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Quality and productivity in aircraft sales: why the welfare costs of fire sales are overstated*

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Abstract

The paper measures the inefficiencies associated with fire sales in the airlines industry. We find evidence that fire sale discounts have been significantly overstated owing to under-maintenance and quality impairment of aircraft sold by distressed airlines. Using productivity data, the paper provides evidence that the bankruptcy process allows reallocation of distressed aircraft from low productivity to high productivity operators, suggesting a bankruptcy process that has a cleansing effect on the industry, rather than one of misallocation. The inclusion of the quality adjustment significantly reduces fire sale discounts on the sale of distressed aircraft, and the differences between Chapter 11 and Chapter 7 sales largely disappear. The results suggest that the welfare costs associated with fire sales might be significantly lower than those documented in prior studies.

1 Introduction

Recent crises have raised the economic importance of fire sales in both academic and policy circles. It is now widely accepted that fire sales are pervasive and associated with large economic inefficiencies. In a fire sale, distressed sellers are forced to liquidate their assets at discounted prices. In an influential paper, [Shleifer and Vishny \(1992\)](#) argue that distress is often driven by an industry-wide shock where specialist buyers of the asset are likely to be distressed at the same time, precluding them from bidding for the asset. As a result, the asset is misallocated to non-specialist users, that are assumed to have lower productivity than specialist users.¹ Besides, fire sales may generate negative externalities for the broader economy and may even contribute to systemic shocks.²

The empirical research on fire sales was pioneered by [Pulvino \(1998, 1999\)](#) in a study of secondary market transactions for used commercial aircraft. He documented that financially constrained airlines sold aircraft at a 15% average discount with significantly larger discounts, 25-35% in magnitude, for airlines operating in US Chapter 11 and Chapter 7 procedures. Similar magnitudes of fire sale discounts have been documented in other settings.³ For example, [Campbell et al. \(2011\)](#) report an average fire sale discount of 27% on the value of houses precipitated by a forced sale transaction.⁴

[Pulvino \(1999\)](#) attributed such high fire sale discounts in part to a misallocation of aircraft from high to low productivity users, suggesting that this result supports the [Shleifer and Vishny \(1992\)](#) hypothesis. He writes “Shleifer Vishny argue that in the presence of capital market imperfections, assets will not necessarily be allocated to the highest-value users. This will be particularly true when forces that caused the insolvent firm’s distress also affect others in the industry... Assets will then be allocated to firms outside the industry who, if the assets are industry specific, are lower valued users... Evidence from commercial aircraft transactions presented in [Pulvino \(1998\)](#) supports these concerns.” (page 152)

Fire sales are not just limited to real assets. [Coval and Stafford \(2007\)](#) document an 8-10% discount in equity markets on fire sales by mutual funds. [Mitchell and Pulvino \(2012\)](#) find that nearly identical corporate

¹Several papers extend this misallocation argument to financial assets: [Allen and Gale \(1994\)](#), [Shleifer and Vishny \(1997\)](#), [Gromb and Vayanos \(2002\)](#), [Brunnermeier and Pedersen \(2009\)](#), and [Duffie \(2010\)](#) attribute fire sales to limited arbitrage capital, arguing that complex securities are normally held by specialized investors who can exploit their knowledge, and when these investors become severely capital-constrained the available pool of specialized capital shrinks.

²For example, [Kiyotaki and Moore \(1997\)](#), model downward price spirals due to deleveraging and fire sales by specialist users of land (farmers), leading to an amplification in the decline in asset values. [Allen and Gale \(1994\)](#) argue that fire sales create a downward pressure on the value of collateralised assets, which drives even more operators into financial distress in a contagion effect. Other papers also document this amplification mechanism including [Krishnamurthy \(2010\)](#), [Geanakoplos \(2003\)](#), [Greenwood et al. \(2015\)](#), [Mian et al. \(2015\)](#) and [Dow and Han \(2018\)](#).

³See [Shleifer and Vishny \(2011\)](#) for a comprehensive survey on the fire sale discount literature.

⁴[Schlingemann et al. \(2002\)](#), [LoPucki and Doherty \(2007\)](#), [Andersen and Nielsen \(2017\)](#), [Strömberg \(2000\)](#) and [Franks et al. \(2020\)](#) document the costs associated with fire sales in real assets.

securities were mispriced by 10% during the 2008 crisis. In a study of fire sales caused by regulatory pressure on insurance companies, [Ellul et al. \(2011\)](#) report a 6-7% discount on corporate bonds.⁵

The large size of the fire sale discount in real asset markets are puzzlingly high, and raises an important question: why are investors leaving so much money on the table, and, why are lenders and borrowers not renegotiating contracts to reach a Coasian solution? This is even more puzzling given the provisions of Chapter 11 bankruptcy procedures allowing for a more patient sale of assets. In this event, we might expect to observe low discounts with little misallocation to lower productivity users.

While the observed higher discount for real assets vis-a-vis financial assets might be explained in part by a greater divergence in the private valuations of real assets as opposed to financial assets, omitted variables such as the inherent quality of the asset may also explain this difference. [Campbell et al. \(2011\)](#) have discussed this quality impairment channel as an important component of forced sale discounts in the housing market.⁶ In general, current methodologies for calculating fire sale discount do not control for quality differences between assets sold by distressed and healthy firms. It is natural to expect that distressed firms which are financially constrained, are more likely to under-maintain their assets, and that may be a direct consequence of the debt overhang problem ([Myers \(1977\)](#)).⁷ The first part of the paper aims to address this issue. Specifically, we examine whether fire sale discounts in the airlines industry, after adjusting for quality, are significantly smaller than the literature has documented. In the second part of the paper, we investigate the extent to which the quality-adjusted fire sale discount, reflects the sale of distressed aircraft to lower productivity users ([Shleifer and Vishny \(1992\)](#)), or is the discount attributable to the greater bargaining power of the buyer. The sample of distressed aircraft also include airline operators that emerge from Chapter 11 as going concerns, and we examine the extent to which the bankruptcy process has a cleansing effect on the companies by improving their productivity. The empirical tests address other issues, including whether the discount is influenced by the intensity of distress, and the particular bankruptcy procedure, Chapter 11 versus Chapter 7, and whether the results are affected by the state of the economy.

The issue of quality, analysed in the first part of the paper, is an important one in the airlines industry. In the U.S., airworthiness maintenance requirements are mandated by the Federal Aviation Administration (FAA). Despite this, there have been instances when airlines operating under bankruptcy have been scrutinized for selling aircraft of impaired quality. For example, during Eastern Airlines' bankruptcy proceedings it was

⁵Several other papers also document fire sales in financial asset markets: [Jotikasthira et al. \(2012\)](#), [Eisenbach et al. \(2014\)](#), [Merrill et al. \(2014\)](#), and [Acharya et al. \(2007\)](#)

⁶[Campbell et al. \(2011\)](#) estimate the importance of the maintenance channel by identifying the motives for a forced sale. For example, they link the high discount on the sales of single family homes on the death of elderly sellers to poor maintenance. However, they do not decompose the foreclosure-related discounts into under-maintenance and liquidity components.

⁷In the real estate market, [Melzer \(2017\)](#) documents evidence of homeowners reducing their home improvement and maintenance expenditures when faced with mortgage debt overhang. However, debt overhang is not a necessary condition for under-maintenance. Distressed firms might be cash constrained and therefore, have to give up investments with positive NPV, such as maintenance expenditures.

revealed that the airline had failed to maintain aircraft as dictated by the terms of their capital leases, and lessors had to make major repairs to many aircraft to ensure they met the mandated operating regulations.⁸ In an analysis of Eastern Airlines' bankruptcy, Weiss and Wruck (1998) noted that, "the discount on Eastern's aircraft could be due to many factors including its distressed situation and/or poor maintenance." It is also common for airlines to swap engines and other parts of an aircraft, and subsequently sell those aircraft with the second-hand parts. However, it is challenging to systematically measure these quality differences between aircraft, because they are not captured in reported aircraft characteristics nor, are they documented in our transaction price database. In this paper we suggest a novel approach to control for these quality differences that are not directly observable or documented in existing studies.

An important proxy for the quality of aircraft sold by bankrupt and distressed airlines is the productivity of aircraft. Using a granular measure of aircraft productivity, flying hours at the aircraft-level, we find that aircraft sold by distressed airlines have around 10% lower utilization compared with other similar aircraft flown by that *same* operator.⁹ We also find that the intensity of distress, measured by the time spent in distress, in particular the period prior to filing for bankruptcy, is highly correlated with flying hours i.e. the quality adjustment. Taken together, our results show that the distress-affected aircraft exhibit lower productivity while in use. After controlling for quality, the quality-adjusted fire sale discount for aircraft sold by bankrupt airlines is around 8%, about one half of the raw fire sale discount. Importantly, the quality discount varies with the length of the distress period. As a result, aircraft sold in Chapter 7 have a higher quality discount than those sold in Chapter 11, because they spend a longer period in distress prior to filing for bankruptcy. The result is, that the quality adjusted fire sale discount is very similar in both Chapter 11 and Chapter 7. Even so, we find that during recessions the quality-adjusted fire sale discount increases by 13%.

In a second proxy for quality, used as a robustness check, we use data on aircraft retirement age, to impute the hazard rate and life expectancy for aircraft. We find that aircraft sold by distressed airlines have 9% lower remaining life expectancy than aircraft sold by non-distressed airlines.¹⁰ The results are similar to those found using flying hours.

We next decompose the quality-adjusted fire sale discount into a pure liquidity channel and the misallocation channel. The liquidity channel represents a transfer from the seller to the buyer and as such the discount does not have any ex-post welfare implications.¹¹ In contrast, where there is misallocation of assets from high to low productivity users, it generates a welfare loss. Our granular dataset on aircraft ownership and utilization

⁸Lessors received a small legal settlement that covered about 20-25% of these additional costs.

⁹Bankruptcy sales are aircraft sales made by airlines that have filed for Chapter 11 or Chapter 7 protection. Distressed sales are sales of aircraft made by airlines during a period of distress prior to their entering bankruptcy, or while they are operating in bankruptcy.

¹⁰Franks et al. (2020) document higher hazard rates and lower life expectancy for sales of ships by distressed sellers. Pricing in this quality correction reduces the 26% raw fire sale discount by about a half.

¹¹Notwithstanding, there still may be ex-ante welfare losses.

allows us to examine this question. We measure misallocation by comparing flying hours and profitability measures of the new users of distressed aircraft with new users of aircraft sold by non-distressed airlines. Our metrics for flying hours control for the aircraft type, age, usage, market thinness, and year fixed effects. We do not find, in our sample, evidence of misallocation of aircraft to lower productivity or less profitable firms. In contrast, we find that for the large majority of bankruptcy sales, the buyers of the aircraft are operationally more efficient than the sellers.¹² This result extends to firms that emerge from Chapter 11 as going concerns with their aircraft fleets largely intact, where their productivity post emergence is higher than their pre-bankruptcy levels. This suggests that the quality-adjusted fire sale discount of 8% is largely a transfer from the seller to the buyer due to the greater bargaining power of the buyer, i.e., the liquidity channel, and not to the misallocation channel. Nor does this result change in recession periods where despite higher quality adjusted fire sale discounts, there is no evidence of misallocation to lower productivity users.¹³ When we examine a sample of bankrupt operators that emerge from bankruptcy as going concerns, we find higher productivity post-bankruptcy compared with pre-bankruptcy consistent with the process having a cleansing effect on industry inefficiencies.¹⁴

The results, also, highlight the important role played by aircraft leasing companies. Since aircraft purchased by lessors are not directly operated by them, we track the final users of these aircraft, and find that leasing companies redeploy aircraft more rapidly to users, thereby performing a valuable intermediary role. This evidence is consistent with [Gavazza \(2011a\)](#), who documents that leasing companies reduce trading frictions in second-hand aircraft markets.

In summary, our paper revisits the issue of the fire sale discount in the airline industry. The recent pandemic in 2020 caused by Covid-19, and the consequent economic crisis it has engendered, has reignited the issue of the fire sale discount and the inefficiencies associated with it. Our analysis of the airline industry suggests that a significant proportion of the fire sale discount is driven by omitted quality differences between forced sales and regular sales. Our analysis suggests that this higher discount reflects the greater need for immediacy, particularly during recessions, and not the misallocation of aircraft to lower productivity users. The paper also reports that this quality discount varies with the length and depth of distress, which explains why the quality discount is higher for aircraft sales in Chapter 7 than in Chapter 11. After quality adjustment, any differences between the fire sale discount largely disappear. Overall, our results suggest that the welfare costs associated with fire sales might be lower than those documented in prior studies.

¹²This evidence is consistent with [Bian \(2020\)](#), who finds that resource reallocation is an important channel through which stronger creditor protection increases productivity in the airlines industry.

¹³This is consistent with [Meier and Servaes \(2019\)](#), who find that the quality-adjusted fire sale discount is primarily a consequence of the lower bargaining power of the distressed seller.

¹⁴In an analysis of the airlines industry, [Phillips and Sertsios \(2013\)](#) document that product quality decreases when airlines are in distress (pre-bankruptcy), while, the product quality improves after the airlines file for bankruptcy.

In retrospect, it should not surprise that the quality-adjusted fire sale discount is substantially below previously reported levels, because of the presence of Chapter 11 procedures. Provisions include an automatic stay on interest and repayments of existing debt and debtor in possession financing. They permit for a more patient sale of assets which should significantly mitigate the problems of misallocation (Shleifer and Vishny (1992)) and illiquidity. Equally important, the bankruptcy process rather than causing a misallocation of assets from high to low productivity users has the opposite effect, which has been described as a ‘cleansing effect’ (see (Caballero and Hammour (1994))). For example, de-contracting provisions allow firms in Chapter 11 to reject or renegotiate expensive contracts with suppliers and labor, thereby both reducing the cost base and improving the competitiveness of the bankrupt firm. In this event, while we might expect the distress period prior to filing to be associated with lower aircraft productivity, we would not expect the same effect during formal bankruptcy procedures. This may explain why we observe the higher productivity of aircraft operators that emerge from Chapter 11 as going concerns.

The rest of the paper is organized as follows. In section 2 we discuss the institutional features of the used commercial aircraft market, describe our data and summary statistics. In section 3 we present evidence on the quality variations between aircraft sold by distressed and non-distressed sellers. Section 4 describes the empirical methodology and results on quality-adjusted fire sale discount. Section 5 presents evidence on aircraft misallocation, and investigates the extent to which the quality-adjusted fire sale discount is attributable to the pure liquidity channel, and the misallocation channel. In section 6 we analyse the effect of bankruptcy procedures on the fire sale discount. Section 7 discusses the role of leasing companies in the airline industry. Section 8 concludes the paper.

2 Institutional Description and Data

2.1 Institutions

The market for used aircraft transactions is organized around privately negotiated transactions. Buyers conduct comprehensive pre-purchase inspections of all installed avionic equipment in the aircraft to establish their condition of airworthiness and maintenance. All the maintenance records for the aircraft are transferred to the buyer upon sale, indicating that there is little asymmetric information between buyers and sellers of used commercial aircraft (see also, Gavazza (2011a)). Such information is private to the parties involved in the transaction, and is not available to the econometrician.

We have selected the airlines industry to answer important questions regarding the estimation of the fire sale discount. There are various reasons that make the airlines industry an excellent laboratory to implement

our framework. First, we are able to obtain a comprehensive sample of aircraft transaction prices as the Department of Transportation (DOT) regulations in the airlines industry mandated price disclosure for all used commercial aircraft transacted in the U.S. between 1978-1991. Second, aircraft of a given model are “relatively” homogeneous which makes possible the calculation of hedonic prices based on their characteristics. Third, the U.S. airline industry presents a sample of firms where bankruptcy filings are common. Therefore, we are able to link an airline’s financial health with any discount it receives on the sale of its aircraft.

Detailed *aircraft-level* utilization data for the airlines industry allows us to overcome the empirical challenge of quantifying the impact of unobservable quality variations on the price of an asset. In real assets there could be significant quality differences between well maintained and under-maintained assets that affect their continuation value. This difference is particularly crucial for aircraft, and it is also well documented in the technical aviation literature. Lower maintenance can decrease aircraft utilization rates, and the effect is particularly strong for older aircraft (Ackert (2012)). Maintenance and safety considerations in the aviation industry have led to wide availability and high accuracy of aircraft level capacity utilization data. This granular aircraft utilization and retirement age data allow us to control for quality variations resulting from the lower flying hours and lower life expectancy of distress-affected aircraft, both of which we use as proxies for the productivity of aircraft. Additionally, rigorous aircraft registration requirements track fleet alterations and economic activity at the airline level. This micro tracking of each aircraft at the airline level allows us to consistently trace aircraft relocation from one user to another, and measure airline level productivity. These data are used to examine the issue of misallocation.

Bankruptcy filings are commonplace in the U.S. airlines industry, and their design and enforcement are likely to influence the fire sale discount. In our sample, 46 U.S. airlines filed for Chapter 11 bankruptcy protection during 1975-2015. Of these 46, 8 airlines emerged from Chapter 11, while the rest were eventually liquidated in Chapter 7, after a period spent in Chapter 11. Given the size of the industry and the incidence of distress and bankruptcy, creditors of airlines have been given special protection for their investments under Section 1110 of the U.S. Bankruptcy Code (Ripple (2002)). However, there is strong empirical evidence that such protection was not effective, until at least 1994 when new legislation was passed improving enforcement procedures. Even then, empirical evidence suggests that sellers of aircraft and aircraft lessors preferred to take back aircraft or reduce the lease rentals rather than pursue court action (see Benmelech and Bergman (2008)). We examine these issues in more detail in Appendix A.

The alternative bankruptcy procedure in the U.S. is Chapter 7, which may be regarded as the process of liquidation. An airline that entered Chapter 7 would be closed down and its assets sold off. The sales process would not be managed by the debtor in possession as in Chapter 11, but rather by a trustee appointed by the bankruptcy court. Aircraft sold in Chapter 7 are owned by airlines that have previously spent time in

Chapter 11.¹⁵ However, the aircraft sold in Chapter 7 belong to operators which have suffered a longer period of distress before filing for bankruptcy, and as a result are in worse financial shape than those airlines surviving Chapter 11. As a result, we might expect that the under-maintenance effect would be larger for those aircraft that are sold in Chapter 7 compared with those sold in Chapter 11.

2.2 Data Sources

We combine several data sources for empirical analysis in this paper.

FlightGlobal: FlightGlobal is a leading producer of aviation market statistics. The database tracks ownership (fleet description) and operations history of commercial aircraft. If the aircraft is no longer operational, then the database provides the date at which the aircraft was retired. The data on aircraft utilization and retirement age spans 1975 to 2015. It also reports comprehensive information on aircraft utilization, i.e. the monthly number of hours flown by an individual aircraft operating in the US. Monthly flying hours are aggregated at the yearly level to obtain an annual panel on aircraft utilization for the 1975–2015 period.

Transaction Prices Database: The data is based on DOT and Federal Aviation Administration (FAA) filings assembled by Avmark Inc. The dataset collects aircraft transaction prices from 1978 to 1991. Prior to 1992, the DOT required price disclosure for all aircraft purchased or sold by U.S. corporations.¹⁶ The dataset reports information of aircraft characteristics including the aircraft’s age, model, and engine noise stage. It also contains the identity of the buyer, the seller, the date of transaction, and the transaction price. In the empirical analysis section, we focus on sales of used aircraft reported in this database. The transaction prices have been adjusted for inflation.

Bureau of Transportation Statistics: We extract traffic data of U.S. commercial airlines (available seat miles (ASMs), revenue passenger miles (RPMs) etc.) from Air Carrier Traffic Statistics (Form 41 and 298C Summary Data). The data are available quarterly beginning 1974.

Bankruptcy filing procedure (Chapter 7 or Chapter 11) and bankruptcy dates are obtained from UCLA-LoPucki Bankruptcy Research Database and Airlines for America.

COMPUSTAT: Financial data of U.S. airlines. Where available, quarterly data are used, otherwise annual data are collected.

S&P Ratings: Data on rating downgrades of bonds held by airline companies (prior to their filing for bankruptcy) is obtained from the S&P Ratings database. These rating downgrades are used to identify the

¹⁵The aircraft sold in Chapter 7 spend on average 2.8 months prior to their sale in Chapter 7.

¹⁶After the DOT removed the price disclosure requirement, airlines and leasing companies mostly ceased reporting transaction prices.

beginning of the period of distress for an airline filing for bankruptcy. When ratings are unavailable we use the year of earnings losses as a proxy for the beginning of the distress period.¹⁷

2.3 Summary Statistics

We have two datasets with different time series. The aircraft productivity and ownership database spans 1975 to 2015. In comparison, the transactions or aircraft price data runs from 1978 to 1991. While our transactions data limits our estimation of fire sale discount, the productivity database for the much longer time series allows us to calculate differences in quality for a much larger sample of distressed sales over 1975 to 2015, and make comparisons with non-distressed aircraft. The longer time series is also used to calculate the differences in productivity between the buyers and sellers of distressed aircraft, and changes in productivity of airlines that emerge from Chapter 11 as a going concern. It therefore, provides a more robust test of the under-maintenance and misallocation hypotheses.

