for each of the three subsamples appear in Table 4. Again, the estimated coefficients for the time dummies are interpreted as percentage point changes so the numerical values for these estimates are much smaller in magnitude in Table 4 than in Table 3 given extended delays attributed to pilots and/or airlines (0.63%) occur very infrequently as reported in Table 2. The H.R. 5900 law led to a statistically significant increase in extended delays in both the short run and long run, the law actually led to a statistically significant increase in extended delays in both the short run and long run. With an estimated coefficient of 0.0015 for $HR5900\_longrun$ in Column (1), extended delays were 23.81% higher in the long run. Therefore, flight duty time limits combined with stricter occupational licensing standards set by

[17] See Forbes and Lederman (2009, 2010) and Tan (2018) for more information on the contractual relationship between major airlines and regional airlines.

H.R. 5900 have exacerbated especially long delays as airlines appear to be having difficulty in finding qualified replacement crews when there has been a schedule disruption in the long run.

Table 4: The Effect of H.R. 5900 on Extended Delays

	(1) Pooled	(2) Majors	(3) LCCs	(4) Regionals
$HR5900\_shortrun$	0.0007**	0.0004	0.0013**	0.0004
	(0.0002)	(0.0002)	(0.0004)	(0.0004)
$HR5900\_longrun$	0.0015**	0.0015**	0.0010**	0.0025**
	(0.0002)	(0.0003)	(0.0003)	(0.0005)
$OriginFlights\_small$	-0.0003	-0.0004	0.0002	0.0005
	(0.0003)	(0.0004)	(0.0008)	(0.0006)
$DestFlights\_small$	-0.0008*	-0.0005	0.0003	-0.0015
	(0.0003)	(0.0004)	(0.0008)	(0.0008)
$Bankrupt\_before$	-0.0008	-0.0014*		0.0004
	(0.0004)	(0.0006)		(0.0005)
$Bankrupt$	0.0001	-0.0003		0.0012*
	(0.0005)	(0.0007)		(0.0005)
$Bankrupt\_after$	-0.0000	0.0000	-0.0016**	0.0010*
	(0.0004)	(0.0006)	(0.0003)	(0.0004)
N	508,942	161,907	166,040	180,995

Note: $Delay180$, the EU's definition for an extended flight delay (arrival at least 180 minutes late), is the dependent variable. Carrier-route fixed effects and carrier-month fixed effects suppressed. Two-way cluster-robust standard errors by carrier-route and carrier-month are reported in parentheses. * and ** indicate statistical significance at the 5% and 1% levels, respectively.

Columns (2), (3), and (4) in Table 4 show a consistent result across all three airline types as airlines experienced a reduction in product quality during the long run as measured by extended delays. In the short run, however, only the low-cost carriers register significantly more extended delays. Since 0.55%, 0.58%, and 0.75% of flights operated by a major airline, low-cost carrier, or regional airlines are extended delays, the regression results are economically significant with major airlines, low-cost carriers, and regional airlines experiencing a long run increase in extended delays of 7.27%, 17.24%, and 33.33%, respectively. Although the increased regulation on flight training affected newly licensed pilots, the stricter schedule restrictions established in H.R. 5900 pertained to all pilots across all airlines.

3.4 Analysis of Treatment Group vs. Control Group

Although the analysis in Section 3.3 focuses on delays that are caused by either the pilot or airline, we can determine whether similar patterns exist for these delays, which we refer to as "treatment" delays, and "control" delays that include delays due to non-aircraft and non-carrier factors (i.e. delays attributed to either weather, national air system, or security issues). First, we replace $Delay15$ and $Delay180$ in Equation (1) with the proportion of flights with control delays ($Delay15\_Control$) and the proportion of flights with extended control delays ($Delay180\_Control$), respectively. If the estimated coefficients when using control delays as the dependent variable are qualitatively similar to those presented from treatment delays in Tables 3 and 4, then the H.R. 5900 legislation did not influence on-time performance; rather, any observed changes would be a reflection of a secular trend in flight delays. If control delays, however, are affected differently than treatment delays, then such a finding would suggest that the more stringent regulations for airline pilots have impacted airline on-time performance above and beyond what was expected.

