Decomposing Fire Sale Discounts

Finance Working Paper N° 722/2021
May 2022

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Abstract

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Decomposing Fire Sale Discounts

Abstract

The paper decomposes the raw fire sale discount into a quality component, a misallocation component, and a residual liquidity component. We find that distressed airlines under-maintain their fleets and, this quality impairment explains half of the discount. We find no evidence of misallocation to lower productivity users. While the raw discounts are much larger for Chapter 7 than Chapter 11 transactions, the difference is largely explained by longer periods of under-maintenance and consequently lower quality of aircraft sold in Chapter 7. The evidence suggests that the magnitude of welfare losses associated with fire sales are likely to be overstated.

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. The assets are thus misallocated to non-specialist users and the discount reflects the value of the asset in its sub–optimal use.[1]

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 selling aircraft in US Chapter 11 and Chapter 7 procedures. Pulvino (1998) attributed the fire sale discount largely to a misallocation of aircraft from high to low productivity users, suggesting that this result supports the Shleifer and Vishny (1992) hypothesis.

Fire sale discounts have been documented in other settings.[2] Campbell et al. (2011) report an average fire sale discount of 27% on the value of houses precipitated by a forced sale transaction.[3] 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 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.[4]

In this paper we revisit the fire sale discount in the context of the airline industry. The size of the fire sale discount in real asset markets is 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 in the airline industry given the provisions of Chapter 11 bankruptcy procedures allowing for a more patient sale of assets. In this event, we might expect to

[1]Several 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. It should be noted that misallocation may not be the only source of inefficiency. Fire sales may generate negative externalities for the broader economy and may even contribute to systemic shocks. For 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).

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

[3]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.

[4]Several 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).

observe low discounts with little misallocation to lower productivity users. While the higher discount for real assets vis-a-vis financial assets might be explained in part by a greater divergence in 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. In a recent paper Nowak and Smith (2020) identify salient features reflecting the quality of houses, and find that these features significantly affect the house price indices. Similar quality impairments have been documented in the shipping industry (Franks et al. (2020)).

The issue of quality is significant in the airline 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 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.[5] 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 standard databases and thus not observable to a researcher.[6]

But why is quality of an aircraft important for fire sale discount estimation? After all quality is missing for both distressed and non-distressed sales. And we know from standard econometrics that quality of the aircraft would not be an issue if it did not vary with the financial health of the airline operating the aircraft. It is, however, natural to expect that distressed firms which are financially constrained, are more likely to under-maintain their assets, a direct consequence of the debt overhang problem (Myers (1977)).[7] As a result, the estimates of fire sale discounts that ignore this quality impairment are likely to be biased upwards.

Our paper aims to correct this bias. We introduce an approach that inherently controls for quality differences between aircraft and examines the impact of such a correction on the magnitude of the fire sale discount. Our paper also investigates whether fire sales result in a misallocation of resources (Shleifer and Vishny (1992)).

The quality correction approach relies on a simple insight that ex-ante differences in quality can be gauged from ex-post performance of the asset. One has to be mindful of the fact that performance is affected not

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

[6]They are, however, likely to be known to buyer at the time of purchase. Maintenance records are available to the buyer and detailed inspections are carried out at the time of purchase to assess the quality of the aircraft.

[7]In the real estate market, Melzer (2017) documents evidence of homeowners reducing their home improvement and maintenance expenditures when faced with mortgage debt overhang.

only by the quality of the underlying asset, in this case an aircraft, but it is also affected by the ability of the operator. To identify the quality component it is therefore essential to control for operator level variables that can confound the inference. Fortunately, our set-up allows us to address this issue in a non-parametric way. We have micro-level data on annual aircraft utilization at the aircraft level. Moreover, a given operator owns a fleet of aircraft. By including operator fixed effects, that is, comparing the performance of the particular aircraft with other similar aircrafts owned by the *same* operator, we are able to purge out any operator level differences that interfere with our identification.