In Table 1 Panel A, we describe the summary statistics for aircraft productivity for the period from 1975 to 2015, as measured by annual flying hours.¹⁸ We have operational data on 4,860 aircraft spanning 59,786 aircraft-years. 1.1% of these cumulative aircraft-years were spent *parked*, during which the aircraft had zero flying hours for the entire year.¹⁹ We show in Panel A for the full sample that an average aircraft flies for 2,171 hours annually. Conditional on it not being parked, an average aircraft flies for 2,195 hours annually. We also report statistics for 3 subsamples: (i) aircraft liquidated by airlines in Chapter 7 bankruptcy, (ii) aircraft sold by airlines during Chapter 11 bankruptcy protection, and, (iii) aircraft that were not sold during bankruptcy. Aircraft that were liquidated by airlines in Chapter 7 bankruptcy fly for 1,269 hours annually. Aircraft that were sold by airlines in Chapter 11 bankruptcy protection spend a higher proportion of their time parked (1.5%), and conditional on not being parked fly for 1,979 hours annually. These levels of productivity are far below the average productivity of aircraft that were never been exposed to bankruptcy.

Table 1 Panel B describes the summary statistics for the used aircraft transactions occurring between 1975 and 2015. We have a total sample of 4,235 secondary market transactions in which one of the parties is a U.S. airline. Of these, 237 aircraft were sold by airlines operating under Chapter 11, while 44 were sold by airlines operating under Chapter 7.²⁰ Using retirement dates in our database, we find that of the 4,235 aircraft

¹⁷For around 70% of the aircraft sold in distress, we have both the ratings and earnings data for the distressed airline. We find that for all these airlines, the year of rating downgrade is the same as the year of earnings losses. Hence, when ratings are not available we use the year of earning losses as a proxy for the beginning of distress period.

¹⁸The aircraft productivity database comprises of all the aircraft types for which we have the transaction prices data.

¹⁹*Parked* is a binary indicator variable taking a value of 1 if the aircraft has zero flying hours for the entire year, and is 0 otherwise.

²⁰The average age of aircraft sold in Chapter 7 is 11 years, compared with 18 years for aircraft sold in Chapter 11. The lower average age of aircraft sold in Chapter 7 is due to 3 very young aircraft (of 2 years age) sold by Air Florida in Chapter 7.

transactions in our sample period, around 2,295 aircraft ceased to operate by the end of 2016.²¹ The average retirement age for aircraft in our sample is roughly 29 years. For the aircraft that are retired from service, we also report the cumulative hours flown by them during their entire lifetime, with an average aircraft flying a total of 64,820 hours during its lifetime. We further split our transactions sample into 3 subsamples: (i) sales by an airline that is liquidated under Chapter 7 bankruptcy, (ii) sales by an airline that operated under Chapter 11 bankruptcy protection, and, (iii) sales made by non-bankrupt airlines. We find that aircraft sold by airlines operating in bankruptcy have a lower retirement age than aircraft sold by non-bankrupt airlines. Also, the aircraft sold by bankrupt airlines fly less than the aircraft sold by non-bankrupt airlines. We explore these differences in retirement age and flying hours in detail in the next section.

In Panel C of Table 1 we describe the summary statistics for the used aircraft sales occurring between 1978 and 1991, for which we have the transaction prices. An identical sample of 1,333 secondary market transactions has been used in Pulvino (1998, 1999). Using data on retirement dates, we find that of the 1,333 transactions, around 97% aircraft ceased to operate by the end of 2016. The average inflation adjusted price for a used commercial aircraft in 1992 dollars is \$11.5 million. We have 131 sales by airlines operating under bankruptcy. Of those, 91 aircraft were sold by airlines operating under Chapter 11, while 40 were sold by airlines operating under Chapter 7. Consistent with Panel B, in the sub sample of transactions for which we have the price data, we report that aircraft sold by airlines operating in bankruptcy have lower retirement age, and lower flying hours than aircraft sold by non-bankrupt airlines.

3 Evidence on Aircraft Quality Impairment

In this section, we present evidence on the quality of aircraft sold by financially distressed airlines. In the U.S. aviation industry aircraft safety standards are monitored by the Federal Aviation Administration (FAA). Even though minimum aircraft safety standards are set by the FAA, airlines are free to set maintenance levels above these minimum targets. Discussions with aviation appraisers suggest there are areas of maintenance and refurbishment of aircraft which can be postponed, or costs reduced without endangering aircraft safety, and maintenance adjustments i.e. quality adjustments are often a significant part of second-hand aircraft prices.²² It is common practice for aircraft leases and security agreements to allow the operator to exchange engines and other parts through pooling or interchange agreements (Scheinberg (2017)). It is natural to expect that the financial health of an airline and the value of its aircraft to be correlated with the quality and maintenance of

²¹However, in some cases an aircraft is parked and is not operating for some years just prior to being retired. We reduce the retirement age to reflect this period during which an aircraft is parked prior to its retirement. This correction is based on the fact that when an aircraft has zero flying hours for an entire year, it is described as being *parked* in the database.

²²For example, worn out or defective parts may be replaced with second-hand rather than new parts, and refurbishments may be postponed.

its aircraft (see Rampini (2019)).²³ Often, airlines operating under bankruptcy have been criticized for selling aircraft of impaired quality.²⁴ In this section, we use granular aircraft level utilization i.e. flying hours and retirement age data, to systematically document the variations in quality between aircraft sold by distressed and non-distressed airlines.

3.1 Aircraft Cumulative Flying Hours

We classify the aircraft sales based on the varying degree of financial distress of their seller. Following Pulvino (1998, 1999), an aircraft sale is classified as a distressed sale if the aircraft is sold by: (i) an airline that is liquidated under Chapter 7 bankruptcy, (ii) an airline that operated under Chapter 11 bankruptcy protection, or (iii) an airline selling aircraft during the distress period prior to filing for bankruptcy. For an airline filing for bankruptcy, rating downgrades are used to identify the beginning of the distress period.

Using data on cumulative aircraft flying hours for the aircraft that are retired from service, we test whether there is a significant difference in the total flying hours of the aircraft sold by distressed airlines compared with other similar aircraft transacted by non-distressed airlines. In Table 2, we analyze the variation in log cumulative flying hours for aircraft that were exposed to distress. The indicator variable *Distressed* equals 1 if the aircraft was ever exposed to a distress event, and equals 0 otherwise. Age at distress measures the age at which the aircraft was sold by the distressed airline.²⁵ In columns (1) and (2), we report that an average aircraft exposed to distress flies around 7% less than a similar aircraft sold by non-distressed sellers. The utilization of aircraft sold by distressed airlines is significantly lower than other similar aircraft, even after including aircraft type, aircraft usage, and retirement year fixed effects. Additionally, we find that the cumulative utilization is lower for aircraft that were exposed to distress earlier in their economic life, compared with aircraft that were similarly exposed to distress later in their life; in other words the cost of under-maintenance is higher for younger aircraft. We return to this issue later in the paper.

In columns (3) and (4) of Table 2, we split our sample of distressed sales, into two subsamples of sales made by airlines in Chapter 7 and Chapter 11. We find that an aircraft sold by an airline being liquidated in Chapter 7 is utilized around 15.5% less over its life than other similar aircraft that have not been exposed to distress. Similarly, an aircraft sold by an airline operating in Chapter 11 bankruptcy protection operates 7.5% less than other similar aircraft not exposed to distress. This suggests that there is variability in the

²³Rampini (2019) argues that constrained firms invest less in durable assets and buy more used assets. The equivalent of used assets in aircraft are second-hand parts, such as engines.

²⁴For example, Eastern Airlines failed to maintain aircraft as dictated by the terms of their capital leases, and lessors had to make major repairs on many aircraft to ensure they met the mandated operating regulations.

²⁵The variable $Age - \overline{Age} (at\ distress)$ measures the difference between the age at distress (\overline{Age}) for the aircraft sold by a distressed airline, and the average age (\overline{Age}) of all aircraft sold by distressed airlines. $Age - \overline{Age} (at\ distress)$ is 0 for aircraft never exposed to distress events.

quality of aircraft transacted by distressed airlines that may reflect the depth of distress, and a greater under-maintenance problem. Alternatively, it may reflect a misallocation to lower productivity buyers. In the subsequent subsections we will explore these alternative explanations.

3.2 Evidence on Aircraft Productivity

We use aircraft level utilization metrics to provide evidence that quality impairment is reflected in lower productivity of an aircraft. The productivity measures allow us to investigate whether aircraft sold by distressed airlines are operated less intensively, while they are in use by the new operator. We use yearly average flying hours, conditional on the aircraft not being parked, to measure aircraft’s productivity. To understand the relation between financial distress of the seller and future utilization of an aircraft, we estimate the following equation:

$$\log(\text{Hours})_{it} = \beta_1 \text{Ch7}_{it} + \beta_2 \text{Ch11}_{it} + \beta_3 \text{PreFiling}_{it} + \beta_t + \beta_{\text{Type} \times \text{Age}} + \beta_{\text{operator}} + \beta X_{it} + \epsilon_{it} \quad (1)$$

where, $\log(\text{Hours})_{it}$ measures the yearly flying hours of aircraft i in year t , conditional on the aircraft not being parked.²⁶ Ch7_{it} is a dummy variable taking value 1 if the aircraft i was ever sold by an airline in Chapter 7 in the years preceding the current year t . Ch11_{it} is a dummy variable taking value 1 if the aircraft i was ever sold by an airline operating in Chapter 11 in the years preceding the current year t . PreFiling_{it} is a dummy variable taking value 1 if the aircraft was ever sold by an airline during the distress period prior to filing for bankruptcy, in the years preceding the current year t . We include year fixed effects (β_t) to control for time specific trends in aircraft flying hours. Fixed effects for Type \times Age ($\beta_{\text{Type} \times \text{Age}}$) allow us to control for any model specific age differences between aircraft. An aircraft type dictates the distance and route over which the aircraft is used and therefore, controlling for aircraft type allows us to control for the distance aspect of the aircraft’s route.²⁷ Finally, operator fixed effects (β_{operator}) ensure that our results are not driven by any airline specific factor, and that aircraft acquired from distressed airlines are compared with other similar aircraft operated by the *same* carrier. The analysis of productivity differentials between the distressed aircraft in the hands of the buyer and the productivity of other aircraft in its fleet allows us to distinguish between the under-maintenance effect and the misallocation effect. We also use controls for market thinness of the aircraft

²⁶The utilization data used here is a panel of yearly individual aircraft flying hours for aircraft operating in the U.S. during the period 1975-2015.

²⁷Using data on airline routes from the T-100 Segment of Form 41 reported by the Bureau of Transportation Statistics (BTS), we find that aircraft of a particular type fly over similar distance routes. For example, narrow body aircraft of Boeing 727, 737, and McDonnell DC-9 mainly fly on routes that are less than 1000 miles. Similarly, aircraft models of Airbus A300 fly over medium distance (1000-2000 miles), while the wide-bodied types of Boeing 747, McDonnell DC-10, and Lockheed L-1011 fly over medium to long distance routes. This ensures that using fixed effects for aircraft type \times age in all our specifications controls for the different distance categories of routes over which the aircraft is operated. We cannot control more granularly for routes, because airlines routinely shuffle and interchangeably use aircraft of similar types (and ages) across routes depending on the demand. The BTS dataset does not document the route on which a particular aircraft (designated by its serial number) is operated.

(X_{it} includes number of same type of aircraft, and operator fleet size). These have been used in Gavazza (2011b), to document that when markets for assets are thin, aircraft’s average productivity is lower.²⁸

Table 3 reports our results for the full sample period (1975-2015). In Panel A columns (1) and (2), we find that aircraft sold by distressed airlines fly 10% less post-sale than other similar aircraft operated by the new carrier i.e, the buyer of the distressed aircraft. In columns (3) and (4), we split our sample of distressed sales, into sales made by airlines while operating in Chapter 7, Chapter 11, and distress period prior to filing for bankruptcy. We find that aircraft sold during Chapter 7 and Chapter 11 have utilization rates post-bankruptcy that are 14% and 10% lower, respectively, than other similar aircraft operated by the new carrier. These differences persist for the remaining life of the aircraft subsequent to their sale. Aircraft sold during the distress period prior to filing for bankruptcy fly 8% less than other aircraft operated by the new carrier. This indicates a fundamental productivity difference between aircraft flown by the *same* operator, that have been exposed to distress and those which have not.²⁹ In columns (5) and (6) of Table 3, we include aircraft operator \times year fixed effects, and find similar results. This confirms that the persistent lower productivity of aircraft sold by distressed airlines is robust to time varying trends in the post-sale operators’ productivity.

One potential concern is that a particular airline may possess proficiency in a specific type of aircraft and not in another. This would imply that the lower productivity of the aircraft is due to the operator-aircraft match, and not due to the under-maintenance of the aircraft by the distressed seller. In columns (7) and (8) of Table 3, we attempt to resolve this concern by including aircraft operator \times aircraft type fixed effects. We find that aircraft sold by distressed airlines fly 7% less post sale compared with other similar aircraft models operated by the new carrier. In column (8), we split our sample of distressed sales by the level of distress, and find that aircraft sold during Chapter 7 and Chapter 11 have around 8% lower utilization, than other similar aircraft models operated by the new carrier.³⁰ Hence, our results on lower productivity of aircraft sold by distressed airlines are robust to controls for the productivity differentials between different types of aircraft operated by the same operator.

We have established that aircraft sold by distressed airlines have lower productivity while they are in use. In Appendix B, we show that our results are robust to alternate explanations. For example, pre-distress we find no evidence of lower productivity of aircraft sold by distressed airlines and, our results suggest that the change

²⁸In commercial aircraft markets, Gavazza (2011b) documents that aircraft with a thinner market are less liquid and more difficult to sell. When markets for assets are thin firms hold on longer to their assets amid profitability shocks, and as a result, the aircraft’s average productivity is lower in thin markets. To account for this, we include controls for aircraft market thinness in our specification.

²⁹We exclude from this analysis very young aircraft (aged less than 5 years) that are transacted by distressed airlines, because they are still under manufacturers’ warranty and as a consequence their maintenance expenses are not borne by the distressed airline. We find that such young aircraft are not under-maintained, therefore, reinforcing our hypothesis that at least some part of the low quality of the aircraft is due to their under maintenance when the seller of the asset is financially distressed.

³⁰In a specification similar to Table 3, we also include both operator \times year \times type, and type \times age fixed effects, and find that aircraft sold by distressed airlines fly significantly less (7.2%) post sale compared with other similar aircraft models operated by the new carrier in the same year.

in ownership is in itself not responsible for the decline in productivity of aircraft sold by distressed airlines. Since, the quality of an aircraft is negatively correlated with the financial distress of the seller, we expect that calculating the fire sale discount ignoring the quality variations between aircraft, would overestimate this discount.

3.3 Aircraft Life Expectancy

As a further robustness check on the lower quality of aircraft sold by distressed sellers, we measure the difference in lifespan of aircraft sold by distressed airlines and other aircraft transacted in our sample. Using the retirement age of aircraft, we apply duration analysis to calibrate the hazard function for an aircraft. The hazard function characterizes the hazard rate for an aircraft as a function of its age. Conditional on surviving up to a given age, the hazard rate represents the probability of an aircraft retiring in the subsequent period. We calculate the hazard rates using the Cox proportional hazard model. Figure 1 plots the hazard rate as a function of age for aircraft sold by airlines operating in bankruptcy relative to other transacted aircraft. We can conclude that the hazard rate is the highest for aircraft sold by airlines in Chapter 7, and higher for aircraft sold by airlines in Chapter 11, relative to aircraft sold by non-bankrupt airlines.

Figure 1 plots the life expectancy of aircraft, conditional on being alive at a given age.³¹ We find that aircraft exposed to bankruptcy have a lower life expectancy versus non-distressed aircraft. The average age of aircraft at sale in our sample is 15 years, and at this age, the hazard model estimates that the life expectancy of an aircraft exposed to Chapter 7 is 26.5 years, and 26.9 years for an aircraft exposed to Chapter 11; this compares with 28.1 years for aircraft not exposed to distress. These estimates suggest that aircraft sold by airlines operating in bankruptcy have around 9% lower remaining life expectancy than aircraft sold by non-distressed airlines.

In Table A.2, we regress the retirement age of the aircraft on distress history. To account for time varying trends that influence aircraft retirement decisions (for example, fuel costs, and economic conditions) we include fixed effects for the year in which the aircraft was retired. We also control for aircraft specific characteristics by including fixed effects for aircraft type, and engine stage category.³² Controlling for these variations in aircraft life, our results in column (1) indicate that aircraft sold by distressed airlines have roughly 2 years lower lifespan, similar to our hazard rate analysis.

³¹We discuss the details of calculating life expectancy in Appendix C.

³²Engine stage categorization refers to the engine noise output.

4 Empirical Methodology and Results

In this section, we begin by quantifying the raw fire sale discount. As we have discussed, a crucial challenge in calculating the fire sale discount is that it subsumes a quality discount. It assumes that aircraft with the same characteristics also have the same maintenance and quality levels. To address this challenge, we describe our empirical methodology for measuring these quality variations between aircraft, and investigate their impact on the fire sale discount. We control for quality in the pricing model, and present the quality-adjusted fire sale discounts for different intensities of financial distress. We find that adjusting for the differences in quality leads to a significant reduction in the raw fire sale discount, and accounts for the economically large differences in raw fire sale discounts between Chapter 7 and Chapter 11 sales.

4.1 Raw Fire Sale Discount

The price of an aircraft i sold at time t , is specified as:

$$\log(\text{Price})_{it} = \alpha_k + \alpha_{bt} + \alpha_n + \alpha_j + \beta Q_{it} + \gamma \text{Distress}_{it} + \epsilon_{it} \quad (2)$$

Where, k is the aircraft model, b is the aircraft size (narrow or wide body), n is the engine noise categorization, and j is the seller of aircraft i . Fixed effects for aircraft model (α_k) control for the time in-varying characteristics of the aircraft model, and the market liquidity associated with the different models of aircraft. Fixed effects for aircraft size \times transaction calendar-quarter (α_{bt}) separately control for the time varying demand and liquidity factors associated with narrow bodied and wide bodied aircraft. Engine noise category fixed effects (α_n) control for the noise stage of the aircraft engines.³³ Including seller fixed effects (α_j) allows us to isolate the effect of bankruptcy on prices from the firm specific effects.³⁴

After controlling for the market liquidity for a given type of an aircraft, the variable Distress_{it} measures the forced sale discount resulting from its sale by a distressed airline. The variable Q_{it} , measures time varying aircraft specific quality component such as the age, and maintenance condition of the aircraft. Previous literature on the measurement of fire sale discount has only focussed on the observable dimensions of quality, for example, Pulvino (1998, 1999) measures the quality of an aircraft using its age. While, age is an appropriate measure of quality for aircraft sold by non-distressed airlines, our analysis in the previous section shows that

³³A stricter specification might allow for aircraft model \times time (α_{kt}) fixed effects to control for time varying market liquidity of different models of aircraft. However, the frequency of transactions in second-hand aircraft markets allow us to only control for a broader classification of aircraft size \times time (size being grouped into narrow and wide bodied). This is consistent with Pulvino (1998, 1999).

³⁴Seller fixed effects control for whether the sale was made by a major U.S. airline, a financial intermediary, or other parties (including cargo companies and international airlines). Including them ensures that our results on fire sale discount are not driven by cross-industry or cross-country effects. This is consistent with Pulvino (1999), and, our main results are robust to not including seller fixed effects.

the quality of aircraft sold by a distressed airlines is lower than other aircraft of similar age and type. The maintenance condition of an aircraft is an omitted variable that is negatively correlated with the distress of the seller. Therefore, these unobservable quality variations between aircraft result in overestimation of the true forced sale discount associated with distressed sales (γ). Our paper aims to resolve this bias in the measurement of the fire sale discount literature.

4.2 Measuring the quality variation between aircraft

In this subsection we outline our methodology for isolating the quality discount from the raw fire sale discount, by modelling the quality variations between aircraft sold by distressed and non-distressed airlines. The quality of an aircraft sold by non-distressed airlines is simply modelled as a function of its age at sale (Age_{it}). While, the lower quality of aircraft exposed to distress implies that such aircraft are effectively older than non-distressed aircraft. For example, the flying hours of aircraft depreciate with age, and a 15 year old distressed aircraft is flown less than a similar 15 year old non-distressed aircraft. This would imply that the distressed aircraft is effectively older than 15 years, and is instead being utilized as a 17 or 18 year old aircraft. Thereby, the overall quality of an aircraft (Q_{it}) is a function of its *effective* age (\tilde{Age}_{it}).

$$\tilde{Age}_{it} = Age_{it} + \delta Distress_{it}$$

The above equation specifies that aircraft exposed to distress are effectively older than non-distressed aircraft by δ years. The quality of an aircraft, is modelled as: $Q_{it} = \Phi(\tilde{Age}_{it})$. Where, the function Φ , measuring the quality of an aircraft is monotonically decreasing in its effective age.

Substituting for quality in the price equation 2 yields:

$$\log(Price)_{it} = \alpha_k + \alpha_{bt} + \alpha_n + \alpha_j + \beta \Phi(Age_{it} + \delta Distress_{it}) + \gamma Distress_{it} + \epsilon_{it} \quad (3)$$

We calibrate δ using two different measures of aircraft quality: i) flying hours post sale and ii) its expected retirement age. More specifically, assuming that the quality (Q_{it}) of an aircraft is a function of its effective age, we can recover δ by regressing:

$$Q_{it} = \phi_0 + \phi_1 Age_{it} + \phi_2 Distress_{it} + \phi_k + \phi_{lt} + e_{it} \quad (4)$$

Where, the dependent variable Q_{it} , is a measure of the aircraft's remaining life or remaining flying hours. k is the aircraft model, and l is the operator or user of the aircraft i in year t . Fixed effects for aircraft

characteristics allow us to isolate the impact of distress on the performance of an aircraft. The quality of an aircraft (Q_{it}) is measured using its expected future flying hours. When we use annual flying hours as the dependent variable, we include fixed effects for aircraft type (ϕ_k), and aircraft operator \times year (ϕ_{lt}).³⁵ Using annual flying hours as a quality measure allows us to control for operator \times year fixed effects, thereby, isolating the quality of an aircraft from the quality of its operator. This control allows us to separate the quality channel from the operator effect channel (that we discuss in the next section). Therefore, by controlling for post sale aircraft allocation, this specification provides a sharp measure of the variation in flying hours resulting from the distress of their sellers.