In order to analyze differences between treatment delays and the control delays, we generate two new dependent variables. $Delay15\_Diff$ and $Delay180\_Diff$ are defined as the difference between treatment delays and control delays using the 15-minute and 180-minute definitions, respectively. For example, we construct $Delay15\_Diff = Delay15 - Delay15\_Control$ and $Delay180\_Diff = Delay180 - Delay\_Control180$. When incorporating either $Delay15\_Diff$ or $Delay180\_Diff$ as the dependent variable in Equation (1), the results suggest that the proportion of treatment delays increased by more than the proportion of control delays if the coefficients for the H.R. 5900 time dummies are positive. On the other hand, if the coefficients for the H.R. 5900 time dummies are negative, then the proportion of treatment delays fell by a larger amount than the proportion of control delays. Finally, the law had the same effect on both types of delays if the coefficients for the time dummies are insignificant.

Table 5 reports the results of the treatment and control delays based on the industry standard definition for a delayed flight (arrival at least 15 minutes late). By construction, Column (1) in Table 5 is identical to Column (1) in Table 3, which reports the results of Equation (1) using

$Delay15$ as the dependent variable. Column (2) in Table 5 uses $Delay15\_Control$, which is the proportion of flights with control delays (15+ minutes), as the dependent variable. So Column (1) includes traditional treatment delays that are attributed to the pilot or airline, whereas Column (2) includes traditional control delays associated with weather, national air system, or security issues. The coefficient for $HR5900\_longrun$ is smaller in Column (1) than in Column (2), suggesting that H.R. 5900 appears to have a stronger negative effect (i.e. improved product quality) on traditional treatment delays than traditional control delays in the long run.

Table 5: Treatment Delays vs. Control Delays

	(1) $Delay15$	(2) $Delay15\_Control$		(3) $Delay15\_Diff$
$HR5900\_shortrun$	0.0191**	0.0030**		0.0161**
	(0.0041)	(0.0010)		(0.0036)
$HR5900\_longrun$	-0.0065*	-0.0014		-0.0051*
	(0.0028)	(0.0012)		(0.0024)
$OriginFlights\_small$	0.0171**	-0.0049		0.0220**
	(0.0044)	(0.0025)		(0.0035)
$DestFlights\_small$	-0.0009	0.0006		-0.0015
	(0.0032)	(0.0026)		(0.0028)
$Bankrupt\_before$	-0.0042	0.0045		-0.0087
	(0.0069)	(0.0033)		(0.0046)
$Bankrupt$	-0.0026	-0.0013		-0.0013
	(0.0075)	(0.0026)		(0.0060)
$Bankrupt\_after$	0.0064	0.0119**		-0.0055
	(0.0059)	(0.0034)		(0.0043)
N	508,942	508,942		508,942

Note: The dependent variable in the regression results reported in Columns (1), (2), and (3) are $Delay15$, $Delay15\_Control$, and $Delay15\_Diff$, respectively. Carrier-route fixed effects and carrier-month fixed effects suppressed. Two-way cluster-robust standard errors by carrier-route and carrier-month are reported in parentheses. * and ** indicate statistical significance at the 5% and 1% levels, respectively.

In order to determine the statistical significance of the differences between the coefficients in Columns (1) and (2), we turn our attention to Column (3) in Table 5, which reports the regression results using $Delay15\_Diff$ as the dependent variable. Note that the coefficients in Columns (1) and (2) generate the coefficients in Column (3). For example, the coefficient for $HR5900\_longrun$ in Column (3) of Table 5 is -0.0051. This is the difference between traditional treatment delays ($Delay15$) and traditional control delays ($Delay15\_Control$) in the long run: $-0.0065-(-0.0014)=-0.0051$. In other words, the difference between traditional treatment delays and traditional control delays in the long run fell by 51 basis points compared to this gap in our baseline time period, the three years between the approval of the H.R. 5900 legislation and its effective date. Again, this suggests a stronger long run improvement in on-time performance in terms of traditional treatment delays compared to traditional control delays.

Table 6: Extended Treatment Delays vs. Extended Control Delays

	(1) $Delay180$	(2) $Delay180\_Control$	(3) $Delay180\_Diff$
$HR5900\_shortrun$	0.0007**	0.0004**	0.0003
	(0.0002)	(0.0001)	(0.0002)
$HR5900\_longrun$	0.0015**	0.0007**	0.0008**
	(0.0002)	(0.0001)	(0.0002)
$OriginFlights\_small$	-0.0003	-0.0006*	0.0004
	(0.0003)	(0.0003)	(0.0003)
$DestFlights\_small$	-0.0008*	-0.0004	-0.0004
	(0.0003)	(0.0003)	(0.0003)
$Bankrupt\_before$	-0.0008	0.0000	-0.0009*
	(0.0004)	(0.0004)	(0.0004)
$Bankrupt$	0.0001	-0.0003	0.0004
	(0.0005)	(0.0003)	(0.0005)
$Bankrupt\_after$	-0.0000	0.0002	-0.0003
	(0.0004)	(0.0004)	(0.0005)
N	508,942	508,942	508,942

Note: The dependent variable in the regression results reported in Columns (1), (2), and (3) are $Delay180$, $Delay180\_Control$, and $Delay180\_Diff$, respectively. Carrier-route fixed effects and carrier-month fixed effects suppressed. Two-way cluster-robust standard errors by carrier-route and carrier-month are reported in parentheses. * and ** indicate statistical significance at the 5% and 1% levels, respectively.