As a robustness check, we also use remaining life as the dependent variable, and include controls for the type (ϕ_k), and retirement year of the aircraft. This allows us to compare the life expectancy differentials between aircraft of the same type, sold by distressed and non-distressed airlines. As the remaining life of an aircraft is an aggregate variable (Q_i), we are not able to control for operator fixed effects in its measurement, because the aircraft is operated by several users during its lifetime.

In Appendix D we solve for the true model. To operationalize the method, we substitute the predicted quality (\hat{Q}_{it}) from equation 4, in the price regression.

$$\log(\text{Price})_{it} = \lambda_k + \lambda_{bt} + \lambda_n + \lambda_j + \lambda_1 \hat{Q}_{it} + \lambda_2 \text{Distress}_{it} + \mu_{it} \quad (5)$$

It can be shown that the quality adjusted fire sale discount, $\gamma = \lambda_2$. By accounting for the predicted quality variations between aircraft at the time of their sale allows us to isolate the true forced sale discount associated with distressed sales.³⁶

4.3 Quality-adjusted fire sale discount

In this subsection, we will discuss our empirical estimates of the quality adjusted fire sale discount using aircraft transaction prices data. We report the raw fire sale discount in columns (1) and (2) of Table 4 Panel A. Using the regression in equation 2, we regress the price of an aircraft on its observable characteristics (including fixed effects for aircraft model, size \times year quarter, engine noise category), age at sale, and incidence of distress of its seller. We find that the raw fire sale discount on distressed aircraft sales is 17.4% in column (1). Also a 1 year increase in age at sale reduces the average price of an aircraft by 3%. Further, in comparison with the sales made to airlines, the sales to financial institutions, mainly leasing companies, occur at an average price

³⁵Our main results are robust to using aircraft type \times operator \times year fixed effects.

³⁶Pulvino (1998, 1999) uses a 2 stage procedure to estimate the fire sale discount. His methodology assumes that distress is not correlated with any of the observable characteristics that are used to calculate the aircraft's hedonic price in the first stage. As we have established that distress is correlated with an important determinant of aircraft price (i.e. its maintenance condition/quality), we estimate the quality adjusted fire sale discount in a single stage regression (using equation 5).

discount of around 5% (in column (2)). In Appendix E, to make an exact comparison with Pulvino (1998), we estimate the raw fire sale discounts following his two stage procedure, and find 16% fire sale discount on distressed aircraft sales.

In Panel A of Table 4 columns (3)-(6) we report the quality-adjusted fire sale discounts by controlling for the quality variations between aircraft sold by distressed and healthy airlines using equation 5. Our first measure of quality ($Quality_1$) is the predicted future flying hours of the aircraft. In columns (3) and (4) of Table 4, we regress the price of an aircraft on its characteristics, predicted flying hours, and incidence of distress of its seller. The price of an aircraft increases significantly with the predicted flying hours, and after controlling for it the quality adjusted fire sale discount is 8%. Similarly in columns (5) and (6), we control for the life expectancy of the aircraft, that reduces the quality adjusted fire sale discount to around 9%. We find that there is a 9.4 percentage points reduction in the raw fire sale discount upon controlling for the lower quality of aircraft sold by distressed airlines (comparing column (4) with column (2)). This difference, that is the quality discount, is statistically significant at the 1% level.³⁷ Quality impairment explains roughly 50% of the raw fire sale discount and, after controlling for these quality variations the fire sale discount declines to 8-9% for the sale of aircraft by distressed airlines. Also, we find that in comparison with the purchases made by other airlines, financial institutions and leasing companies (*Financial Buyer* dummy) purchase aircraft at a significant 5% discount (column (6)). It should be noted that this discount on aircraft purchases by financial buyers is applicable to both distressed and non-distressed sales; an issue we return to in section 7.

We also estimate how the quality adjustment impacts fire sale discounts for different degrees of distress. In Panel B of Table 4, we separate the *distress* sales into *Chapter 7*, *Chapter 11*, and *Pre-Filing (in distress)* sales. As expected, the raw fire sale discount on Chapter 7 sales of 29%, is higher than the discount of 20% on Chapter 11 sales (column (2)).³⁸ Comparing columns (2) and (4), we find that the raw fire sale discount reduces by around 14 percentage points (or 50%) for Chapter 7 sales and, by about 7 percentage points (35%) for Chapter 11 sales, reflecting the quality adjustment. The large difference in the quality adjustment between Chapter 7 and 11, reflects both the lower life expectancy of aircraft sold in Chapter 7, and their substantially lower productivity i.e. lower flying hours, for their remaining lives after the sale; see Table 3 above. For sales made by an airline during the distress period prior to filing for bankruptcy, the raw fire sale discount reduces by around 3.8 percentage points (30%) after controlling for quality (column (2) versus (4)). The fire sale discount after controlling for quality is not significantly different for aircraft sold by airlines operating under Chapter 7 liquidation or Chapter 11 reorganization, around 15.3% and 13.1%, respectively. The quality-adjusted fire sale discount is similar for aircraft sold in the distress period prior to entering bankruptcy, and for airlines operating

³⁷p-value for the coefficient equality test on the *Distress* variable between columns (1) and (3), (and (1) and (5)) is 0.0000.

³⁸This difference is not statistically significant at the 10% level. In column (1), the p-value for testing the null hypothesis $H_0 : Chapter7 = Chapter11$ is 0.2692, while the p-value for testing the null hypothesis $H_0 : Chapter7 = Chapter11 = PreFiling$ is 0.0650.

under Chapter 11.³⁹ The quality impairment on aircraft increases with the depth of distress, as proxied by the length of distress period prior to filing for bankruptcy; an issue we examine in section 6. It is worth noting that the going concern provisions of Chapter 11, when compared with the liquidation process conducted by a trustee in Chapter 7, seem to have made only a small economic difference to the quality-adjusted fire sale discount, and this difference is not statistically significant.⁴⁰

In summary, our results have established that quality impairment is a significant part of the raw fire sale discount, an issue that has not been adequately addressed in the literature. By controlling for quality in the hedonic regression model, we can conclude that around half of the raw liquidation discount can be attributed to financially distressed airlines selling low quality aircraft.⁴¹ The remaining half can be attributed to the fire sale discount. Crucially, the quality adjustment for aircraft sold by distressed airlines is attributable to the lower productivity of the asset and its under-maintenance, and not to the attributes of the purchaser. The productivity of these aircraft is lower than the other aircraft operated by the non-distressed purchaser that have not been exposed to distress. In Table 6 we summarize the fire sale discounts for different definitions of financial distress. Interestingly, we find that after controlling for quality, financially distressed airlines sell aircraft at around 8% fire sale discounts. In magnitude, this is similar to the fire sale discounts reported in the financial assets literature by Coval and Stafford (2007) and Mitchell and Pulvino (2012) among others.⁴² Finally, the quality adjusted fire sale discounts are only marginally larger in Chapter 7 than in Chapter 11, and this difference is not statistically significant. In contrast, Pulvino (1999) reports average fire sale discounts of 22% for Chapter 11 sales, and 32% for Chapter 7 sales, the differences are economically large, although statistically not significant. Our results suggest that there are no economically meaningful differences between the two samples.

³⁹In column (4), the p-value for testing the null hypothesis $H_0 : Chapter7 = Chapter11$ is 0.6455, while the p-value for testing the null hypothesis $H_0 : Chapter7 = Chapter11 = PreFiling$ is 0.5323.

⁴⁰In contrast, Bris et al. (2006) find that the Chapter 7 process destroys value compared with the Chapter 11 process. The low cost of Chapter 7 in our sample might be attributable to the short period aircraft spend in Chapter 7, 2.8 months, compared with the 2 years spent in Chapter 7 in the Bris et al. (2006) sample.

⁴¹Our quality adjustment measures quality based on the operational characteristics of the aircraft like utilization and life expectancy. However, anecdotal evidence suggests that there can be significant differences in the interior furnishing of aircraft operated by different airlines. Aircraft owned by distressed airlines might have lower quality furnishing as opposed to aircraft operated by healthy airlines. This reflects another dimension of quality that our measure is unable to capture. However, we expect it to be correlated with our measures of operational quality, i.e. it is likely that the internal quality of an aircraft is positively correlated with the financial health of the selling airline. Nevertheless, the quality-adjusted fire sale discount which we calculate might still overestimate the actual fire sale discount.

⁴²Coval and Stafford (2007) document 8-10% discount in equity markets owing to fire sales in mutual funds. Mitchell and Pulvino (2012) document that corporate securities were mispriced at 10% discount during 2008 crisis. Ellul et al. (2011) document 7% discount in corporate bonds from fire sales caused by regulatory pressure on insurance companies.

5 Evidence on Aircraft Misallocation

In this section, we investigate the extent to which this quality-adjusted fire sale discount is attributable to the pure liquidity channel, and the misallocation channel. The liquidity channel represents a transfer from the seller to the buyer as a consequence of the lower bargaining power of the distressed seller, and as such this channel does not have any ex-post welfare implications, in contrast, to the misallocation channel.⁴³ To distinguish between the two effects, we compare the average productivity of the post-sale users of distress-affected aircraft with other users of aircraft purchased from non-distressed sellers. We also compare the average productivity of the post-sale users of distress-affected aircraft with the average productivity of the sellers of these aircraft. We address the question whether aircraft sold by distressed airlines are misallocated to suboptimal users. [Shleifer and Vishny \(1992\)](#) argue that this is an alternate, or additional, channel that could generate a fire sale discount and, the inefficiencies associated with it. Our granular data of aircraft productivity coupled with aircraft level ownership data allows us to empirically isolate this channel, and directly address whether it is present in the airlines industry.⁴⁴

An alternative conjecture is that bankruptcy and distress in the airlines industry are the means by which the industry restructures and reallocates resources to more productive users. To distinguish these two effects, whether forced sales of aircraft lead to misallocation to suboptimal users, or such sales are simply a mechanism for transferring resources, we begin by identifying the operators and status of aircraft post their sale. Stringent aircraft registration requirements allow us to track airline level fleet alterations. This micro tracking of each aircraft at its operator level allows us to consistently trace aircraft redeployment. In case the aircraft is sold to a leasing company or a financial buyer we are able to match the aircraft in the year of sale with its user (i.e. the lessee), using our aircraft-level operator database.⁴⁵ Using this methodology, the transacted aircraft are matched to their post-sale operators.

Following [Gavazza \(2011a\)](#) and [Bernstein et al. \(2019\)](#), we measure asset allocation and utilization at the aircraft level using statistics on parking and flying hours. Parking indicates that an aircraft is inactive and involves costly downtime. We find that aircraft sold by distressed airlines do not have a higher probability of being parked post sale. At the end of the same year as the sale, 24 of the 164 (14.6%) aircraft sold by distressed airlines are parked by their new users, as opposed to 162 of the 1,134 (14.3%) aircraft sold by non-distressed sellers. By the end of the second year following the sale, 3% of the aircraft sold by distressed airlines are parked, versus 6% of the aircraft sold by non-distressed operators. We find no evidence of misallocation even at the extreme level of distress, i.e. aircraft sold by bankrupt airlines do not have a higher probability of

⁴³Notwithstanding, there may still be ex-ante welfare losses associated with the liquidity channel.

⁴⁴[Shleifer and Vishny \(1992\)](#) were referring to fire sales in the absence of Chapter 11 type procedures. It maybe that in the absence of such procedures the fire sale discounts would be much larger.

⁴⁵For example, 76% of the distressed sales were directly made to the final user, and 24% were sold to leasing companies.

being parked post sale.⁴⁶ This suggests that most aircraft sold by distressed airlines are quickly redeployed to operational use. In the analysis that follows, we develop several measures to compare aircraft redeployment on the basis of a comparison between post-sale users of distressed aircraft with those users of non-distressed aircraft.

5.1 Measures of user productivity using flying hours

To measure the intensity of economic activity for an airline we use the aircraft flying hours of its fleet. Aircraft flying hours have been used extensively to measure productivity (Gavazza (2011a,b), Benmelech and Bergman (2011) and Bian (2020)). They are considered as a key performance indicator in the airline industry. An advantage of using operational metrics like flying hours, rather than other performance measures such as load factor or profitability is the wide availability and extreme accuracy of these data, due to maintenance and safety considerations. In contrast, the measures of financial performance are mostly available only for large, listed airlines. Nevertheless, in the next subsection we will also use financial measures to ascertain the robustness of our analysis.

Using aircraft flying hours aggregated at the airline level, we compare the productivity of the user of the aircraft to other airlines in the industry. We restrict our sample to aircraft flown by US operators post their sale.⁴⁷ We construct the following measures of aircraft operators' productivity. The first measure is the average flying hours of the operator across all the aircraft that are flown by that operator. We also control for differences in aircraft flying hours owing to aircraft type, aircraft age, and other macro trends in aircraft productivity. More specifically, we regress, for plane i flown by operator j in year t :

$$\log(Hours)_{ijt} = \beta_t + \beta_{Type \times Age} + \epsilon_{ijt} \quad (6)$$

where, $\log(Hours)_{ijt}$ measures the yearly flying hours of an aircraft i , flown by operator j , in year t . From the above regression we calculate the residuals (ϵ_{ijt}), after effectively partialling out aircraft specific factors ($\beta_{Type \times Age}$), and year specific trends (β_t) in aircraft productivity. The unexplained differences in flying hours of the above regression capture the productivity of the operator. Our second measure averages these residuals across all the aircraft that are flown by the operator j . Our final measure of productivity also controls for aircraft usage, and market thinness of the aircraft.⁴⁸ Post sale, both in the case of distressed and non-distressed

⁴⁶At the end of the same year as the sale, 15 of the 131 (11%) aircraft sold by bankrupt airlines are parked with their new users. By the end of the next year following the sale, only 3 (or 2%) of the aircraft sold by bankrupt airlines are parked.

⁴⁷Post sale, 155 of the 164 (95%) aircraft sold by distressed operators are flown by US operators. Post sale, 126 of the 131 (97%) aircraft sold by bankrupt operators are flown by US operators. In 78% of sales by non-distressed owners, the aircraft are used by US operators post sale.

⁴⁸Market thinness is measured by the number of same type of aircraft in operation, and the fleet size of the operator. The same measures of market thinness have been used in Table 3.

aircraft sales, 82% of the aircraft are used as passenger aircraft, while the rest are used by cargo airlines.⁴⁹ After adding these controls to the previous regression we calculate the residuals. This measure of productivity averages these residuals over all the aircraft operated by the same operator.

Panel A of Table 7 compares these measures for post-sale operators of aircraft sold by distressed airlines with the operators of aircraft purchased from non-distressed sellers. This allows us to test directly the misallocation hypothesis for the sample of aircraft for which we have calculated the quality-adjusted fire sale discount. We find that there is no significant difference in the means of average flying hours of the two groups. The log average flying hours of post-sale users of aircraft sold by distressed airlines is 7.4, which is identical to the log average flying hours of post-sale users of other aircraft sold in non-distress transactions. Even after controlling for aircraft specific features, aircraft usage, and time trends in productivity, the residuals for the two groups are similar. In Panel B, we repeat our tests of misallocation by restricting our sample to NBER recession periods. We continue to find that the users of the distress-affected aircraft are at least as productive as the users of non-distressed aircraft. Figure 2 plots the kernel density for operator productivity residuals, after controlling for aircraft type \times age, aircraft usage, year, and market thinness. The distributions of residuals for post-sale users of the distressed and non-distressed sales further confirm that the users of the distress-affected aircraft are not on average less productive than other airlines in the industry.⁵⁰

An alternate test of the misallocation hypothesis is based on whether the aircraft sold by distressed airlines are allocated to operators that are less productive than their sellers. The presence of misallocation, as proposed by Shleifer and Vishny (1992) would imply that assets sold in fire sales get allocated to less productive buyers, and thereby, the productivity of the buyer (or user) is lower than that of the seller. Conversely, the reallocation of aircraft to more productive users in the economy, would imply that the buyer is operationally more efficient than the seller. In our sample, we test these hypotheses empirically by comparing the differential productivity across the buyer and seller of the asset. Using the previously defined measures of productivity, we calculate the productivity of the buyer and the seller of the aircraft using our transactions data ending in 1991. We do this by averaging the residuals (ϵ_{ijt}) obtained from Equation 6 across all the aircraft flown by the same operator.⁵¹ Next we calculate δ , as the difference between the buyer and the seller productivity. δ is positive if the productivity of the buyer (or user) is higher than that of the seller. Figure 3 plots δ for aircraft sold by distressed airlines (blue curve), and for aircraft sold during other transactions (red curve). As δ is positive in the majority of the sales made by distressed operators, we can conclude that post their sale, these aircraft are

⁴⁹Both in the case of distressed and non-distressed aircraft sales, the average age at sale of the 18% aircraft that are used by cargo companies is 16 years.

⁵⁰The standard Kolmogorov-Smirnov test of the equality of distributions rejects the null hypothesis of equal distributions at the 1 percent level (the asymptotic p-value is equal to 0.004).

⁵¹The residuals are calculated by regressing aircraft flying hours on controls for aircraft type \times age, usage, year, fleet size, and the number of same type of aircraft operating in the market.

operated by users that are more productive than the seller. This is consistent with the finding that markets for used capital reallocate assets from less productive to more productive firms (Maksimovic and Phillips (2001)).

5.2 Efficient relocation of aircraft in distress

We now use our data on flying hours for the entire sample period (1975 to 2015) to test whether aircraft are relocated to higher productivity users following distress episodes. In Table 8, we specify the dummy variable *Distressed Transaction*, that equals 1 for all aircraft that are operated by the distressed seller and the buyer of these aircraft in the year of aircraft sale. *Buyer × Distressed Transaction* equals 1 for all aircraft operated by the buyer in the year it purchases an aircraft from a distressed seller. In a given year, for all aircraft operated by the carrier, *Buyer × Non-Distressed Transaction* equals 1 if the carrier purchases an aircraft from a non-distressed seller. Controlling for aircraft type \times age, usage, and year fixed effects, this specification allows us to extract and compare the operator-level time varying productivity of the sellers and buyers of distressed aircraft. In Table 8, column (1) we report that on average the distressed sellers are 8% less productive than the industry average, and 12% less productive than the buyers of these aircraft. These differences are statistically significant at the 1% level. In the same specification we can also compare the productivity of buyers of distressed aircraft with other buyers in the second-hand aircraft market. The productivity of buyers of distressed aircraft is about 4% higher than the industry average, and almost the same as the productivity of other buyers in the second-hand aircraft market.⁵² In column (2) we find almost identical results after including additional controls for market thinness, indicating that these differences are unlikely to be explained away by the liquidity of an aircraft type.

While we find no direct evidence of misallocation to low productivity users following aircraft fire sales, a potential concern is that aircraft with airlines emerging from Chapter 11 as a going concern are not being transacted because of the expectation of a high fire sale discount. In this case, it could be construed that the aircraft that *remain* with a distressed operator are being misallocated. We test this hypothesis by measuring the productivity of aircraft that are not transacted, but are retained by airlines that file for Chapter 11 and subsequently emerge as going concerns.

In Table 8 columns (3) and (4), we split the distressed airlines into two groups, those that were finally liquidated in Chapter 7, and those that emerged from Chapter 11 as going concerns. We define the variable *Finally Liquidated: Transactions*, that equals 1 for all the aircraft that are operated by a distressed seller that was finally liquidated in Chapter 7, and the buyer of these aircraft in the year of aircraft sale. For aircraft that

⁵²The productivity of buyers of distressed aircraft compared with the industry average is computed as $12.3\% - 8.1\% = 4.2\%$. This difference is significant at the 1% level. The productivity of buyers of distressed aircraft compared with the productivity of other buyers in the second-hand aircraft market is $12.3\% - 8.1\% - 2.9\% = 1.3\%$. This difference is not significant at the 10% level.

Survived Bankruptcy, we split their productivity into 3 periods: (i) pre-bankruptcy filing while in distress, (ii) while operating under Chapter 11 protection, and (iii) in the year the airline emerges as a going concern. This specification allows us to measure and compare the productivity of aircraft over the cycle of distress that were retained by airlines that survived Chapter 11 with those that were liquidated. In column (3), we report that the productivity of airlines that were finally liquidated in Chapter 7 is 13% lower than the industry average, and 18% lower than the buyers of its aircraft. We also find that the productivity of airlines that survived Chapter 11 is 7% lower than the industry average while they are in distress pre-filing. Their productivity is only marginally lower (2%) while they are operating under Chapter 11 protection. More importantly, their productivity is around 12% higher than the industry average after they emerge from bankruptcy. In column (4), we find almost identical results after controlling for market thinness. This indicates that the aircraft that were retained by airlines that survived bankruptcy were not misallocated, and rather perform better than other similar aircraft in the industry. Our findings are consistent with [Eckbo and Thorburn \(2003, 2008\)](#), who report that restructured firms have a post-bankruptcy operating performance on a par with those of non-bankrupt industry rivals.

One explanation for the improving productivity of aircraft owned by airlines emerging from Chapter 11 is that the bankruptcy code allows the bankrupt company to reject contracts (i.e. de-contract) that were made prior to filing for distress. Such contracts typically include labor contracts and lease agreements. Such de-contracting has the potential to improve a company's cost base and its competitive position vis a vis other airlines. [Shleifer and Summers \(1988\)](#) argued that hostile takeovers in industries such as aviation, were based upon these de-contracting provisions, designed to lower operating costs by rejecting existing labor contracts. Other forms of de-contracting are documented by [Benmelech and Bergman \(2008\)](#) who find that airlines in bankruptcy return unwanted aircraft to lessors or renegotiate the terms of the leases with reductions in some cases exceeding 30% of the present value of the lease contracts. The plan of reorganization filed in 2005 under Chapter 11 of Northwestern Airlines, reveals that the airline returned 71 unwanted aircraft out of 330 leased aircraft to the lessor, and restructured the leasing terms on another 90 aircraft. The company reported that as a result they eliminated \$2.5 billion of its \$9.8 billion debt and leasing obligations. [Ciliberto and Schenone \(2012\)](#) study the channel whereby airlines improve productivity during bankruptcy, using micro level data at the aircraft and route level. They find that bankrupt airlines surrender around 25% of their routes, reduce by 26% the number of markets they serve out of airports, and lower flight frequency. They find that the savings initiated in Chapter 11 are continued after emergence from bankruptcy. The implication is that the process of de-contracting in Chapter 11 is having a cleansing effect on the economic efficiency of bankrupt companies.⁵³

⁵³[Shleifer and Summers \(1988\)](#) have provided a contrary argument that such de-contracting might destroy implicit contracts between the parties, for example, the company and its employees, and as a result constitute a breach of trust.

It can be argued that all of our airlines, by filing for bankruptcy, were economically distressed. However, the misallocation hypothesis, as described by [Shleifer and Vishny \(1992\)](#), is largely about financial distress, that is firms facing a crisis of liquidity are forced to downsize their fleet to meet their liquidity needs. In that respect, the sample so far analysed cannot easily be described as a sample of financially distressed firms. To meet this challenge we have collected a separate sample of airlines that were distressed, but did not enter formal bankruptcy procedures. Our proxy for identifying financial constraints is whether the airline engaged in a distressed exchange. Such firms exchange securities with a subset of their claimholders, usually bondholders, which are frequently accompanied by some form of haircut, as described by [Franks and Torous \(1994\)](#). In columns (5) and (6) of [Table 8](#), we analyse 4 financially constrained airlines that engaged in distressed exchanges over the period 1975-2015, and sold 64 aircraft, or roughly 10% of their fleet during the distress period immediately prior to the exchange, where the onset of distress is indicated by a rating downgrade to sub-investment grade.⁵⁴ None of these airlines filed for bankruptcy within 5 years of the distressed exchange.

To test the misallocation hypothesis, we compare the productivity differences between the sellers and buyers of aircraft sold by financially constrained firms. We specify the dummy variable *Financially Constrained Transaction*, that equals 1 for all aircraft that are operated by the 4 financially constrained airlines and the buyers of these aircraft in the year of aircraft sale. $Buyer \times Financially\ Constrained\ Transaction$ equals 1 for all aircraft operated by the buyer in the year it purchases an aircraft from a financially constrained airline. In a given year, for all aircraft operated by the buyer, $Buyer \times Other\ Transaction$ equals 1 if the carrier purchases an aircraft from a non-distressed or non-constrained seller. In column (5) we report that on average the financially constrained sellers are 1.6% less productive than the industry average, and 3.8% less productive than the buyers of these aircraft. These differences are not statistically significant. In column (6) we find almost identical results after including additional controls for market thinness. Our results indicate that aircraft sold by financially constrained airlines are not misallocated.

Reallocation of aircraft to more productive users would suggest that the airlines buying the distressed aircraft would be able to grow and use modern technology at the cost of their less productive competitors ([Hsieh and Klenow \(2009\)](#), [Bartelsman et al. \(2013\)](#), [Bian \(2020\)](#)). To further test this hypothesis we measure whether there is a differential impact of productivity on firms' growth prospects when firms purchase distress-affected aircraft, versus when firms purchase other aircraft not exposed to distress. In [Appendix Table A.7](#), we find no significant differences between the sensitivity of productivity to firms' growth prospects for post-sale users of distress-affected aircraft versus post-sale users of non-distressed aircraft.⁵⁵

⁵⁴Another 4 airlines made distressed exchanges, but did not sell any aircraft in distress.

⁵⁵[Table A.7](#) is described in detail in [Appendix F](#)

We also use financial variables of the airlines as evidence for whether there is resource misallocation in the airlines industry. Our analysis in Appendix F and Figure 4, allows us to conclude that operators of distress-affected aircraft do not perform worse than other operators using measures of Tobin's Q, marginal product of capital, and profitability. The evidence presented in this section illustrates that the resource misallocation channel does not appear to operate in the airlines industry. On all measures of productivity and financial indicators, the post-sale users of distress-affected aircraft perform just as well as post-sale users of aircraft not sold in distress.

6 How do bankruptcy procedures affect fire sale discounts?

6.1 How under-maintenance varies with the intensity of distress

In this subsection we explore whether the size of the under-maintenance effect is related to the intensity of distress, proxied by the period in distress. For an airline we define the onset of distress using the event of a bond downgrade (to sub investment grade status) prior to the airline filing for Chapter 11 bankruptcy. The end of the distress period is defined as the date when the aircraft is sold. In the event that an airline's bonds are not rated, we use the year of earnings losses prior to filing for bankruptcy as a proxy for the onset of distress. 73% of aircraft sold in distress were sold by airlines that experienced a bond rating downgrade prior to filing; the remaining aircraft were sold by airlines that did not have bond ratings. We find a sharp difference in the average time spent in distress for aircraft sold in Chapter 11 compared with those sold in Chapter 7, 2 years versus 3.9 years, respectively. Since all airlines filing for Chapter 7 had previously entered Chapter 11, we use the common filing date to determine the length of the distress period pre-filing. For Chapter 11 sales the distress period prior to filing is 1.2 years, and 1.9 years for Chapter 7 sales. We would predict that aircraft sold in Chapter 7 are more under maintained than those sold in Chapter 11 because they have been subject to a longer period of distress.

In Table 9 columns (1) and (2) we show that every year spent in distress reduces the future productivity of an aircraft by around 3%, and the coefficient is statistically significant at the 1 percent level in both specifications. This finding is further confirmation that aircraft sold by distressed airlines are significantly under maintained, and this under maintenance effect increases with the time spent in distress. In columns (3) and (4) we further show that the period of distress, both for Chapter 11 and Chapter 7, is negatively correlated with future flying hours. The coefficient for the two Chapters is the same, indicating that the annual decline in productivity (i.e. the depreciation rate) is virtually identical. However, given the longer period in distress for aircraft sold in Chapter 7 the accumulated under maintenance effect will be around 13% ($3.9 \times 3.3\%$), and for aircraft sold

in Chapter 11 it will be 6% ($2 \times 3\%$). These coefficients are similar to the under-maintenance effects reported in Table 3. It appears that much of the under maintenance comes from the period prior to filing, since in columns (5) and (6), the period after bankruptcy filing is not significantly correlated with future flying hours. The annual depreciation rate for the distress period pre filing is substantially higher than that for the period post filing, 4.9% versus 1.1%. This result may reflect the provisions in Chapter 11 and Chapter 7 that increase the cashflows of the bankrupt firm by allowing for the suspension of most payments of interest and capital repayments, and in Chapter 11 for the additional provision of DIP financing.⁵⁶

6.2 Fire Sale Discount in Business Cycles

In this section, we explore the interaction of aircraft under-maintenance and misallocation with business cycles. We start by documenting the quality adjusted fire sale discount during recessions, using the methodology from section 4. We classify recessions based on NBER business cycles dating.⁵⁷ In Table 10 Panel A column (2), we report that distressed aircraft sold during recessions have an additional raw fire sale discount of 18%. This could be driven by greater under-maintenance of aircraft, higher costs of liquidity, or poor allocation of aircraft to other users during recessions. In columns (3)-(6), we calculate the quality adjusted fire sale discounts, using quality measures developed in section 4. We find that the additional fire sale discount for distressed aircraft sold during recessions reduces to almost 11-13% (in columns (4) and (6)) once we control for the differential quality of aircraft sold during recessions. The quality adjustment is around 7% higher during recessions, accounting for 40% of the increase in the raw fire sale discount.

In Table 10 Panel B, we further investigate the quality impairment channel during recessions. In a specification similar to Table 2, we use data on cumulative aircraft flying hours for the aircraft that are retired from service, to test whether there is a significant difference in the total flying hours of the aircraft sold by distressed airlines during recessions. The variable *Distress* equals 1 if the aircraft was at any time exposed to a distress event, and equals 0 otherwise. *Recessions* equals 1 for the aircraft that were transacted during recessions, *Distress* \times *Recession* equals 1 for aircraft that were sold by distressed airlines during recessions.⁵⁸ In Table 10 Panel B, column (2) we report that aircraft sold by distressed airlines during recessions fly 8.7% less compared with other similar aircraft sold by distressed airlines (not sold during recessions). This further supports our evidence of distressed airlines selling lower quality aircraft during recessions.

⁵⁶Aircraft spend on average only 2.8 months in Chapter 7 prior to sale.

⁵⁷During our transactions sample period of 1978-1991, based on NBER business cycle dating, we classify 1980, 1982-1983, and 1990-1991 as recession periods. These match closely with the airline industry recession periods identified by Pulvino (1998) using an index of second-hand aircraft prices.

⁵⁸The variable $Age - \overline{Age}$ (*at distress*) measures the difference between the age at distress (*Age*) and the average age at distress (\overline{Age}) for aircraft sold by distressed airlines.

In Table 10 Panel C, we test if distressed aircraft sold during recessions are misallocated to worse quality buyers. In a triple difference setting similar to Table 8, we investigate the misallocation during recessions. The dependent variable measures the average productivity of the buyer and the seller of the aircraft for which we have the transaction prices (transacted during 1978-1991). We specify the dummy variable *Distressed Transaction*, that equals 1 for the distressed seller and the buyer of these aircraft. *Buyer* equals 1 for the buyers of second-hand aircraft. *Distressed Transaction* \times *Buyer* equals 1 for the buyer that purchases an aircraft from a distressed seller. If the distressed aircraft is sold in a recession, *Distressed Transaction* \times *Recession* equals 1 for the distressed seller and the buyer of these aircraft. *Buyer* \times *Recession* equals 1 if the carrier purchases a second-hand aircraft in recessions. Our main variable of interest, *Distressed Transaction* \times *Buyer* \times *Recession* equals 1 for the buyer if it purchases an aircraft from a distressed seller during recessions. In Table 10 Panel C, column (1) we report that an average buyer of distressed aircraft is 12.6% more productive than its seller (*Distressed Transaction* \times *Buyer*). We find that the coefficient on the interaction term of *Distressed Transaction* \times *Buyer* \times *Recession* is positive and significant indicating that distressed aircraft do not seem to be misallocated to lower productivity users during recessions. In columns (2) and (3), we establish that these results are robust to controlling for aircraft characteristics at sale, that might influence the kind of buyers that purchase these aircraft. In Appendix Table A.10, we use our complete sample of flying hours data from 1975-2015, to compare the productivity of the sellers and buyers of distressed aircraft during recessions, and show that distressed aircraft do not appear to be misallocated during recessions.

To summarize, consistent with Pulvino (1998), we find evidence that the raw fire sale discount for sales of distressed aircraft is 30% (or 18% higher) during recessions. After quality adjustment the fire sale discount is around 16% in recessions, compared with around 3-4% in non-recession periods.⁵⁹ Since we find no evidence of misallocation of distressed aircraft during recessions, we attribute the higher discount in recessions to the greater need for immediacy.⁶⁰

7 The Role of Financial Buyers in Aviation Industry

In this section, we explore the role played by leasing companies in improving the market efficiency of the airlines industry. The Airline Deregulation Act of 1978 increased competition, and made airline profits more volatile, thereby, requiring airlines to adjust their fleet more frequently. This need for flexibility, and increased trading of aircraft in the secondary market, led to the growth of intermediaries (leasing companies) that helped to match sellers and buyers of aircraft across geographies. According to an aircraft financing report by Boeing,

⁵⁹Pulvino (1998) reports that financially constrained airlines sell aircraft at 15% discount during recessions compared with industry booms.

⁶⁰One caveat is that we have not controlled for the possibility that industry distress maybe so severe that it effects the average prices of all second-hand aircraft transacted in recessions .

there are 153 leasing companies and, roughly 41% of the global fleet is leased.⁶¹ Shleifer and Vishny (1992) note that the financial innovation of operating leases and its rapid growth was a response to the high fire sale discount in the airline industry.

Aircraft leasing companies, however, have been an object of much discussion in the academic literature (Pulvino (1998), Gavazza (2010, 2011a), Gilligan (2004), Shleifer and Vishny (1992)) with differing perspectives on their efficiency roles. Pulvino (1998) considers leasing companies as low-valuation industry outsiders that are potentially sub-optimal users of aircraft, as opposed to other airline companies that are considered to be high-valuation buyers. He interprets the high discount associated with aircraft sales to financial buyers as evidence consistent with the misallocation of assets. However, leasing companies are not the final users of aircraft. They act as intermediaries and allocate the aircraft to other airline companies.

Following Gavazza (2011a), we use our granular data on aircraft utilization and ownership to document that leasing companies provide a valuable intermediary service in second-hand aircraft transactions by reducing the time it takes for an airline to sell an aircraft. We find that the probability of an aircraft being parked by the seller increases to 16.4% the year before the aircraft is sold to another airline (a non-financial buyer). This is much higher than the probability of an aircraft being parked in the year before its sale, when the aircraft is purchased by a leasing company (5.8%). This indicates that after the decision to sell an aircraft, the transaction period is longer in those cases where the sale is made to a non-financial buyer.

In Table 11, we formally test this by comparing the flying hours (if the aircraft is not parked) of an aircraft in the last year of its sale, with other aircraft that are not subject to sale. We report in column (1) that aircraft fly 9.5% less one year prior to sale compared with other aircraft that are not subject to sale. In columns (3) and (4), we control for operator fixed effects, and find that these aircraft fly around 16% less prior to sale, compared with other aircraft being operated by the *same* carrier that are not subject to sale. This under-utilization of aircraft is avoided in those cases where the purchaser is a leasing company. To examine this issue, in Table 11, we specify the productivity of an aircraft one year prior to sale, for the cases in which it is sold to a leasing company (*Pre-sale* \times *Financial Buyer*). We find that being purchased by a financial buyer reverses this under utilization effect, and these aircraft have almost the same flying hours as similar aircraft not subject to sale. These effects are even stronger in cases when the airlines selling the aircraft are distressed.⁶² We find that an airline that is distressed, flies its aircraft around 41% less than other non-distressed sellers (*Distressed aircraft pre-sale*). Further, we document that this under-utilization of aircraft prior to sale by distressed airlines, is greatly reduced when the sale is made to a financial buyer (*Distressed aircraft pre-sale* \times *Financial Buyer*). The results are similar when we control for operator fixed effects in columns (3) and (4).

⁶¹Refer to Current Aircraft Finance Market Outlook by Boeing (2019).

⁶²The probability of an aircraft being parked with a distressed seller the year before the aircraft is sold to a non-financial buyer is 20.7%. This probability reduces to 2.1% in cases the distressed aircraft is being purchased by a leasing company.

In summary, we document that leasing companies improve allocative efficiency by reducing the time it takes to sell an aircraft, and their involvement provides further efficiency gains when the seller is in distress.

We repeat our tests on misallocation based on the average flying hours of the user. Our results suggest that there is no difference in productivity of users, for distressed aircraft purchased by financial buyers versus those purchased by non-financial buyers.⁶³ We can therefore conclude that in our sample, we find no evidence of misallocation of aircraft following sales by distressed airlines to financial buyers. In contrast, we find that leasing companies significantly reduce the under-utilization of an aircraft in the hands of a distressed seller.

Another consideration is the price discount of 5-6% that is associated with a financial buyer purchasing an aircraft (Table 4 column (2)). As discussed earlier, this discount on purchases by financial buyers is also present when they purchase aircraft from non-distressed airlines.⁶⁴ We believe this discount should not be interpreted as a forced sale discount, but instead should be considered a convenience yield effect. By selling the aircraft to a leasing company, the airline unloads the costs of maintenance and parking and the uncertainty (risk) it would otherwise have to incur in a regular sale. Industry specialists and market participants consider these frictions an important fundamental characteristic of aircraft markets. For example, according to Lehman Brothers (1998, 82) (as quoted in Gavazza (2011a)), “The ratings agencies require an 18-month source of liquidity because this is the length of time they feel it will take to market and resell the aircraft in order to maximize value.” Calibrating a structural model for wide body aircraft, Gavazza (2011a) estimates the total transaction costs to be around 16% of the value of the aircraft.⁶⁵ Our price discount of around 6% for sales to financial buyers, in the combined sample of narrow and wide body aircraft transactions, is similar to these estimates.

The growing presence of leasing companies in the aviation industry can be construed as a Coasian response to the high market frictions and increased volatility in this industry (Shleifer and Vishny (1992)). Lessors, through their knowledge of secondary markets, their scale economies, and reach across geographies, operate as specialists facilitating the reallocation of aircraft to more productive operators.

⁶³The log average user flying hours is 7.46 for distressed aircraft purchased by financial buyers, versus 7.43 for distressed aircraft purchased by non-financial buyers. The difference in productivity of the users of distressed aircraft brought by financial versus non-financial buyers is not statistically significantly different, even after controlling for aircraft type \times age, usage, market thinness, and year fixed effects (results available on request).

⁶⁴In the sample of aircraft sales from 1978-1991 for which we have the price data, 35% of sales by non-distressed airlines are to financial buyers, and 24% of sales by distressed airlines are to financial buyers.

⁶⁵In his model Gavazza (2011a) specifies that for an aircraft sold at price p , the transaction costs amount to τp . Calibrating the model to match utilization moments for wide body aircraft in the data, he estimates that parameter $\tau = 0.1583$.

8 Conclusion

In this paper we revisit empirical evidence from the airline industry to quantitatively disentangle the quality impairment channel from the fire sale discount in used commercial aircraft sales. While quality might be observable to a potential buyer, an econometrician does not easily observe this variable, leading to upward biases in reported fire sale discounts. We find that financially distressed airlines sell lower quality aircraft, that have lower life expectancy and lower productivity while in use, compared with aircraft sold by healthy airlines. After accounting for these quality differentials between aircraft, the quality-adjusted fire sale discount can be interpreted as the cost of immediacy, or the cost of selling an asset quickly in an illiquid market.

The quality impairment channel explains about half of the raw fire sale discount. The raw fire sale discount for aircraft sold by distressed airlines is 17%, and the quality impairment component is 9%, giving a quality-adjusted discount rate of 8%. The quality impairment component is higher at 14% for aircraft sold in Chapter 7, versus 7% in Chapter 11. We find that the quality adjustment is highly correlated with the time spent in distress prior to filing for Chapter 11. This pre-filing period is longer for aircraft sold in Chapter 7 than in Chapter 11, and therefore, explains the higher quality adjustment for Chapter 7 sales. After adjusting for quality, we find similar fire sale discounts in both Chapter 7 and Chapter 11 bankruptcies, 13% and 12%, respectively. It is also worth noting that the quality-adjusted discount rates in airlines are similar to those documented in the financial assets' literature.

Our paper also sheds light on whether the asset misallocation mechanism proposed by [Shleifer and Vishny \(1992\)](#) is present in the airline industry, operating under Chapter 11 protection. While this is a plausible channel that may generate further inefficiencies, we find no direct evidence of misallocation of aircraft to lower productivity users, at least in this particular industry during our sample period. Rather we find that purchasers of distressed aircraft are significantly more productive than distressed sellers, indicating that bankruptcy procedures may have a cleansing effect on the industry. One explanation is that the problem of misallocation is mitigated by the provisions in Chapter 11 that permit a more patient sale of assets.

Moreover, the airlines industry includes many leasing companies which act as intermediaries, and are able to improve the resource allocation in the industry. While these firms buy assets at discounted prices, such a discount may represent a fee for taking on market making risks that would otherwise be borne by airlines. This may reflect the ability of lessors to relocate aircraft to ultimate users without the additional costs of being parked. Our results are in line with [Gavazza \(2011a\)](#) who finds that lessors deploy assets to more productive users. However, it contrasts with Pulvino's (1998) interpretation of the role played by leasing companies as less efficient (outside) buyers of the aircraft.

Notwithstanding, our results should not be interpreted as understating the importance of fire sales. Fire sale discounts are still large at around 10%. Furthermore, it has been well documented that fire sales create negative externalities that might amplify the downward spiral in asset prices, and thereby, affect the borrowing capacity and investment of firms.

The size of fire sale discounts have had an important policy influence in so far as they have been used as an important justification for mandatory bankruptcy codes like the U.S. Chapter 11. By refining the methodology on the measurement of the fire sale discount, our evidence connects to that debate, as to whether going concern bankruptcy codes are able to significantly mitigate the size of the fire sale discount. Such an analysis would require comparisons across jurisdictions that have weak going concern bankruptcy procedures. These issues have re-emerged in the economic crisis resulting from the pandemic of 2020, where the airlines industry has been particularly badly hit, and where it is likely that several airlines will file for bankruptcy protection, and their assets might be sold at fire sale prices.

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Figure 1: HAZARD RATE AND LIFE EXPECTANCY FOR AIRCRAFT

In this figure, we plot the probability of a breakup, i.e. hazard rate (top panel), and life expectancy (bottom panel) for an aircraft sold by an airline operating in Chapter 7 (green line), Chapter 11 (red line) and non-bankrupt airline (blue line). The hazard rates and life expectancies for aircraft of a given age are estimated using a Cox Proportional Hazard model.