In a similar fashion, Table 6 analyzes extended treatment delays (i.e. extended delays due to the pilot or airline) compared to extended control delays (i.e. extended delays that are unrelated to the H.R. 5900 legislation). Once again, Column (3) in Table 6 is constructed as the difference between Columns (1) and (2). In contrast to the results in Table 5, the estimated coefficients for $HR5900\_longrun$ are positive in Table 6, which not only indicate an increase in extended treatment delays (Column (1)) and extended control delays (Column (2)) but also the difference (Column (3)) is positive so that H.R. 5900 exacerbated extended treatment delays more severely than extended control delays. As with Table 5, Column (3) in Table 6 also tests the statistical significance of these differences. For example, the Column (3) coefficient value for $HR5900\_longrun$ is 0.0008, which suggests that the difference between extended treatment delays and extended control delays rose by 0.08 percentage points in the long run compared to our baseline time period. Since treatment delays exhibit a different pattern than control delays in both Tables 5 and 6, this indicates that H.R. 5900 effectively reduced traditional treatment delays (15+ minutes), while increasing extended treatment delays (180+ minutes) relative to extended control delays. In sum, this analysis reaffirms our findings in Section 3.3 that one measure of product quality (15+ minute arrival delays) improves following the H.R. 5900 legislation, while another aspect of product quality (180+ minute arrival delays) worsens.

3.5 Right Start Flights

Since extended delays could be caused by the propagation of flight delays earlier in the day, we turn our attention to early morning flights in which an extended delay can be primarily attributed to either rest restrictions or weather. In particular, American Airlines refers to flights with a scheduled departure between 5:00AM and 9:00AM as "Right Start" flights. Since the aircraft should arrive at the departure airport the night before and maintenance issues can be taken care of overnight, these early morning flights are less likely to be affected by the cascading effect of flight delays. In order to analyze the effect of H.R. 5900 on Right Start flights, we keep flights in the raw data with an early morning scheduled departure time (5:00AM - 9:00AM) and aggregate these observations to the airline-route-year-month level. We re-estimate Equation (1) using this Right Start sample as a robustness check to the results presented in Sections 3.3 and 3.4. The number of observations in the Right Start sample is now less than the observations reported in Table 2 since not all airlines service every route with early morning flights.

We start by examining whether traditional delays are affected by Right Start flights. According to industry experts, Right Start flights set up flight crews and operations for optimal on-time performance. As such, delays for Right Start flights are most likely due to pilot rest restrictions as opposed to anything dealing with the pilots' ability or skills. Therefore, it is unsurprising that

Column (1) in Table 7 shows that the benefit of better trained pilots provides a statistically insignificant long run improvement in traditional delays across all airlines. As with Table 3, low-cost carriers are the only airline type that experiences a reduction in product quality (i.e. increase in traditional delays) in both the short run and long run. Interestingly, the estimated coefficients for $HR5900\_longrun$ for both major airlines and regional airlines are negative as in Table 3, but are no longer statistically significant in Table 7.

Table 7: The Effect of H.R. 5900 on Delays for Right Start Flights

	(1) Pooled	(2) Majors	(3) LCCs	(4) Regionals
$HR5900\_shortrun$	0.0041**	0.0020	0.0071**	0.0037
	(0.0011)	(0.0016)	(0.0017)	(0.0021)
$HR5900\_longrun$	-0.0000	-0.0021	0.0038**	-0.0036
	(0.0010)	(0.0016)	(0.0012)	(0.0024)
$OriginFlights\_small$	0.0024	0.0201	0.0085	-0.0572*
	(0.0097)	(0.0105)	(0.0185)	(0.0274)
$DestFlights\_small$	-0.0027	-0.0109	0.0220	-0.0050
	(0.0060)	(0.0075)	(0.0116)	(0.0129)
$Bankrupt\_before$	-0.0036	-0.0120**	0.0000	0.0049
	(0.0035)	(0.0036)	(0.0000)	(0.0052)
$Bankrupt$	-0.0055	-0.0056	0.0000	-0.0066
	(0.0035)	(0.0048)	(0.0000)	(0.0053)
$Bankrupt\_after$	-0.0005	-0.0026	-0.0120**	0.0029
	(0.0027)	(0.0036)	(0.0028)	(0.0039)
N	267,787	103,690	85,387	78,710