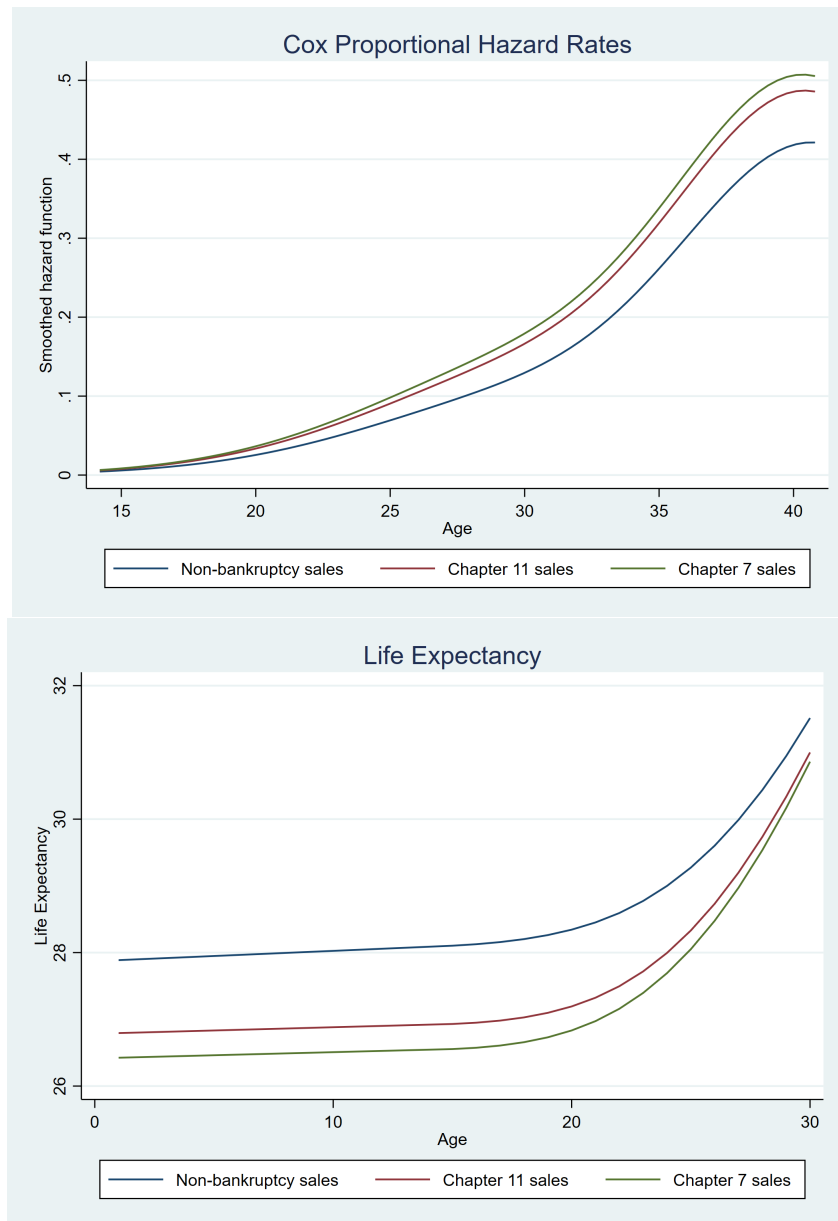


Figure 2: AVERAGE FLYING HOURS RESIDUALS FOR POST-SALES USERS OF AIRCRAFT

In this figure, we plot the kernel density of average demeaned operator flying hours for post-sale users of distress-affected aircraft and non-distressed aircraft. We compute the flying hours' residuals from the regression of log flying hours on controls for aircraft type \times age, usage, year, fleet size, and number of same type of aircraft operating in the market. We average the residuals predicted from this regression across all aircraft flown by the operator, and thereby, calculate the average demeaned operator flying hours.

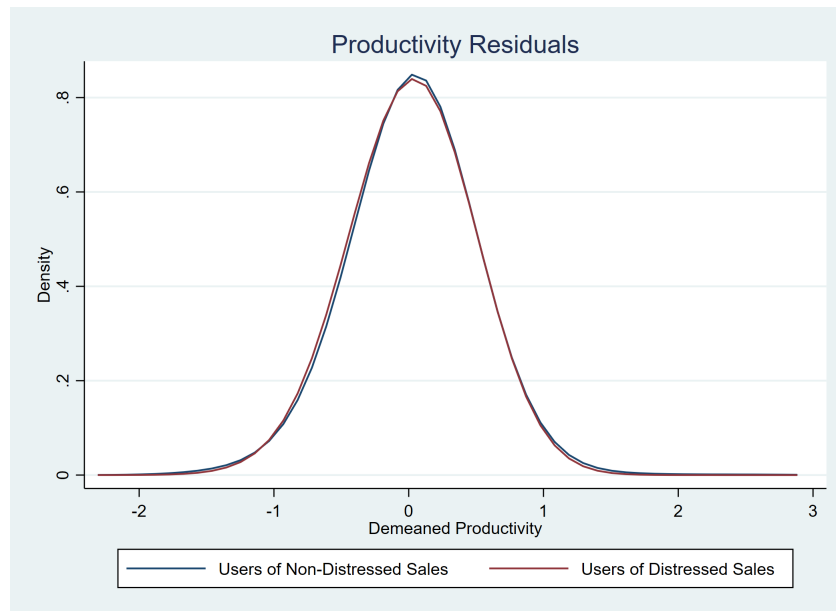


Figure 3: DIFFERENCE IN PRODUCTIVITY BETWEEN THE BUYER AND SELLER OF AIRCRAFT

In this figure, we plot the kernel density for the difference in productivity of the buyer and seller of the aircraft. We compute the flying hours' residuals from the regression of log flying hours on controls for aircraft type \times age, usage, year, and market thinness. We average the residuals predicted from this regression across all aircraft flown by the operator, and thereby, calculate the average operator productivity. Then the difference is calculated by subtracting the seller's productivity from the buyer's productivity for a given aircraft.



Figure 4: TOBIN'S Q FOR POST-SALES USERS OF AIRCRAFT

In this figure, we plot the kernel density of Tobin's Q for post-sale users of distress-affected aircraft and users of aircraft not sold by distressed airlines.

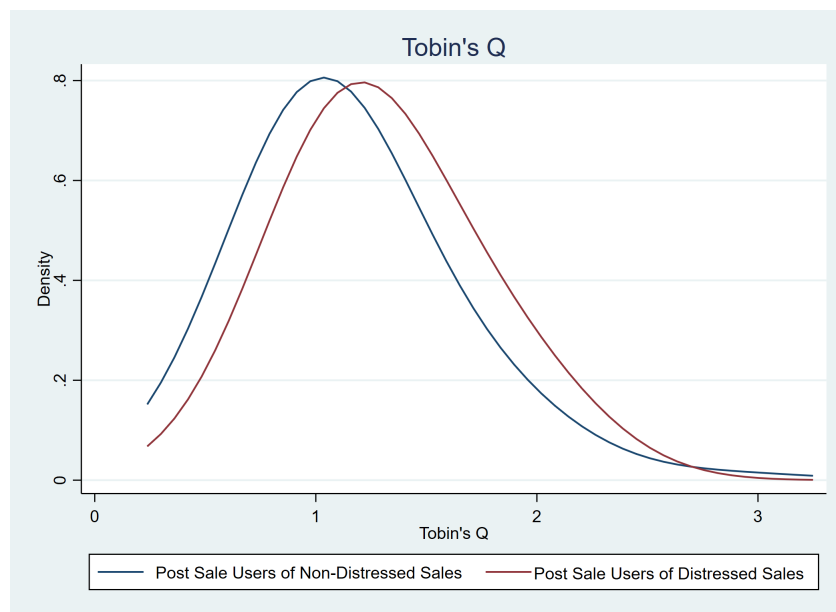


Table 1: Summary Statistics

This table reports the summary statistics for the data used in our paper. In Panel A, we report the aircraft utilization statistics for all aircraft operating in the U.S. for the period 1975 to 2015. The unit of observation is aircraft-year. *Annual flying hours* measure the total annual flying hours of an aircraft. *Annual flying hours (conditional on flying)* measure the total annual flying hours of an aircraft, excluding the aircraft that are parked. *Parked Aircraft* is a binary indicator variable taking a value of 1 if the aircraft has zero flying hours for the entire year, and is 0 otherwise. We report utilization statistics for 3 sub samples of: (i) aircraft that were sold during Chapter 7 liquidation, (ii) aircraft that were sold during Chapter 11 reorganization, and, (iii) aircraft that were not sold during bankruptcy. In Panel B, we report the second-hand aircraft transactions during the period 1975 to 2015. *Age at Sale* is the age of the aircraft in years at sale. *Retirement Age* is the age at which the aircraft was retired from service. For the aircraft that are retired from service, *Cumulative Flying Hours* reports the total hours flown by the aircraft during its entire lifetime. Panel C reports the summary statistics for the sample of used aircraft transactions for which we have the price data (i.e. aircraft transacted between 1978-1991). *Aircraft Price* is the inflation-adjusted price of a second-hand aircraft in million dollars (in terms of 1992 index).

Panel A: Aircraft Productivity Statistics (1975-2015) (N = 59,786 aircraft-years)									
	Mean			Median			SD		
Annual Flying hours	2,171			2,418			1,063		
Flying hours (condition on flying)	2,195			2,430			1,044		
Parked Aircraft	0.011			0.00			0.104		
	Sold in Ch 7 (N = 575)			Sold in Ch 11 (N = 3,035)			Non bankruptcy (N = 56,176)		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Annual Flying hours	1,269	911	811	1,979	2,212	957	2,190	2,436	1,066
Flying hours (conditional on flying)	1,278	913	807	2,009	2226	933	2,214	2,448	1,047
Parked Aircraft	0.007	0.00	0.083	0.015	0.00	0.121	0.011	0.00	0.103
Panel B: Full Sample of Aircraft Transactions (1975-2015) (N = 4,235 transactions)									
	Mean			Median			SD		
Age at sale (years)	18.97			19			8.98		
Retirement Age (years)	29.03			29			6.10		
Cumulative flying hours	64,820			64,602			16,042		
	Sold in Ch 7 (N=44)			Sold in Ch 11 (N=237)			Non bankruptcy (N=3,954)		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Age at sale (years)	11.07	9	6.04	17.92	19.00	5.60	19.09	19	9.07
Retirement Age (years)	27.67	27.00	4.50	28.32	27.00	6.27	29.14	29.00	6.10
Cumulative flying hours	47,800	44,151	9,970	64,763	63,313	15,581	65,169	65,262	16,016
Panel C: Sample of Transactions with Prices (1978-1991) (N = 1,331 transactions)									
	Mean			Median			SD		
Aircraft Price (\$ million)	11.54			7.67			11.12		
Age at sale (years)	14.26			14			5.65		
Retirement Age (years)	29.69			29			5.93		
Cumulative flying hours	65,079			64,115			16,676		
	Sold in Ch 7 (N=40)			Sold in Ch 11 (N=91)			Non bankruptcy (N=1,202)		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Aircraft Price (\$ million)	9.1	8.07	4.28	7.52	6.49	6.05	11.92	7.74	11.51
Age at sale (years)	10.13	11	3.15	17.03	19	5.8	14.18	14	5.60
Retirement Age (years)	27.21	27	3.88	29.52	29	4.9	29.73	29	5.95
Cumulative flying hours	49,444	44,154	12,437	61,438	62,824	11,885	65,903	64,681	16,815

Table 2: Total Flying Hours of Aircraft with Distress History

The table shows how a distress event affects the total productivity of an aircraft. *Distress* is an indicator variable that equals 1 if the aircraft was ever operated by an airline in bankruptcy or by an airline during the distress period prior to its filing for bankruptcy. *Chapter 7* is an indicator that equals 1 if the aircraft was ever sold by an airline liquidating in Chapter 7. *Chapter 11* is an indicator that equals 1 if the aircraft was ever sold by an airline operating in Chapter 11 protection. Age at distress measures the age at which the aircraft was sold by the distressed airline. $Age - \overline{Age}$ (*at distress*) measures the difference between the age at distress (*Age*) and the average age at distress (\overline{Age}) for aircraft sold by distressed airlines. $Age - \overline{Age}$ (*at distress*) is 0 for aircraft never exposed to distress events. Aircraft type and aircraft usage fixed effects are included in all specifications. Additionally, year of retirement fixed effects are included in columns (2) and (4). The dependent variable, $\log(\text{Aircraft Total Flying Hours})$ measures the log of cumulative hours flown by the aircraft during its entire lifetime. The unit of observation is the aircraft. Standard errors are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	log(Aircraft Total Flying Hours)			
	(1)	(2)	(3)	(4)
Distress	-0.070*** (0.016)	-0.075*** (0.015)		
$Age - \overline{Age}$ (at distress)	0.013*** (0.002)	0.015*** (0.002)	0.010*** (0.002)	0.012*** (0.002)
Chapter 7			-0.160*** (0.035)	-0.155*** (0.032)
Chapter 11			-0.076*** (0.020)	-0.075*** (0.018)
Aircraft Type FE	YES	YES	YES	YES
Aircraft Usage FE	YES	YES	YES	YES
Year of Retirement FE	NO	YES	NO	YES
Observations	996	996	996	996
Adjusted R^2	0.474	0.580	0.484	0.587

Table 3: Productivity of Aircraft and Distress History

The table shows how a history of distress affects the future productivity of an aircraft. *Distress* is an indicator variable that equals 1 if the aircraft was ever sold by an airline operating in bankruptcy or during the distress period prior to filing for bankruptcy. *Chapter 7* is an indicator that equals 1 if the aircraft was ever sold by an airline liquidating in Chapter 7. *Chapter 11* is an indicator that equals 1 if the aircraft was ever sold by an airline operating in Chapter 11 protection. *Pre-filing (in distress)* is an indicator variable that equals 1 if the aircraft is sold by an airline during the distress period prior to filing for bankruptcy. The dependent variable is the log of yearly flying hours for an aircraft. Controls are included for the fleet size of an airline ($\ln(\text{Fleet Size})$), and the number of same model aircraft operating during that time period ($\ln(\#\text{type aircraft})$). Aircraft type \times age, aircraft operator, and year fixed effects are included in all specifications. Additionally, aircraft operator \times year fixed effects are included in columns (5) and (6). Aircraft operator \times type, and aircraft operator \times year fixed effects are included in columns (7) and (8). The unit of observation is aircraft-year. Standard errors clustered by aircraft type are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	ln(Flying Hours)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Distress	-0.104*** (0.017)	-0.105*** (0.017)			-0.099*** (0.014)		-0.072*** (0.014)	
Chapter 7			-0.144*** (0.029)	-0.138*** (0.030)		-0.133*** (0.031)		-0.090*** (0.020)
Chapter 11			-0.100*** (0.020)	-0.102*** (0.022)		-0.096*** (0.026)		-0.083** (0.029)
Pre-filing (in distress)			-0.076* (0.033)	-0.083** (0.035)		-0.074* (0.035)		-0.032 (0.029)
ln(#type aircraft)		0.129 (0.092)		0.128 (0.092)	0.101 (0.069)	0.100 (0.069)	0.199* (0.096)	0.199* (0.096)
ln(Fleet Size)		0.0419 (0.024)		0.0420 (0.024)				
Year FE	YES	YES	YES	YES	-	-	-	-
Type \times Age FE	YES	YES	YES	YES	YES	YES	YES	YES
Operator FE	YES	YES	YES	YES	-	-	-	-
Operator \times Year FE	NO	NO	NO	NO	YES	YES	YES	YES
Operator \times Type FE	NO	NO	NO	NO	NO	NO	YES	YES
Observations	58,844	58,844	58,844	58,844	57,269	57,269	57,190	57,190
Adjusted R^2	0.595	0.596	0.595	0.596	0.633	0.633	0.655	0.655

Table 4: Quality Adjusted Fire Sale Discount

Panel A: Fire Sale Discount for Distressed Airlines

This table reports the results on fire sale discount. The dependent variable is log of the sales price of aircraft. In columns (1) and (2) we report the fire sale discount with no quality correction, by regressing aircraft's $\log(\text{SalePrice})$ on Ageatsale and Distress . The Distress dummy takes value 1 if the aircraft was sold by an airline (i) liquidating in Chapter 7 bankruptcy, (ii) operating in Chapter 11 bankruptcy protection, or (iii) during the distress period prior to filing for bankruptcy. The financial buyer dummy takes value 1 if the aircraft was purchased by a bank or a leasing company. In columns (3)-(6) we control for quality by including a measure for predicted quality in the specification. $\text{Predicted flying hours}$ or Quality_1 measures the aircraft's expected post-sale flying hours. $\text{Predicted remaining life}$ or Quality_2 measures the aircraft's remaining life expectancy. Fixed effects for aircraft characteristics - aircraft model, noise level(stage), and year quarter \times size are included in all the regressions. Aircraft are grouped in 2 size categories: narrow body and wide body. Bootstrapped standard errors are reported in parentheses to account for generated quality regressors. *** denotes significance at 1%, ** at 5%, and * at 10%.

	log(Sales Price)					
	Raw Fire Sale Discount		Quality_1 Discount		Quality_2 Discount	
	(1)	(2)	(3)	(4)	(5)	(6)
Distress	-0.174*** (0.054)	-0.183*** (0.033)	-0.080*** (0.028)	-0.089*** (0.025)	-0.081*** (0.024)	-0.090*** (0.022)
Financial Buyer		-0.050* (0.030)		-0.050 (0.030)		-0.053* (0.028)
Age	-0.030*** (0.006)	-0.030*** (0.006)				
Predicted flying hours			1.284*** (0.390)	1.300*** (0.403)		
Predicted remaining life					0.755*** (0.147)	0.769*** (0.145)
Aircraft Model FE	YES	YES	YES	YES	YES	YES
Aircraft Stage FE	YES	YES	YES	YES	YES	YES
Year Quarter \times Size FE	YES	YES	YES	YES	YES	YES
Seller FE	YES	YES	YES	YES	YES	YES
Observations	1,333	1,333	1,333	1,333	1,333	1,333
Adjusted R^2	0.867	0.867	0.866	0.866	0.867	0.867

Panel B: Fire Sale Discount for Bankrupt Airlines

In Panel B, we segregate the sales by *distressed* airlines, into *Chapter 7*, *Chapter 11* and *Pre-filing (in distress)* sales. The *Chapter 7* dummy takes value 1 if the airline selling the aircraft was operating under Chapter 7 liquidation. The *Chapter 11* dummy takes value 1 if the airline selling the aircraft was operating under Chapter 11 protection. *Pre-filing (in distress)* dummy takes value 1 if the aircraft is sold by an airline during the distress period prior to filing for bankruptcy. The *financial buyer* dummy takes value 1 if the aircraft was purchased by a bank or a leasing company. In columns (3)-(6) we control for quality by including a measure for predicted quality in the specification. *Predicted flying hours* or *Quality₁* measures the aircraft's expected post-sale flying hours. *Predicted remaining life* or *Quality₂* measures the aircraft's remaining life expectancy. Fixed effects for aircraft characteristics - aircraft model, noise level(stage), and year quarter \times size are included in all the regressions. Aircraft are grouped in 2 size categories: narrow body and wide body. Bootstrapped standard errors are reported in parentheses to account for generated quality regressors. *** denotes significance at 1%, ** at 5%, and * at 10%.

	log(Sales Price)					
	Raw Fire Sale Discount		<i>Quality₁</i> Discount		<i>Quality₂</i> Discount	
	(1)	(2)	(3)	(4)	(5)	(6)
Chapter 7	-0.268*** (0.068)	-0.293*** (0.070)	-0.131** (0.053)	-0.153*** (0.047)	-0.065*** (0.013)	-0.087*** (0.004)
Chapter 11	-0.194*** (0.072)	-0.204*** (0.071)	-0.122*** (0.035)	-0.131*** (0.035)	-0.060 (0.065)	-0.069 (0.070)
Pre-filing (in distress)	-0.115** (0.057)	-0.121** (0.033)	-0.069** (0.036)	-0.083** (0.036)	-0.115*** (0.056)	-0.079** (0.015)
Financial Buyer		-0.053* (0.032)		-0.052* (0.031)		-0.053 (0.041)
Age	-0.031*** (0.006)	-0.031*** (0.006)				
Predicted flying hours			0.996** (0.497)	1.016** (0.524)		
Predicted remaining life					0.785** (0.310)	0.794** (0.328)
Aircraft Model FE	YES	YES	YES	YES	YES	YES
Aircraft Stage FE	YES	YES	YES	YES	YES	YES
Year Quarter \times Size FE	YES	YES	YES	YES	YES	YES
Seller FE	YES	YES	YES	YES	YES	YES
Observations	1,333	1,333	1,333	1,333	1,333	1,333
Adjusted R^2	0.867	0.867	0.865	0.865	0.867	0.867

Table 5: Summary of Fire Sale Discount Results

This table summarizes raw fire sale discounts, quality-adjusted fire sale discounts and the quality discount for different definitions of financial distress. Table 4 Panel A columns (2) and (6) report the fire sale discounts on sale of aircraft by airlines operating under *Distress*. Table 4 Panel B columns (2) and (6) report the fire sale discounts on sale of aircraft by airlines in *Chapter 7*, *Chapter 11*, and *Pre-filing (in distress)*. *Quality Discount* in column (3) is calculated by subtracting the quality-adjusted fire sale discount (in column(2)) from the raw fire sale discount (in column (1)).