Note: This data sample consists of observations in the raw data for flights with a scheduled departure between 5:00AM and 9:00AM (Right Start flights) and then have been aggregated to the airline-route-year-month level. *Delay*15, the industry standard definition for a delayed flight (arrival at least 15 minutes late), is the dependent variable. Carrier-route fixed effects and carrier-month fixed effects suppressed. Two-way cluster-robust standard errors by carrier-route and carrier-month are reported in parentheses. * and ** indicate statistical significance at the 5% and 1% levels, respectively.

Table 8 reports the regression results on the effect of H.R. 5900 on extended delays for Right Start flights. As with Table 4, the estimated coefficients for the long run time dummies are positive and statistically significant not only industry wide (Column (1)) but also for each of the three types of airlines (Columns (2) - (4)). In other words, we observe that Right Start flights experience a significant increase in extended delays for all airline types. Since extended delays of Right Start flights most likely occur due to binding work schedule restrictions rather than the cascading effect of previously delayed flights, this analysis supports the finding in Section 3.3 that extended delays due to increased employee rest requirements have become more prevalent as a result of H.R. 5900.

Table 8: The Effect of H.R. 5900 on Extended Delays for Right Start Flights

	(1) Pooled	(2) Majors	(3) LCCs	(4) Regionals
HR5900_shortrun	0.0007**	0.0002	0.0006**	0.0016**
	(0.0001)	(0.0002)	(0.0002)	(0.0003)
HR5900_longrun	0.0016**	0.0008*	0.0006**	0.0048**
	(0.0003)	(0.0003)	(0.0001)	(0.0006)
OriginFlights_small	-0.0015	-0.0008	0.0003	0.0001
	(0.0013)	(0.0017)	(0.0016)	(0.0038)
DestFlights_small	-0.0016	0.0006	0.0006	-0.0042
	(0.0013)	(0.0016)	(0.0018)	(0.0034)
Bankrupt_before	-0.0004	-0.0019**	0.0000	0.0027**
	(0.0005)	(0.0005)	(0.0000)	(0.0006)
Bankrupt	0.0005	-0.0004	0.0000	0.0028**
	(0.0004)	(0.0005)	(0.0000)	(0.0005)
Bankrupt_after	0.0007	0.0001	-0.0012	0.0021**
	(0.0004)	(0.0005)	(0.0006)	(0.0007)
N	267,787	103,690	85,387	78,710

Note: This data sample consists of observations in the raw data for flights with a scheduled departure between 5:00AM and 9:00AM (Right Start flights) and then have been aggregated to the airline-route-year-month level. *Delay*180, the EU's definition for an extended flight delay (arrival at least 180 minutes late), is the dependent variable. Carrier-route fixed effects and carrier-month fixed effects suppressed. Two-way cluster-robust standard errors by carrier-route and carrier-month are reported in parentheses. * and ** indicate statistical significance at the 5% and 1% levels, respectively.

Table 9 presents the estimated coefficients for the analysis of extended treatment delays (i.e. extended delays due to the pilot or airline) compared to extended control delays (i.e. delays due to weather, national air system, or security issues) using the Right Start subsample. As previously mentioned, extended treatment delays for Right Start flights are primarily due to binding work schedule restrictions; however, extended control delays of early morning departures are typically due to inclement weather such as fog reducing visibility below legal minimums or overnight snow accumulation. Using a similar estimation strategy as in Section 3.4, the results in Column (3) can be calculated as the difference between the regression estimates in Column (1) and Column (2). Consistent with Table 6, the positive and significant coefficients for *HR*5900*_longrun* in Column (3) suggest that the incidence of extended treatment delays due to rest restrictions increased compared to the incidence of extended control delays due to severe weather conditions.