Selling Airline	(1)	(2)	(3)
	Raw Fire Sale Discount	Quality-Adjusted Fire Sale Discount	Quality Discount
Distressed	18%	8%	10%
Chapter 7	29%	15%	14%
Chapter 11	20%	13%	7%
Pre-filing (in distress)	12%	8%	4%
Low Spare Debt Capacity (CAPLO)	15%	10%	5%

Table 6: Comparison of Productivity across Post-Sale Users of Aircraft

This table reports the differences in average user productivity for post-sale users of aircraft sold by distressed airlines and post-sale users of aircraft sold by non-distressed airlines. We measure average user productivity using the following three metrics. *Average Flying Hours* for a user averages the yearly flying hours across all the aircraft that are flown by that user. For an operator, *Residuals Flying Hours** averages residuals across all aircraft flown by the operator, where the residuals are obtained by regressing log flying hours on aircraft *Type* \times *Age*, and *Year* fixed effects. For an operator, *Residuals Flying Hours*** averages residuals across all aircraft flown by the operator, where the residuals are obtained by regressing log flying hours on aircraft *Type* \times *Age*, *Usage*, *Year*, $\ln(\text{Fleet Size})$ and $\ln(\#\text{type aircraft})$. The last column reports the p-values for mean comparison tests between the users of distress-affected aircraft and the users of non-distressed aircraft, without the assumption of equal variance. Panel A compares our productivity measures for the complete sample. Panel B compares the productivity measures for aircraft sales during NBER recession years.

Panel A: Complete Sample of Sales							
	Non-Distressed Sales			Distressed Sales			Difference
	Obs.	Mean	SD	Obs.	Mean	SD	p-value
Average Flying Hours	862	7.45	0.022	154	7.44	0.039	0.5226
Residuals Flying Hours*	862	0.012	0.017	154	0.019	0.021	0.8104
Residuals Flying Hours**	862	0.013	0.013	154	0.012	0.019	0.9668
Panel B: Transactions during Recessions							
	Non-Distressed Sales			Distressed Sales			Difference
	Obs.	Mean	SD	Obs.	Mean	SD	p-value
Average Flying Hours	240	7.31	0.044	55	7.52	0.066	0.0090
Residuals Flying Hours*	240	-0.100	0.036	55	0.040	0.035	0.0058
Residuals Flying Hours**	240	-0.050	0.024	55	0.049	0.031	0.0142

*Residuals demeaned for Aircraft Type \times Age, and year fixed effects

**Residuals demeaned for Aircraft Type \times Age, usage, market thinness, and year fixed effects

Table 7: Average productivity of aircraft operators during distressed transactions

This table compares the productivity of sellers with buyers of distressed aircraft. *Distressed Transaction* equals 1 for all aircraft that are operated by the distressed seller and the buyer of these aircraft in the year of aircraft sale. *Buyer × Distressed Transaction* equals 1 for all aircraft operated by the buyer in the year it purchases an aircraft from a distressed seller. In a given year, for all aircraft operated by the carrier, *Buyer × Non-Distressed Transaction* equals 1 if the carrier purchases aircraft from a non-distressed seller. Further, we split the distressed airlines into two groups: (i) airlines that were finally liquidated in Chapter 7, and (ii) airlines that emerged from Chapter 11 as a going concern. *Finally Liquidated: Transactions* equals 1 for all the aircraft that are operated by a distressed seller that was finally liquidated in Chapter 7, and the buyer of these aircraft in the year of aircraft sale. *Survived Bankruptcy: before bankruptcy filing* equals 1 for all the aircraft that are operated by an airline that survives Chapter 11, while it was in distress before filing for Chapter 11. *Survived Bankruptcy: during Chapter 11* equals 1 for all the aircraft that are operated by an airline that survives Chapter 11, while it was operating under Chapter 11 protection. *Survived Bankruptcy: after emerging* equals 1 for all the aircraft that are operated by an airline that survives Chapter 11, in the year after it emerges from Chapter 11 as a going concern. *Financially Constrained Transaction* equals 1 for all aircraft that are operated by the financially constrained seller and the buyer of these aircraft in the year of aircraft sale. Financially constrained airlines are those have engaged in distressed exchanges, as defined by [Franks and Torous \(1994\)](#). *Buyer × Constrained Transaction* equals 1 for all aircraft operated by the buyer in the year it purchases an aircraft from a financially constrained seller. In a given year, for all aircraft operated by the carrier, *Buyer × Other Transaction* equals 1 if the carrier purchases aircraft from a non-distressed and non-constrained seller. The dependent variable is the log of yearly flying hours for an aircraft. Controls are included for the fleet size of an airline ($\ln(\text{Fleet Size})$), and the number of same model aircraft operating during that time period ($\ln(\#\text{type aircraft})$) in columns (2),(4), and (6). Aircraft type \times age, aircraft usage, and year fixed effects are included in all specifications. The unit of observation is aircraft-year. Robust standard errors are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	ln(Flying Hours)					
	(1)	(2)	(3)	(4)	(5)	(6)
Distressed Transaction	-0.081*** (0.014)	-0.082*** (0.014)			-0.082*** (0.014)	-0.084*** (0.014)
Buyer \times Distressed Transaction	0.123*** (0.018)	0.106*** (0.018)	0.179*** (0.033)	0.145*** (0.033)	0.122*** (0.018)	0.109*** (0.018)
Buyer \times Non-Distressed Transaction	0.029*** (0.008)	0.003 (0.008)	0.018** (0.008)	-0.008 (0.008)		
Finally Liquidated: Transactions			-0.135*** (0.031)	-0.119*** (0.031)		
Survived Bankruptcy: before bankruptcy filing			-0.074*** (0.022)	-0.058*** (0.022)		
Survived Bankruptcy: during Chapter 11			-0.019* (0.011)	-0.010 (0.011)		
Survived Bankruptcy: after emerging			0.116*** (0.015)	0.129*** (0.015)		
Financially Constrained Transaction					-0.016 (0.010)	-0.045*** (0.010)
Buyer \times Constrained Transaction					0.038 (0.027)	0.029 (0.027)
Buyer \times Other Transactions					0.030*** (0.008)	0.003 (0.008)
ln(#type aircraft)		0.098*** (0.020)		0.098*** (0.020)		0.096*** (0.021)
ln(Fleet Size)		0.054*** (0.004)		0.054*** (0.004)		0.055*** (0.004)
Year FE	YES	YES	YES	YES	YES	YES
Type \times Age FE	YES	YES	YES	YES	YES	YES
Aircraft Usage FE	YES	YES	YES	YES	YES	YES
Observations	59,109	59,109	59,109	59,109	59,109	59,109
Adjusted R^2	0.498	0.501	0.498	0.501	0.498	0.501

Table 8: Flying Hours of Aircraft and Time spent in Distress

The table shows how time spent in distress affects the future productivity of an aircraft. *Time in distress* measures the total time spent in distress (in years) for an aircraft that was ever sold by an airline operating in distress. *Time in distress* \times *Chapter 11* measures the total time spent in distress (in years) for an aircraft that was ever sold by an airline operating in Chapter 11, while *Time in distress* \times *Chapter 7* measures the total time spent in distress (in years) for an aircraft that was sold by an airline liquidating in Chapter 7. *Time before bankruptcy filing* measures the time that was spent in distress before filing for bankruptcy (in years) for an aircraft. *Time after bankruptcy filing* measures the time that was spent in distress after the airline operating the aircraft filed for bankruptcy (in years). The dependent variable is the log of yearly flying hours for an aircraft. Controls are included for the fleet size of an airline ($\ln(\text{Fleet Size})$), and the number of same model aircraft operating during that time period ($\ln(\#\text{type aircraft})$). Aircraft type \times age, aircraft operator, and year fixed effects are included in all specifications. The unit of observation is aircraft-year. Standard errors clustered by aircraft type are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	ln(Flying Hours)					
	(1)	(2)	(3)	(4)	(5)	(6)
Time in distress (years)	-0.0315*** (0.005)	-0.0304*** (0.006)				
Time in distress \times Chapter 11			-0.0304*** (0.005)	-0.0298*** (0.006)		
Time in distress \times Chapter 7			-0.0325*** (0.007)	-0.0310*** (0.007)		
Time before bankruptcy filing (years)					-0.0493*** (0.013)	-0.0450*** (0.013)
Time after bankruptcy filing (years)					-0.0108 (0.022)	-0.0133 (0.022)
ln(#type aircraft)		0.125 (0.091)		0.125 (0.092)		0.124 (0.091)
ln(Fleet Size)		0.0414 (0.024)		0.0414 (0.024)		0.0414 (0.024)
Year FE	YES	YES	YES	YES	YES	YES
Type \times Age FE	YES	YES	YES	YES	YES	YES
Operator FE	YES	YES	YES	YES	YES	YES
Observations	58,844	58,844	58,844	58,844	58,844	58,844
Adjusted R^2	0.595	0.596	0.595	0.596	0.595	0.596

Table 9: Fire Sales and Business Cycles

Panel A: Fire Sale Discount over Business Cycles

This table reports the results on fire sale discount during recessions. The dependent variable is log of the sales price of aircraft. In columns (1) and (2) we report the fire sale discount with no quality correction, by regressing aircraft's $\log(\text{SalePrice})$ on Ageatsale , Distress and $\text{Distress} \times \text{Recession}$. The Distress dummy takes value 1 if the aircraft was sold by an airline (i) liquidating in Chapter 7 bankruptcy, (ii) operating in Chapter 11 bankruptcy protection, or (iii) during the distress period prior to filing for bankruptcy. The Recession dummy takes value 1 if an aircraft sale was made in NBER recession periods. $\text{Distress} \times \text{Recession}$ takes value 1 if a distressed airline sold the aircraft during recession periods. The financial buyer dummy takes value 1 if the aircraft was purchased by a bank or a leasing company. In columns (3)-(6) we control for quality by including a measure for predicted quality in the specification. $\text{Predicted flying hours}$ or Quality_1 measures the aircraft's expected post-sale flying hours. $\text{Predicted remaining life}$ or Quality_2 measures the aircraft's remaining life expectancy. Fixed effects for aircraft characteristics - aircraft model, noise level(stage), and year quarter \times size are included in all the regressions. Aircraft are grouped in 2 size categories: narrow body and wide body. Bootstrapped standard errors are reported in parentheses to account for generated quality regressors. *** denotes significance at 1%, ** at 5%, and * at 10%.

	log(Sales Price)					
	Raw Fire Sale Discount		Quality_1 Discount		Quality_2 Discount	
	(1)	(2)	(3)	(4)	(5)	(6)
Distress	-0.126*** (0.028)	-0.135*** (0.025)	-0.033 (0.033)	-0.040 (0.030)	-0.025 (0.021)	-0.033 (0.024)
Distress \times Recession	-0.179*** (0.054)	-0.181*** (0.053)	-0.131** (0.052)	-0.132*** (0.050)	-0.107* (0.058)	-0.108*** (0.038)
Financial Buyer		-0.051 (0.035)		-0.053 (0.039)		-0.051 (0.040)
Age	-0.031*** (0.006)	-0.031*** (0.006)				
Predicted flying hours			1.080** (0.456)	1.103** (0.478)		
Predicted remaining life					0.823*** (0.151)	0.830** (0.328)
Aircraft Model FE	YES	YES	YES	YES	YES	YES
Aircraft Stage FE	YES	YES	YES	YES	YES	YES
Year Quarter \times Size FE	YES	YES	YES	YES	YES	YES
Seller FE	YES	YES	YES	YES	YES	YES
Observations	1,333	1,333	1,333	1,333	1,333	1,333
Adjusted R^2	0.867	0.867	0.866	0.866	0.867	0.867

Panel B: Total Flying Hours of Distressed Aircraft sold during Recessions

The table shows how a distress event during recessions affects the total productivity of an aircraft. *Distress* is an indicator variable that equals 1 if the aircraft was ever operated by an airline operating in bankruptcy, or by an airline during the distress period prior to its filing for bankruptcy. The *Recession* dummy takes value 1 if the aircraft was transacted during NBER recession periods. *Distress* \times *Recession* takes value 1 if a distressed airline sold the aircraft during recession periods. Age at distress measures the age at which the aircraft was sold by the distressed airline. $Age - \overline{Age}$ (at distress) measures the difference between the age at distress (*Age*) and the average age at distress (\overline{Age}) for aircraft sold by distressed airlines. $Age - \overline{Age}$ (at distress) is 0 for aircraft never exposed to distress events. Aircraft type and aircraft usage fixed effects are included in all specifications. Additionally, year of retirement fixed effects are included in columns (2). The dependent variable, $\log(\text{Aircraft Total Flying Hours})$ measures the log of cumulative hours flown by the aircraft during its entire lifetime. The unit of observation is the aircraft. Standard errors are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	log(Aircraft Total Flying Hours)	
	(1)	(2)
Distress	-0.040** (0.019)	-0.049*** (0.017)
Distress \times Recession	-0.099*** (0.036)	-0.087*** (0.033)
Recession	-0.022 (0.014)	-0.011 (0.013)
$Age - \overline{Age}$ (at distress)	0.011*** (0.002)	0.013*** (0.002)
Aircraft Type FE	YES	YES
Aircraft Usage FE	YES	YES
Year of Retirement FE	NO	YES
Observations	996	996
Adjusted R^2	0.481	0.584

Panel C: Misallocation during Business Cycles

This table compares the productivity of sellers with buyers of distressed aircraft during business cycles. The dependent variable is *Operator Productivity Residuals*. For an operator, *Operator Productivity Residuals* averages residuals across all aircraft flown by the operator, where the residuals are obtained by regressing log flying hours on aircraft *Type* \times *Age*, *Usage* and *Year* fixed effects. *Distressed Transaction* equals 1 for the buyer and seller of distressed aircraft. *Buyer* equals 1 for the buyers of aircraft. *Distressed Transaction* \times *Buyer* equals 1 for the buyer of distressed aircraft. The *Recession* dummy takes value 1 if an aircraft sale was made in NBER recession periods. *Distressed Transaction* \times *Recessions* equals 1 for the distressed seller and the buyer of these aircraft, if the distressed aircraft is sold during recession periods. *Buyer* \times *Recession* equals 1 if the buyer purchases an aircraft during recessions. *Distressed Transaction* \times *Buyer* \times *Recession* equals 1 for the buyer that purchases a distressed aircraft during recessions. *Age at Sale* equals the age at which the aircraft was transacted. Aircraft type and year of sale fixed effects are included in column (2) and (3). Robust standard errors are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	Operator Productivity Residuals		
	(1)	(2)	(3)
Distressed Transaction	-0.196*** (0.012)	-0.190*** (0.016)	-0.180*** (0.017)
Buyer	0.030* (0.016)	0.019 (0.018)	0.025 (0.017)
Recession	-0.010 (0.010)		
Distressed Transaction \times Buyer	0.126*** (0.037)	0.127*** (0.033)	0.122*** (0.033)
Distressed Transaction \times Recession	0.102*** (0.020)	0.104*** (0.027)	0.055* (0.032)
Buyer \times Recession	-0.069** (0.031)	-0.072** (0.033)	-0.086*** (0.033)
Distressed Transaction \times Buyer \times Recession	0.114** (0.055)	0.127** (0.051)	0.140*** (0.051)
Age at Sale			-0.007*** (0.002)
Aircraft Type FE	NO	YES	YES
Year of Sale FE	NO	YES	YES
Observations	1,716	1,716	1,716
Adjusted R^2	0.036	0.083	0.091

Table 10: Productivity of aircraft one year before sale

This table reports the productivity of aircraft in the last year of their sale with the seller. *Pre-sale (last year with seller)* equals 1 if the aircraft is in its final year of operation with its seller. *Pre-sale × Financial buyer* equals 1 if the aircraft is in its final year of operation with the seller, and post-sale is purchased by a leasing company. *Distressed aircraft pre-sale (last year with distressed seller)* equals 1 if the aircraft is in its final year of operation with a seller that is operating in distress. *Distressed aircraft pre-sale × Financial buyer* equals 1 if the aircraft is in its final year of operation with a distressed seller and post-sale it is purchased by a leasing company. The dependent variable is the log of yearly flying hours for an aircraft. Controls are included for the fleet size of an airline ($\ln(\text{Fleet Size})$), and the number of same model aircraft operating during that time period ($\ln(\#\text{type aircraft})$). Aircraft type \times age, aircraft usage, and year fixed effects are included in all specifications. Aircraft operator fixed effects are included in columns (3) and (4). The unit of observation is aircraft-year. Robust standard errors are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	ln(Flying Hours)			
	(1)	(2)	(3)	(4)
Pre-sale (last year with seller)	-0.0951*** (0.030)	-0.0876*** (0.030)	-0.169*** (0.029)	-0.163*** (0.028)
Pre-sale \times Financial buyer	0.129*** (0.047)	0.140*** (0.047)	0.120*** (0.044)	0.114*** (0.044)
Distressed aircraft pre-sale (last year with distressed seller)	-0.426*** (0.073)	-0.412*** (0.073)	-0.351*** (0.070)	-0.343*** (0.070)
Distressed aircraft pre-sale \times Financial buyer	0.334*** (0.090)	0.332*** (0.090)	0.335*** (0.088)	0.339*** (0.088)
$\ln(\#\text{type aircraft})$		0.0920*** (0.020)		0.115*** (0.019)
$\ln(\text{Fleet Size})$		0.0531*** (0.004)		0.0320*** (0.009)
Year FE	YES	YES	YES	YES
Type \times Age FE	YES	YES	YES	YES
Aircraft Operator FE	NO	NO	YES	YES
Aircraft Usage FE	YES	YES	-	-
Observations	59,032	59,032	58,762	58,762
Adjusted R^2	0.500	0.503	0.598	0.598

Appendix

A. Section 1110 of the U.S. Bankruptcy Code

Given the size of the industry and the incidence of distress and bankruptcy, creditors of airlines have been given special protection for their investments under Section 1110 of the U.S. Bankruptcy Code (Ripple (2002)). Specifically, creditors of airlines operating under court protection are provided relief from automatic stay. Section 1110 of Chapter 11 allows the financiers of aircraft and aircraft parts to repossess their collateral within 60 days after a bankruptcy filing, subject to conditions described below. Section 1110 was first introduced in 1979, and was later amended in 1994 to clarify the secured creditors' rights so as to resolve issues arising from previous litigation.

The financier's repossession rights may not be very valuable for three reasons. First, the debtor may elect under Section 1110A, that repossession may not take place providing it continues to observe the contractual obligations of the creditor, for example, by agreeing to make lease payments, maintaining the aircraft and curing any previous defaults specific to the aircraft.⁶⁶ Second, if the airline industry is in a downturn and the creditor is unable to find a buyer for the aircraft, seizing and repossessing the aircraft without having a secondary buyer (or lessee) forces the financier to absorb the carrying costs for an indeterminate period of time. For example, a non-operational user of an aircraft will need to rent hangar space or absorb the cost of mothballing the aircraft in a 'boneyard' so as to preserve and prevent damage to the aircraft. Adding to this expense will be the costs of repeated transactions, including regular inspections.⁶⁷ Benmelech and Bergman (2008) provide evidence on airlines successfully renegotiating their lease obligations downwards when their financial position is sufficiently poor and when the liquidation value of their fleet is low. Several airlines also de-contract their leases and return significant numbers of unwanted aircraft to the lessor during Chapter 11. This suggests that the bargaining power of creditors from Section 1110 is not as strong as it first appears. Third, given that our sample of aircraft transaction prices ends in 1991, the litigation and the lack of clarity that led to the 1994 amendments to Section 1110, would have imposed significant restrictions on the ability of creditors to use that Section to end the automatic stay and repossess their aircraft.⁶⁸

B. Robustness tests on the productivity of distressed aircraft

In this subsection we analyze whether a change in ownership could in itself be responsible for a decline in productivity of the aircraft. In Table A.9, we compare the productivity of non-distressed second-hand aircraft

⁶⁶For a description of Section 1110 and how it operates, in particular how airlines may, subject to court permission, elect for a continuance of the automatic stay, see Bankruptcy and Aircraft Finance, F.H. Top III, S. Tetro, R. Klein and J. Heiser, in The Harvard Law School Bankruptcy Roundtable posts, April 2020

⁶⁷Gray et al. (2015) document that the inspection tasks required to return an aircraft to service can cost more than \$2 million if the aircraft is left unused for one month. Another example of a costly repossession, is where aircraft leases and security agreements allow the operator to exchange engines and other parts through pooling or interchange agreements (Scheinberg (2017)). In such cases seizing the aircraft, would require the creditor to reconfigure and reinstall new parts, which can prove to be a costly and litigious exercise.

⁶⁸Before 1992, the average time an aircraft spent in Chapter 11 prior to their sale was 267 days, and 728 days in Chapter 7. This is consistent with the view that Section 1110 was not used by creditors to repossess their aircraft in Chapter 11.

with those aircraft purchased from the distressed seller by the same buyer. In columns (1) and (2), we find that non-distressed second-hand aircraft purchased by the buyers of distressed aircraft fly around 6% higher than similar aircraft in the buyers' fleet. In column (3) we establish that this result is robust to controlling for time varying trends in the buyers' productivity (using operator \times year fixed effect). We also measure the utilization of other non-distressed second-hand aircraft, purchased by the buyer of distressed aircraft in the same year it purchased a distressed aircraft. In columns (4) and (5) our results confirm that the productivity of other non-distressed aircraft purchased in the same year in which the buyer purchased a distressed aircraft, is similar or higher than those other aircraft in the buyers' fleet (i.e. aircraft that were not transacted in that year). The consequence is that the productivity of the distressed aircraft purchased by the buyer is 10% lower than other similar aircraft in its fleet. These results establish that non distressed second-hand aircraft *purchased* by the buyer of distressed aircraft do not under perform other similar aircraft in the buyers' fleet. This further strengthens our claim that aircraft sold by distressed airlines are under-maintained, and therefore, are systematically utilized less than all the other similar aircraft operated by the airline.

The analysis in Table 3 is performed on the full sample of bankruptcies from 1975-2015. Since we have pricing data only for the period 1978-1991, in Appendix Table A.3, we check whether the 131 aircraft transacted in bankruptcy during 1978-1991 (in Table 1), exhibit similar lower productivity post-sale. Since, the coefficients reported in Table A.3 and Table 3 Panel A are virtually identical, we perform our remaining tests on the full sample of bankruptcies from 1975-2015.

In Table 2, we documented that for the aircraft that were retired from service, there is a significant difference in the total flying hours of the aircraft sold by distressed airlines compared with other similar aircraft transacted by non-distressed airlines. We have also established that aircraft that have suffered from a distress episode, are less productive than other similar aircraft in the market during their remaining life after sale. It is possible that the aircraft sold by distressed airlines, were of lower quality even before the airline entered distress.⁶⁹ In Appendix Table A.4, we directly test this pre-trends hypothesis, by splitting the flying hours of a distressed aircraft into pre-distress, during distress, and post-distress periods. In column (1), we find that before the airline enters into distress, there is no difference in the productivity of the aircraft that were subsequently sold during the distress period, compared with other similar non-distressed aircraft. These transacted aircraft fly 6% less than other similar aircraft operated by the distressed carrier.⁷⁰ Post sale, these aircraft fly 10% less, than other similar aircraft operated by the new carrier. Similar trends are confirmed in column (3), when we further split distress episodes into Chapter 7 and Chapter 11 sales. It shows that quality impairment continues to affect distressed aircraft after their sale, , although it is not present in the period prior to distress.

⁶⁹Although, this hypothesis would be unable to explain why the total flying hours of an aircraft vary with the age at which the aircraft enters into distress (Table 2).

⁷⁰These similar aircraft include those are subsequently sold, and those that are retained on emergence from bankruptcy

C. Cox Proportional Hazards model for aircraft life expectancy

We apply duration analysis to the retirement age data to calibrate the hazard function for an aircraft. The hazard function characterizes the hazard rate for an aircraft as a function of its age, t . Conditional on surviving up to a given age, the hazard rate represents the probability of an aircraft retiring in the subsequent period. We calculate the hazard rates using the Cox proportional hazard model. The Cox relative hazard regression estimates coefficients ($\hat{\beta}$) for aircraft characteristics (X : aircraft type, age, and bankruptcy or distress of its operator) and a baseline hazard rate ($h_0(t)$). Then, $h_0(t) \exp(\hat{\beta}'X)$ gives the predicted hazard rate ($\lambda_i(t)$) for each aircraft, controlling for its specific characteristics.

We calculate the life expectancy of an aircraft using its predicted hazard rate ($\lambda_i(t)$). We compute the cumulative hazard rate ($\Lambda_i(t)$), as the CDF of the hazard rate. Using $\Lambda_i(t)$ we estimate the total life expectancy for an aircraft i , as a function of its age, t . If we denote the cumulative hazard rate by $\Lambda_i(t)$, then its corresponding total life expectancy $L_i(t)$ can be calculated as:

$$L_i(t) = t + \int_0^{\infty} \exp[\Lambda_i(t) - \Lambda_i(t+x)] dx \quad (\text{A-1})$$

Using the above method, we calculate the life expectancy separately for aircraft sold by airlines in Chapter 7, Chapter 11 and non-bankrupt airlines.⁷¹ Figure 1 plots the life expectancy of aircraft, conditional on being alive at a given age.

D. Estimating the quality adjusted fire sale discount

The overall quality of an aircraft (Q_{it}) is modelled as a function of its *effective* age (\tilde{Age}_{it}).

$$\tilde{Age}_{it} = Age_{it} + \delta Distress_{it}$$

The above equation specifies that aircraft exposed to distress are effectively older than non-distressed aircraft by δ years.⁷² The quality of an aircraft, is modelled as: $Q_{it} = \Phi(\tilde{Age}_{it})$. Where, the function Φ , measuring the quality of an aircraft is monotonically decreasing in its effective age.

Substituting for quality in the price equation 2 yields:

$$\log(Price)_{it} = \alpha_k + \alpha_{bt} + \alpha_n + \alpha_j + \beta \Phi(Age_{it} + \delta Distress_{it}) + \gamma Distress_{it} + \epsilon_{it} \quad (\text{A-2})$$

⁷¹In estimating the life expectancy from the post-Cox proportional hazard rates, a potential concern is that there might be substantial noise in the predicted hazard rates. Therefore, in our main specification we group our aircraft according to narrow body and wide body types. To check the robustness of our results, we also use several other approaches to group the aircraft. For example, we segregate aircraft by different engine noise levels and model types. We find that our main results are robust to different grouping procedures.

⁷²For simplicity we assume a parallel shift (δ) in effective age for distressed aircraft. We can relax this assumption, and the model can also be identified by assuming shifts that are a function of the age at which the aircraft was exposed to distress.

We calibrate δ using two different measures of aircraft quality: i) its expected retirement age and ii) flying hours post sale. More specifically, assuming that the quality (Q_{it}) of an aircraft is a function of its effective age, we can recover δ by regressing:

$$Q_{it} = \phi_0 + \phi_1 Age_{it} + \phi_2 Distress_{it} + \phi_k + \phi_{lt} + e_{it} \quad (\text{A-3})$$

Where, the dependent variable Q_{it} , is a measure of the aircraft's remaining life or remaining flying hours. k is the aircraft model, and l is the operator or user of the aircraft i in year t . Fixed effects for aircraft characteristics allow us to isolate the impact of distress on the performance of an aircraft.

Comparing equation 3 with the coefficient estimates of equation A-3, we can recover δ as:⁷³

$$\delta = \frac{\phi_2}{\phi_1}$$

We substitute for δ in the price equation 3, and compare with the following reduced form equation A-4:

$$\log(Price)_{it} = \rho_k + \rho_{bt} + \rho_n + \rho_j + \rho_1 Age_{it} + \rho_2 Distress_{it} + \zeta_{it} \quad (\text{A-4})$$

$$\gamma = \rho_2 - \delta \rho_1$$

We can estimate the reduced form coefficients and solve for the true model as above. To operationalize this method, we substitute the predicted quality (\hat{Q}_{it}) from equation A-3, in the price regression.

$$\log(Price)_{it} = \lambda_k + \lambda_{bt} + \lambda_n + \lambda_j + \lambda_1 \hat{Q}_{it} + \lambda_2 Distress_{it} + \mu_{it} \quad (\text{A-5})$$

It can be shown that the quality adjusted fire sale discount, $\gamma = \lambda_2$.

E. Raw Fire Sale Discount on Distressed Aircraft Sales

In this section, we report our results from replicating the 2 stage methodology followed by Pulvino (1998, 1999) to estimate the raw fire sale discount. Here, we briefly summarize the main steps. In the first step we calculate the hedonic prices of the aircraft that are a function of the aircraft attributes and time using all available market transactions data. For aircraft i sold by airline j in year quarter t , the hedonic model specifies:

$$\log(PRICE)_{ijt} = \beta_{Age} \log(1 + Age_i) + \beta_t + \beta_{Model} + \beta_{Stage} + \epsilon_{ijt} \quad (\text{A-6})$$

Where, $\log(PRICE)_{ijt}$ is the log of the inflation-adjusted sales price of the aircraft. Age_i represents the aircraft age at sale. We include fixed effects for calendar quarter of sale (β_t), aircraft model type (β_{Model}),

⁷³Comparing equations A-2 and A-3 we get $\Phi'(Age_{it}) = \phi_1$ and $\delta \Phi(Age_{it}) = \phi_2$. These imply that: $\delta = \phi_2 / \phi_1$.

and engine stage or noise level (β_{Stage}). We run the above regression separately for narrow body and wide body aircraft and use all available market transactions data.⁷⁴

We regress the residuals obtained from the first stage hedonic regression ($RESID$), described above on variables measuring the sellers' financial health.⁷⁵ More specifically, to quantify the raw fire sales discount, we regress:

$$RESID = \beta_1 Chapter7 + \beta_2 Chapter11 + \beta_3 PreFiling + \beta_4 FinancialBuyer + \beta_{Seller} + \eta \quad (A-7)$$

The first 3 variables are defined in Equation 1. *Financial Buyer* equals 1 if the aircraft was purchased by a financial institution or a leasing company. Seller fixed effects (β_{Seller}) are included to isolate the impact of distress on transaction prices from unobservable firm specific factors.

The raw fire sale discounts calculated from regressing the residuals on financial health variables are reported in Table A.5, Panel A columns (1) and (2). We find that distressed airlines sell aircraft at a raw fire sale discount of 16%, a significant discount to the average market price. Further, in comparison to the sales made to airlines, the sales to financial institutions, mainly leasing companies occur at an average price discount of around 9% (in column (2)). In columns (3) and (4) of Table A.5, we separate the *distress* sales into *Chapter 7*, *Chapter 11*, and *Pre-Filing (in distress)* sales. As expected, the raw fire sale discount on Chapter 7 sales of 28%, is higher than the discount of 16% on Chapter 11 sales (column (2)).⁷⁶

Following Pulvino (1998), we classify an airline as a low spare debt capacity airline if its leverage ratio is above the industry median, and its current ratio is below the industry median in the calendar quarter preceding the aircraft sale.⁷⁷ In the first stage, we calculate the hedonic price of an aircraft using all available market transactions. In the second stage, we restrict our sample to sales by major U.S. airlines (listed in Appendix Table A.1, for which financial data is available for the quarter preceding the transaction. We regress the residuals (ϵ) obtained from the first stage on variables measuring airlines' financial health.

We do this only for the sample of used narrow body aircraft sold by the airlines whose financial data are available for the quarter preceding the transaction. The variables are: *CAPLO* is a dummy variable equal to 1 if the selling airline had a leverage ratio above the industry median and a current ratio below the industry median in the calendar quarter preceding the transaction; *CAPHI* is a dummy variable equal to 1 if the airline had a leverage ratio below the industry median and a current ratio above the industry median in the preceding

⁷⁴As a robustness check we have excluded the aircraft sold by bankrupt airlines in establishing the first stage market prices (or the hedonic prices), and our main results remain almost unchanged.

⁷⁵We transform the residuals obtained in the above regression (ϵ), to actual discounts rates via the following transformation: $Discount = \exp(\epsilon) - 1$. The log residuals approximate the actual discount rates for small discounts. Nevertheless, we transform log residuals to actual discount rates to be more precise. Our main results are robust to both specifications.

⁷⁶This difference is statistically significant at the 5% level. In column (1), the p-value for testing the null hypothesis $H_0 : Chapter7 = Chapter11$ is 0.0449, while the p-value for testing the null hypothesis $H_0 : Chapter7 = Chapter11 = PreFiling$ is 0.0152.

⁷⁷These sales are identical to the *CAPLO* sales in Pulvino (1998).

quarter⁷⁸; Q equals (Market value of assets/Book value of assets)⁷⁹; REV equals (Revenue/Available-seat-miles); $COST$ equals (Cost-of-goods-sold/Available-seat-miles); N equals the number of narrow-body sales by the selling airline in the calendar quarter of the transaction; FIN equals 1 if the aircraft was purchased by a financial institution or a leasing company; $OTHER$ equals 1 if the buyer of the aircraft is a regional airline, foreign airline, foreign government, or cargo company (i.e. the buyer is neither a financial buyer, nor one of the major U.S. airlines listed in Table A.1). In order to separate the effects of financial distress from the effects of economic distress, the above specification controls for firm prospects (using three variables: Q , Revenue/ASM and COGS/ASM).⁸⁰ Transactions are only included in the above regression if financial data for the quarter preceding the sale date are available. To be consistent with Pulvino (1998), in this specification we drop sales by bankruptcy-affected airlines where there is a lack of availability of financial data.

The raw fire sale discounts calculated from regressing the residuals on financial health variables are reported in Panel B Table A.5, columns (1) and (2). The discounts are identical to Pulvino (1998). Airlines with low spare debt capacity sell aircraft at an average discount of 15%, a significant discount to the average market price. Further, in comparison to sales made to major U.S. airlines, the sales to financial institutions and leasing companies occur at an average price discount of around 12% (in column (2)).

F. Robustness tests for misallocation

An alternate test of the misallocation hypothesis is based on whether the aircraft sold by distressed airlines are allocated to operators that are less productive than their sellers. The presence of misallocation, as proposed by Shleifer and Vishny (1992) would imply that assets sold in fire sales get allocated to less productive buyers, and thereby, the productivity of the buyer (or user) is lower than that of the seller. Conversely, the reallocation of aircraft to more productive users in the economy, would imply that the buyer is operationally more efficient than the seller. In our sample, we test these hypotheses empirically by comparing the differential productivity across the buyer and seller of the asset. In Table A.6, we test for difference in productivity between buyers and sellers of aircraft (δ), controlling for aircraft specific characteristics at the time of sale. The dependent variable measures the average productivity of the buyer and the seller of the aircraft for which we have the transaction prices (transacted during 1978-1991).⁸¹ Every aircraft transaction is reported twice, both for the buyer and seller of the aircraft. *Distressed Transaction* equals 1 for the buyer and seller of distressed aircraft. *Buyer* equals 1 for the buyers of aircraft. *Distressed Transaction* \times *Buyer* equals 1 for the buyer of distressed aircraft. In column (1), we report that the difference between buyer and seller productivity (δ) in distressed aircraft

⁷⁸Leverage ratio is defined as book value of debt plus capitalized lease obligations divided by the sum of book value of debt, capitalized lease obligations, and book value of equity. Current ratio is defined as current assets divided by current liabilities. Airlines with both high leverage ratios and low current ratios are classified as CAPLO.

⁷⁹The market value of assets equals the book value of assets plus the market value of common equity less the book value of common equity and balance sheet deferred taxes

⁸⁰To avoid potential control problems, we have repeated this regression using firm level control variables (Q , Revenue/ASM, Cost/ASM) from the quarter preceding the transaction. The discount on aircraft sales by financially distressed airlines remains almost unchanged. Results available on request.

⁸¹Similar to Figure 3, the productivity of an operator is obtained by averaging the residuals (ϵ_{ijt}) obtained from Equation 6 across all the aircraft flown by the same operator. The residuals are calculated by regressing aircraft flying hours on controls for aircraft type \times age, usage, and year fixed effects.

sales is 16%, and there is no significant difference between buyer and seller productivity in sales made by non-distressed airlines. We also report that the productivity of the buyer of distressed aircraft is virtually identical to the productivity of the buyer of non-distressed aircraft. In columns (2) and (3), we control for aircraft characteristics at sale, that might influence the kind of buyers that purchase these aircraft. For example, in column (3), a significant negative coefficient on *Age at sale* indicates that older aircraft are transacted by less productive operators. After controlling for aircraft type, age at sale, and the year of sale, we find that the difference between buyer and seller productivity in distressed aircraft sales is 17%, and the productivity of the buyer of distressed aircraft is virtually identical to the productivity of the buyer of non-distressed aircraft.

Reallocation of aircraft to more productive users would suggest that the airlines buying the distressed aircraft would be able to grow and use modern technology at the cost of their less productive competitors (Hsieh and Klenow (2009), Bartelsman et al. (2013), Bian (2020)). In Table A.7 we directly test this hypothesis using fleet size, and a younger vintage of aircraft with newer technology as proxies for firm growth. The unit of observation is firm-year. In column (1) we use the log of total number of aircraft in a firm’s fleet as the dependent variable, and measure its sensitivity to pre-determined measures of average productivity of the firm. Lagged productivity is measured as the average flying hours of the operator across all its aircraft that are flown in the previous year. More productive airlines invest more in new aircraft, as is reflected by the coefficient on *Productivity*. In addition, the coefficient on the interaction term of (*Productivity* \times *Buyer of distressed aircraft*) is positive, and statistically significant, although not significantly different from the coefficient on productivity of users of non-distressed aircraft (*Productivity* \times *Buyer of non-distressed aircraft*). This further strengthens our claim that the sensitivity of productivity to firms’ growth is not different for users of distress-affected aircraft versus the users of non-distressed aircraft, thereby indicating that there is no evidence of misallocation in the airlines industry following instances of distress. In column (2) of Table A.7, the dependent variable is the average age of the firm’s fleet. More productive airlines are able to maintain a younger vintage of aircraft, and the difference between the interaction terms for distress-affected aircraft users and non-distressed aircraft users is not statistically significant.

The results are similar when we proxy for firms’ growth prospects using the average technological age of the fleet in column (3) of Table A.7. The technological age of an aircraft is defined as the number of years since the introduction of an aircraft’s type (our definition is similar to Benmelech and Bergman (2011)). Our results in column (3) indicate that airlines with higher productivity acquire modern technologically advanced aircraft, while the less productive airlines are left with obsolete fleet. We find no significant differences between the sensitivity of productivity to firms’ growth prospects for post-sale users of distress-affected aircraft versus post-sale users of non-distressed aircraft.⁸²

We use financial variables of the airlines as evidence for whether there is resource misallocation in the airlines industry. Using COMPUSTAT, we match the financial data of the users, for the fiscal year preceding the purchase of the aircraft. Since financial data are not available for all operators, we are left with only a

⁸²The same airline may appear as a Buyer of distressed aircraft and as a Buyer of non-distressed aircraft at different time periods. In our specification we use a lag of one year in productivity. As a robustness check, we increase the lag in productivity to 2 years, and our results are virtually unchanged (results available on request).

subsample of users for which we have the financial data. [Bian \(2020\)](#) documents that aircraft flying hours are closely related to profitability and other financial performance variables of the firm. An alternative test of the misallocation channel used in the literature is based upon the sensitivity of capital expenditure to financial metrics such as Tobin’s Q and marginal product of capital (see for example, [Ozbas and Scharfstein \(2010\)](#), and [Hsieh and Klenow \(2009\)](#)). We construct the following financial measures to determine whether there is resource misallocation in the economy. We estimate the responsiveness of users to acquiring aircraft using *Tobin’s Q*. We follow the data definition of [Kaplan and Zingales \(1997\)](#), and compute *Tobin’s Q* as MVA/BVA , where the market value of assets equals the book value of assets plus the market value of common equity less the book value of common equity and balance sheet deferred taxes. Following the methodology of [Cong et al. \(2019\)](#), we use the log of marginal product of capital as another measure of resource misallocation.⁸³ $\text{Log}(MPK)$ is defined as the natural log of sales divided by book value of fixed assets. We define *Profitability* of the operator as operating income before depreciation, interest and taxes scaled by lagged assets. For these financial variables we compare the performance of post-sale users of aircraft sold by distressed airlines, to the post-sale users of aircraft sold by non-distressed airlines.

Table [A.8](#) Panel A reports our results. Using measures of *Tobin’s Q*, $\text{log}(MPK)$, and *Profitability* we can conclude that the users operating distress-affected aircraft are at least as efficient users of capital as other users of non-distressed aircraft. Our comparison using Tobin’s Q suggests that post-sale users of distressed aircraft have a higher average Tobin’s Q of 1.31, versus the average of other users’ at 1.14. There is no significant difference in the other measures of profitability across the two groups. Figure [4](#) plots the kernel density for operators’ Tobin’s Q. It confirms that the users of distress affected aircraft have a higher Tobin’s Q versus other users.⁸⁴ To control for macroeconomic trends affecting the financial performance of firms we demean all our measures using year fixed effects. Our comparisons on the demeaned variables are presented in Table [A.8](#) Panel B. Our analysis allows us to conclude that operators of distress and bankruptcy-affected aircraft do not perform worse than other operators using measures of Tobin’s Q, marginal product of capital, and profitability.

To address the selection concern that there could be a systematic difference in users for which we have the financial data in the distressed and non-distressed sales groups, we undertake the following test. We compare our previously defined measures of productivity for the subsample for which we do not have all the financial data. Table [A.8](#) Panel C shows our results. In the subsample of operators for which we do not have the financial data, there is no difference in average productivity of the users in the distressed and non-distress groups. Also, Table [A.8](#) Panel D compares operator productivity for the subsample for which we have all the financial data. We again find that controlling for aircraft type, age, and year fixed effects there is no significant difference in operator productivity between the distress and non-distressed sales group. Therefore, since there is no difference in productivity between the two groups, we are able to rule out the concern that our subsamples for which financial data exist are different due to a selection issue.

⁸³[Cong et al. \(2019\)](#) present a model of resource misallocation based on [Hsieh and Klenow \(2009\)](#). The measure $\text{log}(MPK)$ is a rough estimation of productivity under the following assumptions: marginal product of capital equals average product of capital; labor share and mark-ups are the same within a given industry-year.

⁸⁴The standard Kolmogorov-Smirnov test of the equality of distributions rejects the null hypothesis of equal distributions at the 1 percent level (the asymptotic p-value is equal to 0.000).

The evidence presented in this section illustrates that the resource misallocation channel does not appear to operate in the airlines industry. On all measures of productivity and financial indicators, the post-sale users of distress and bankruptcy-affected aircraft perform just as well as post-sale users of aircraft not sold in bankruptcy. Therefore, we can conclude that in the airlines industry fire sales resulting from forced sales do not lead to ex-post misallocation of resources.

Table A.1: Summary of Narrow & Wide Body Aircraft Sales

This table reports the total number of sales of narrow body and wide body aircraft by major U.S. airlines from 1978-1991. Airlines that filed for bankruptcy at least once during that period are in bold face.