Table 9: Extended Treatment Delays vs. Extended Control Delays for Right Start Flights

	(1) $Delay180$	(2) $Delay180\_Control$	(3) $Delay180\_Diff$
$HR5900\_shortrun$	0.0007**	0.0005**	0.0002
	(0.0001)	(0.0001)	(0.0001)
$HR5900\_longrun$	0.0016**	0.0006**	0.0010**
	(0.0003)	(0.0001)	(0.0002)
$OriginFlights\_small$	-0.0015	0.0035**	-0.0050**
	(0.0013)	(0.0009)	(0.0014)
$DestFlights\_small$	-0.0016	-0.0003	-0.0013
	(0.0013)	(0.0009)	(0.0014)
$Bankrupt\_before$	-0.0004	-0.0001	-0.0003
	(0.0005)	(0.0003)	(0.0006)
$Bankrupt$	0.0005	-0.0008*	0.0013**
	(0.0004)	(0.0003)	(0.0005)
$Bankrupt\_after$	0.0007	-0.0000	0.0007
	(0.0004)	(0.0003)	(0.0005)
N	267,787	267,787	267,787

Note: This data sample consists of observations in the raw data for flights with a scheduled departure between 5:00AM and 9:00AM (Right Start flights) and then have been aggregated to the airline-route-year-month level. The dependent variable in the regression results reported in Columns (1), (2), and (3) are $Delay180$, $Delay180\_Control$, and $Delay180\_Diff$, respectively. Carrier-route fixed effects and carrier-month fixed effects suppressed. Two-way cluster-robust standard errors by carrier-route and carrier-month are reported in parentheses. * and ** indicate statistical significance at the 5% and 1% levels, respectively.

4 Conclusion

The primary objective of the H.R. 5900 legislation was to improve the safety of U.S. airline transportation and this objective appears to have been achieved given that no fatal accidents due to pilot error have occurred in the U.S. during the twelve year period since the Colgan Air flight 3407 in February 2009. This legislation which increased the occupational licensing requirements to obtain an air transport pilot license and mandated stricter scheduling restrictions for all pilots, however, had unintended consequences on product quality and pilot productivity.

While most prior research on occupational licensing (Kleiner, 2006; Kleiner, 2013; Kleiner and Kurdle, 2000; Kleiner et al., 2016) has shown stricter occupational licensing standards have no measurable impact on product quality, we find significant changes have occurred in aviation product quality. More specifically, using the U.S. aviation industry standard definition of flight delay (arrivals 15+ minutes late), we find evidence of improvements in on-time performance industry wide in both the short run and long run since the implementation of H.R. 5900. These on-time improvements are being driven by better on-time performance by major and regional airlines. We believe that the 15 minute delay standard is the best indicator of pilot effort since it takes greater effort to get an aircraft to arrive on-time. Comparing treatment delays with control delays unaffected by H.R. 5900 confirm that these results are not being driven by systemic trends in on-time performance in the airline industry.

These findings that stricter licensing requirements lead to increased productivity of airline pilots raises the question of why does this occur in aviation but not in other industries? There is evidence that increased licensing restrictions were led by rent-seeking behavior of people in the profession who wanted to be regulated in an effort to reduce competition (Kleiner, 2006, 2013). This was clearly not the case for the airline industry as these changes in occupational licensing guidelines for airline pilots were mandated by the U.S. Congress following an airline crash.

A caveat to our findings is that when using the European Union's definition of an extended flight delay (arrivals 180+ minutes late) as a measure of product quality we find product quality has gotten worse for extended delays. These lengthy delays do not reflect pilot effort, but instead may reflect a tight pilot labor market where airlines have difficulty in finding replacement flight crews following a schedule disruption. The implementation of H.R. 5900, which raised the occupational licensing requirements to certify new airline pilots, has led to a severe pilot shortage in the industry, which Great Lakes Airlines and Republic Airways have both cited as reasons for their bankruptcy filing. Hence, airlines may lack having sufficient qualified replacement crews that can fill in at the last minute for pilots that have reached maximum duty time limits. A consequence of the pilot shortage is that flight schedules can be quite fragile. In other words, a minor schedule disruption which previously caused a short delay can now lead to an extended delay.

Since regional airlines offer lower paid entry-level pilot positions compared to the other types of airlines,[18] the increase in occupational licensing requirements for pilots has created a pilot shortage primarily for regional airlines.[19] One impact of the pilot shortage is a reduction in flight frequency for regional airlines (Luttmann and Nehiba, 2020). We find another problem that the pilot shortage has created as extended delays (180+ minutes) are more prevalent in both the short run and long run since H.R. 5900 became effective. These pilot shortages may not be limited to regional airlines since we also observe an uptick in extended delays in the long run for major airlines and low-cost carriers, which suggests that all airlines may be facing logistical challenges with their workforce.

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