	Narrow Body Sales	Wide Body Sales	Total Sales
Air Florida	10	0	10
AIRCAL	0	0	0
Alaska Airlines	6	0	6
Aloha Airlines	3	0	3
America West Airlines	8	0	8
American Airlines	38	3	41
Braniff Airlines	55	1	56
Braniff Liq. Trust	26	0	26
Continental Airlines	12	0	12
Delta Airlines	50	16	66
Eastern Airlines	132	21	153
Frontier Airlines	0	0	0
Hawaiian Airlines	4	0	4
Midway Airlines	6	0	6
Muse Air	0	0	0
New York Air	0	0	0
Northwest Airlines	49	0	49
Ozark Airlines	2	0	2
Pacific Southwest	21	0	21
Pan Am World Airways	33	30	63
People Express Airlines	0	1	1
Piedmont Airlines	5	0	5
Republic Airlines	4	0	4
Southwest Airlines	0	0	0
TWA	40	4	44
United Airlines	54	8	62
US Air	25	0	25
Western Airlines	25	3	28
TOTAL	608	87	695

Table A.2: Retirement Age of Aircraft and Distress History

The table shows how the retirement age of an aircraft is affected after suffering from a distress episode, i.e. after being sold by an airline that was distressed. *Distress* is an indicator variable that equals 1 if the aircraft was ever sold by an airline operating in bankruptcy, or by an airline during the distress period prior to its filing for bankruptcy. *Chapter 7* is an indicator that equals 1 if the aircraft was sold by an airline liquidating in Chapter 7. *Chapter 11* is an indicator that equals 1 if the aircraft was sold by an airline operating in Chapter 11 protection. *Pre-filing (in distress)* dummy takes value 1 if the aircraft is sold by an airline during the distress period prior to filing for bankruptcy. The dependent variable in columns (1) and (2), *Retirement Age* is the age at which the aircraft is retired. The *Remaining Life* of an aircraft is its retirement age minus its age at sale. *Age at Sale* controls for the age at which the aircraft was transacted. Fixed effects for aircraft characteristics - aircraft type, noise level(stage), and year of retirement are included in the regressions. Robust standard errors are reported in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	Retirement Age	
	(1)	(2)
Distress	-2.163*** (0.207)	
Chapter 7		-3.767*** (0.363)
Chapter 11		-2.308*** (0.230)
Pre-Filing (in distress)		0.056 (0.388)
Age at Sale	0.579*** (0.016)	0.563*** (0.016)
Aircraft Type FE	YES	YES
Aircraft Stage FE	YES	YES
Year of Retirement FE	YES	YES
Observations	1,287	1,287
Adjusted R ²	0.7866	0.7917

Table A.3: Productivity of Aircraft and Distress History

The table shows how a history of distress affects the future productivity of an aircraft, for aircraft transacted in distress during 1978-1991 (for which we have the transactions price data). *Distress* is an indicator variable that equals 1 if the aircraft was ever operated by an airline operating in bankruptcy or during the distress period prior to its filing for bankruptcy, and its transaction price is available to us. *Chapter 7* is an indicator that equals 1 if the aircraft was ever sold by an airline liquidating in Chapter 7, and its transaction price is available. *Chapter 11* is an indicator that equals 1 if the aircraft was ever sold by an airline operating in Chapter 11 protection, and its transaction price is available. *Pre-filing (in distress)* is an indicator variable that equals 1 if the aircraft is sold by an airline during the distress period prior to filing for bankruptcy, and its transaction price is available. The dependent variable is the log of yearly flying hours for an aircraft. Controls are included for the fleet size of an airline ($\ln(\text{Fleet Size})$), and the number of same model aircraft operating during that time period ($\ln(\#\text{type aircraft})$). Aircraft type \times age, aircraft operator, and year fixed effects are included in all specifications. The unit of observation is aircraft-year. Standard errors clustered by aircraft type are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	log(Flying Hours)			
	(1)	(2)	(3)	(4)
Distress	-0.115*** (0.027)	-0.117*** (0.028)		
Chapter 7			-0.135*** (0.029)	-0.129*** (0.031)
Chapter 11			-0.117** (0.050)	-0.122** (0.051)
Pre-Filing (in distress)			-0.083* (0.041)	-0.093* (0.043)
$\ln(\#\text{type aircraft})$		0.128 (0.091)		0.127 (0.092)
$\ln(\text{Fleet Size})$		0.041 (0.023)		0.041 (0.023)
Year FE	YES	YES	YES	YES
Type \times Age FE	YES	YES	YES	YES
Operator FE	YES	YES	YES	YES
Observations	57,871	57,871	57,871	57,871
Adjusted R^2	0.596	0.597	0.596	0.597

Table A.4: Breakdown of Total Flying Hours: Pre and Post Distress

The table shows how distress affects the total productivity of an aircraft. *Pre Distress* is an indicator variable that equals 1 before the airline enters into distress. *Pre Distress: Chapter 7 sale* is an indicator variable that equals 1 before an airline selling the aircraft in Chapter 7, enters into distress. *Pre Distress: Chapter 11 sale* is an indicator variable that equals 1 before an airline selling the aircraft in Chapter 11, enters into distress. *During distress (and bankruptcy)* equals 1 while the airline is operating in distress, and bankruptcy. *Post Sale (Distressed aircraft with new operator)* is an indicator variable that equals 1 post-sale of an aircraft that was ever operated by a distressed airline. *Post Sale: Chapter 7 sale* is an indicator variable that equals 1 post-sale of an aircraft that was sold in Chapter 7. *Post Sale: Chapter 11 sale* is an indicator variable that equals 1 post-sale of an aircraft that was sold in Chapter 11. The dependent variable is the log of yearly flying hours for an aircraft. Controls are included for the fleet size of an airline ($\ln(\text{Fleet Size})$), and the number of same model aircraft operating during that time period ($\ln(\#\text{type aircraft})$). Aircraft type \times age, aircraft operator, and year fixed effects are included in all specifications. The unit of observation is aircraft-year. Standard errors are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	log(Flying Hours)			
	(1)	(2)	(3)	(4)
Pre Distress	-0.005 (0.012)	-0.005 (0.012)		
Pre Distress: Chapter 7 sale			0.062 (0.047)	0.063 (0.047)
Pre Distress: Chapter 11 sale			-0.008 (0.012)	-0.008 (0.012)
During distress (and bankruptcy)	-0.062*** (0.009)	-0.054*** (0.010)	-0.062*** (0.009)	-0.054*** (0.010)
Post Sale (Distressed aircraft with new operator)	-0.103*** (0.015)	-0.104*** (0.015)		
Post Sale: Chapter 7 sale			-0.140*** (0.024)	-0.133*** (0.025)
Post Sale: Chapter 11 sale			-0.097*** (0.023)	-0.099*** (0.023)
$\ln(\#\text{type aircraft})$		0.128*** (0.019)		0.125*** (0.019)
$\ln(\text{Fleet Size})$		0.035*** (0.009)		0.035*** (0.009)
Year FE	YES	YES	YES	YES
Type \times Age FE	YES	YES	YES	YES
Operator FE	YES	YES	YES	YES
Observations	58,844	58,844	58,844	58,844
Adjusted R^2	0.596	0.596	0.595	0.596

Table A.5: Panel A: Fire Sale Discount for Distressed Airlines (Two-stage model: Second stage)

This table reports the results from the second stage which regresses the price discount (residuals from the first stage hedonic regression) on dummy variables indicating whether the airline selling the aircraft was distressed. The price discount is calculated ignoring the quality correction in the first stage. The *Distress* dummy takes value 1 if the aircraft was sold by an airline (i) liquidating in Chapter 7 bankruptcy, (ii) operating in Chapter 11 bankruptcy protection, or (iii) during the distress period prior to filing for bankruptcy. The *Chapter 7* dummy takes value 1 if the airline selling the aircraft was operating under Chapter 7 liquidation. The *Chapter 11* dummy takes value 1 if the airline selling the aircraft was operating under Chapter 11 protection. *Pre-filing (in distress)* dummy takes value 1 if the aircraft is sold by an airline during the distress period prior to filing for bankruptcy. The *financial buyer* dummy takes value 1 if the aircraft was purchased by a bank or a leasing company. Columns (1) and (2) report the fire sale discounts for aircraft sold by *distressed* airlines. In columns (3) and (4) we segregate the sales by *distressed* airlines, into *Chapter 7*, *Chapter 11* and *Pre-filing (in distress)* sales. Robust standard errors are reported in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	(1)	(2)	(3)	(4)
	Discount	Discount	Discount	Discount
Distress	-0.159*** (0.034)	-0.158*** (0.033)		
Chapter 7			-0.255*** (0.040)	-0.282*** (0.041)
Chapter 11			-0.157*** (0.039)	-0.159*** (0.039)
Pre-filing (in distress)			-0.128*** (0.041)	-0.110*** (0.041)
Financial Buyer		-0.090*** (0.034)		-0.097*** (0.035)
Seller FE	YES	YES	YES	YES
Observations	695	695	695	695
Adjusted R^2	0.177	0.192	0.177	0.195

Panel B: Fire Sale Discount for Low Spare Debt Capacity Airlines

This table reports the results from the second stage which regresses the price discount (residuals from the first stage hedonic regression) on dummy variables indicating whether the airline selling the aircraft was operating under low spare debt capacity (*CAPLO*-high leverage and low current ratio), or high spare debt capacity (*CAPHI*). The price discount is calculated ignoring the quality correction in the first stage. There are control variables for Revenue/Available Seat Mile (*REV*), Costs/Available Seat Mile (*COST*), Tobin's Q (*TQ*), and number of aircraft sold by an airline in a given calendar quarter (*NSALE*). Also included is a dummy variable for whether the aircraft was purchased by a *financial buyer*, that takes a value one if the aircraft buyer is a bank or leasing company. *Other buyer* is a dummy variable that takes a value 1 if the buyer is not a financial institution, leasing company, or a large U.S. airline listed in Appendix Table A.1. Robust standard errors are reported in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	(1)	(2)
	Discount	Discount
CAPLO	-0.145*** (0.033)	-0.148*** (0.033)
CAPHI	-0.025 (0.042)	-0.037 (0.043)
TQ	0.061** (0.029)	0.033 (0.034)
REV	3.742 (2.363)	1.359 (2.756)
COST	-4.481* (2.703)	-1.616 (3.182)
NSALE	-0.006 (0.004)	-0.007* (0.004)
Financial Buyer		-0.116*** (0.040)
Other Buyer		-0.057 (0.040)
Constant	0.021 (0.045)	0.121* (0.064)
Observations	467	467
Adjusted R^2	0.058	0.070

Table A.6: Productivity differences between buyers and sellers of aircraft

This table reports the differences in average productivity between sellers and post-sale users of aircraft sold by distressed airlines and non-distressed airlines. The dependent variable is *Operator Productivity Residuals*. For an operator, *Operator Productivity Residuals* averages residuals across all aircraft flown by the operator, where the residuals are obtained by regressing log flying hours on aircraft *Type* \times *Age*, *Usage* and *Year* fixed effects. *Distressed Transaction* equals 1 for the buyer and seller of distressed aircraft. *Buyer* equals 1 for the buyers of aircraft. *Distressed Transaction* \times *Buyer* equals 1 for the buyer of distressed aircraft. *Age at Sale* equals the age at which the aircraft was transacted. Aircraft type and year of sale fixed effects are included in column (2) and (3). Robust standard errors are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	Operator Productivity Residuals		
	(1)	(2)	(3)
Distressed Transaction	-0.159*** (0.010)	-0.153*** (0.013)	-0.161*** (0.013)
Buyer	0.012 (0.014)	-0.004 (0.016)	-0.002 (0.016)
Distressed Transaction \times Buyer	0.159*** (0.028)	0.168*** (0.027)	0.168*** (0.026)
Age at Sale			-0.008*** (0.001)
Aircraft Type FE	NO	YES	YES
Year of Sale FE	NO	YES	YES
Observations	1,716	1,716	1,716
Adjusted R^2	0.025	0.072	0.084

Table A.7: Impact of Purchasing Distressed Aircraft on Airlines' Growth

The table shows how aircraft reallocation across firms contributes to firms' growth, and compares the post-sale users of distress-affected aircraft with the post-sale users of non-distressed aircraft. The following dependent variables proxy for firm growth: in column (1) $\ln(\text{Fleet Size})$ is calculated as the log of the number of aircraft in the operator's fleet in a given year; in column (2) Fleet Age is calculated as the average age of all aircraft flown by the operator in a given year; in column (3) Fleet Tech Age is calculated as the average tech age of the operators' fleet in a given year. Tech Age measures aircraft technological age, and is defined as the number of years since the introduction of the underlying aircraft's type. These variables for firm's growth prospects are regressed on previous year's firm productivity. The lagged variable, Productivity is defined as the average yearly flying hours of the operator across all the aircraft that are flown by that operator in the previous year. $\text{Productivity} \times \text{Buyer of Distressed Aircraft}$ is equal to the operator's lagged productivity if the operator purchased a distress-affected aircraft in a given year (i.e. the operator is the post-sale user of a distress-affected aircraft). $\text{Productivity} \times \text{Buyer of Non-Distressed Aircraft}$ is equal to the operator's lagged productivity if the operator is the post-sale user of a non distressed aircraft. The unit of observation is airline-year. The p-values of coefficient equality t-test comparing the sensitivity of productivity to firms' growth prospects for the users of distress-affected aircraft with the users of non-distressed aircraft are reported in the last row. Robust standard errors are included in parenthesis. *** denotes significance at 1%, ** at 5%, and * at 10%.

	(1)	(2)	(3)
	$\ln(\text{Fleet Size})$	Fleet Age	Fleet Tech Age
Productivity	0.715*** (0.030)	-1.623*** (0.114)	-1.012*** (0.094)
Productivity \times Buyer of Distressed Aircraft	0.242*** (0.042)	-0.201* (0.115)	-0.081 (0.061)
Productivity \times Buyer of Non-Distressed Aircraft	0.200*** (0.015)	-0.110*** (0.042)	-0.081** (0.036)
Year FE	YES	YES	YES
Observations	1,671	1,671	1,671
Adjusted R^2	0.385	0.503	0.632
(Productivity \times Buyer of Distressed Aircraft) versus (Productivity \times Buyer of Non-Distressed Aircraft) t-test p-value	0.3481	0.4544	0.9945

Table A.8: Comparison of Financial Variables across Post-Sale Users of Aircraft

This table reports the differences in lagged financial variables for post-sale users of aircraft sold by distressed airlines and post-sale users of aircraft sold by non-distressed airlines. For a user, *Tobin's Q* is measured as MVA/BVA , where the market value of assets equals the book value of assets plus the market value of common equity less the book value of common equity and deferred taxes. $\text{Log}(MPK)$ for a user is defined as the natural log of sales divided by book value of fixed assets. *Profitability* of the user is measured as operating income before depreciation, interest and taxes scaled by lagged assets. Panel A compares the performance of users of distress-affected aircraft to users of aircraft sold by non-distressed airlines on these financial variables. In Panel B, we report this comparison after demeaning the financial variables using year fixed effects. The last column reports the p-values for mean comparison tests between the users of distress-affected aircraft and the users of aircraft sold by non-distressed airlines, without the assumption of equal variance. Panels C and D report the differences in average user productivity for post-sale users of aircraft sold by distressed airlines and post-sale users of aircraft sold by non-distressed airlines based on whether financial data are available for the post-sale users. Panel C restricts the sample to users for which financial data are not available. Panel D reports comparisons across users for which financial data are available. *Average Flying Hours* for a user averages the yearly flying hours across all the aircraft that are flown by that user. For an operator, *Residuals Flying Hours** averages residuals across all aircraft flown by the operator, where the residuals are obtained by regressing log flying hours on aircraft $Type \times Age$, and $Year$ fixed effects.

Panel A: Financial Variables							
	Non-Distressed Sales			Distressed Sales			Difference
	Obs.	Mean	SD	Obs.	Mean	SD	p-value
Tobin's Q	426	1.14	0.017	89	1.31	0.034	0.0001
Log(MPK)	512	0.52	0.014	109	0.57	0.028	0.3127
Profitability	482	0.15	0.004	99	0.15	0.006	0.9865
Panel B: Financial Variables demeaned for Year Fixed Effects							
	Non-Distressed Sales			Distressed Sales			Difference
	Obs.	Mean	SD	Obs.	Mean	SD	p-value
Tobin's Q	426	-0.060	0.019	89	0.019	0.030	0.0337
Log(MPK)	512	-0.092	0.013	109	-0.104	0.023	0.6891
Profitability	482	0.038	0.004	99	0.064	0.006	0.0045
Panel C: Subsample of Users without financial data							
	Non-Distressed Sales			Distressed Sales			Difference
	Obs.	Mean	SD	Obs.	Mean	SD	p-value
Average Flying Hours	432	7.20	0.036	65	7.07	0.042	0.1875
Residuals Flying Hours*	432	-0.098	0.031	65	-0.109	0.032	0.8910
Panel D: Subsample of Users with financial data							
	Non-Distressed Sales			Distressed Sales			Difference
	Obs.	Mean	SD	Obs.	Mean	SD	p-value
Average Flying Hours	426	7.74	0.015	89	7.70	0.041	0.4634
Residuals Flying Hours*	426	0.123	0.010	89	0.112	0.022	0.6798

*Residuals demeaned for Aircraft Type \times Age, and year fixed effects

Table A.9: Flying Hours of Other Second-hand Aircraft Purchased by Buyers of Distressed Aircraft

The table reports the utilization of second-hand aircraft purchased by a buyer of distressed aircraft. *Distress* is an indicator variable that equals 1 if the aircraft was ever sold by an airline operating in bankruptcy, or by an airline during the distress period prior to its filing for bankruptcy. *Other second-hand aircraft* equals 1 for all other second-hand aircraft (not exposed to distress) purchased by the buyer of *distressed* aircraft. *Other second-hand aircraft in purchase year* equals 1 for the non-distressed second-hand aircraft purchased by the buyer of *distressed* aircraft, in the same year it purchases a distressed aircraft. The dependent variable is the log of yearly flying hours for an aircraft. Controls are included for the fleet size of an airline ($\ln(\text{Fleet Size})$), and the number of same model aircraft operating during that time period ($\ln(\text{\#type aircraft})$). Aircraft type \times age, aircraft operator, and year fixed effects are included in all specifications. Additionally, aircraft operator \times year fixed effects are included in columns (3) and (6). The unit of observation is aircraft-year. Standard errors clustered by aircraft type are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	ln(Flying Hours)					
	(1)	(2)	(3)	(4)	(5)	(6)
Distress	-0.084*** (0.020)	-0.086*** (0.020)	-0.079*** (0.016)	-0.104*** (0.017)	-0.105*** (0.017)	-0.097*** (0.014)
Other second-hand aircraft	0.061*** (0.017)	0.059*** (0.017)	0.057*** (0.016)			
Other second-hand aircraft in purchase year				0.011 (0.030)	0.007 (0.032)	0.031 (0.032)
$\ln(\text{\#type aircraft})$		0.123 (0.092)	0.094 (0.069)		0.129 (0.092)	0.100 (0.069)
$\ln(\text{Fleet Size})$		0.042 (0.024)			0.042 (0.024)	
Year FE	YES	YES	-	YES	YES	-
Type \times Age FE	YES	YES	YES	YES	YES	YES
Operator FE	YES	YES	-	YES	YES	-
Operator \times Year FE	NO	NO	YES	NO	NO	YES
Observations	58,844	58,844	57,269	58,844	58,844	57,269
Adjusted R^2	0.596	0.596	0.633	0.595	0.596	0.633

Table A.10: Misallocation during Business Cycles

This table compares the productivity of sellers with buyers of distressed aircraft during business cycles. *Distressed Transaction* equals 1 for all aircraft that are operated by the distressed seller and the buyer of these aircraft in the year of aircraft sale. *Buyer* equals 1 for all aircraft operated by the buyer in the year it purchases an aircraft. *Distressed Transaction* \times *Buyer* equals 1 for all aircraft operated by the buyer in the year it purchases an aircraft from a distressed seller. *Distressed Transaction* \times *Recessions* equals 1 for all aircraft that are operated by the distressed seller and the buyer of these aircraft in the year of aircraft sale, if the distressed aircraft is sold during NBER recession periods. In a given year, for all aircraft operated by the carrier, *Buyer* \times *Recessions* equals 1 if the carrier purchases an aircraft from a seller during recessions. *Distressed Transaction* \times *Buyer* \times *Recessions* equals 1 for all aircraft that are operated by the buyer of distressed aircraft in the year of aircraft sale, if the distressed aircraft is sold during recessions. The dependent variable is the log of yearly flying hours for an aircraft. Controls are included for the fleet size of an airline ($\ln(\text{Fleet Size})$), and the number of same model aircraft operating during that time period ($\ln(\#\text{type aircraft})$) in column (2). Aircraft type \times age, aircraft usage, and year fixed effects are included in all specifications. The unit of observation is aircraft-year. Robust standard errors are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	log(Flying Hours)	
	(1)	(2)
Distressed Transaction	-0.069*** (0.015)	-0.067*** (0.015)
Buyer	0.043*** (0.008)	0.017** (0.008)
Distressed Transaction \times Buyer	0.100*** (0.021)	0.109*** (0.021)
Distressed Transaction \times Recessions	-0.033 (0.023)	-0.045* (0.023)
Buyer \times Recessions	-0.107*** (0.022)	-0.103*** (0.022)
Distressed Transaction \times Buyer \times Recessions	0.067* (0.036)	0.073** (0.036)
$\ln(\#\text{type aircraft})$		0.101*** (0.020)
$\ln(\text{Fleet Size})$		0.054*** (0.004)
Year FE	YES	YES
Type \times Age FE	YES	YES
Aircraft Usage FE	YES	YES
Observations	59,109	59,109
Adjusted R^2	0.498	0.501