Using a granular measure of aircraft utilization, flying hours at the aircraft-level, we find that aircraft sold by distressed airlines have around 10% lower utilization post-distress compared with other similar aircraft flown by that *same* operator, i.e. buyer.[8] Furthermore, we find that aircraft sold by distressed airlines have 9% lower remaining life expectancy than aircraft sold by non-distressed airlines. Thus, aircraft sold by distressed airlines fly less and are retired earlier than those sold by non-distressed airlines.[9] After controlling for quality, the quality-adjusted fire sale discount for aircraft sold by bankrupt airlines is around 9%, or about one half of the raw fire sale discount. Importantly, the quality discount varies with the length of the distress period. This explains why aircraft sold in Chapter 7 have a higher quality discount than those sold in Chapter 11: they spend a longer period in distress prior to filing for bankruptcy and are therefore more under maintained. As a consequence, quality-adjusted, the fire sale discount is very similar in both Chapter 11 and Chapter 7.[10] We also find that, during recessions the quality-adjusted fire sale discount increases by 11%.

Using our productivity data, 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 allows us to examine this question. We measure misallocation by comparing flying hours and profitability measures of the new users of distressed aircraft with the following counterfactual: new users of *similar* aircraft sold by non-distressed airlines. The counterfactual provides us with a useful benchmark to examine the extent of misallocation.

We do not find, in our sample, evidence of misallocation of aircraft to lower productivity or less profitable firms. We find that buyers of aircraft that were sold by distressed airlines are no different in terms of

[8] Aircraft sales by distressed airlines include sales made by airlines that are operating in Chapter 11 or Chapter 7 bankruptcy, or in the distress period prior to filing for bankruptcy. The beginning of the distress period is defined using the event of a bond downgrade (to sub investment grade status) prior to the airline filing for bankruptcy.

[9] Given that the average depreciate rate of the aircraft is 2.5% in our sample, this is equivalent to the aircraft that is being sold in a distressed sale being effectively 4 years older when compared to an otherwise similar non-distressed aircraft.

[10] Franks 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.

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

productivity or profitability to the buyers of aircraft sold by non-distressed airlines. In other words, the fact that an asset is transacted in a distressed sale does not have an impact on its allocation to a particular buyer. We augment this analysis by comparing buyer minus seller productivity for distressed sales with non-distressed sales. We find that if anything the difference is higher for distressed sales. That is, there is a bigger gain in productivity and profitability for distressed sales than regular sales, suggesting that sellers were economically distressed and the change in ownership represents an efficiency gain and not a loss arising from a misallocation of assets.

This result extends to firms that emerge from Chapter 11 as going concerns with their aircraft fleets largely intact. We find their productivity post emergence is higher than their pre-bankruptcy distress levels. This suggests that the quality-adjusted fire sale discount of 9% is not due to the misallocation channel, but is more likely a transfer from the seller to the buyer due to the greater bargaining power of the buyer, i.e., the liquidity 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.[12] For the sample of bankrupt operators that emerge as going concerns, we find higher productivity post-bankruptcy compared with the pre-filing period, which is consistent with the bankruptcy process having a cleansing effect on industry inefficiencies, rather than any misallocation.[13]

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. However, neither the previous literature, nor our paper, takes account of the externalities associated with fire sales.

[12]This 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.

[13]In 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 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. The bankruptcy process rather than causing a misallocation of assets from high to low productivity users should have 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, and describe the data and summary statistics. In section 3 we describe the evidence for the quality variations between aircraft sold by distressed and non-distressed sellers. Section 4 describes the empirical methodology and provides estimates of the quality-adjusted fire sale discount. Section 5 presents evidence on aircraft reallocation, and 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, how the discount varies with economic activity, and the role of leasing companies in the airline industry. Section 7 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 prior to any sale, indicating that there is little asymmetric information between buyers and sellers of used commercial aircraft (see also, Gavazza (2011a)). Such information, however, is private to the parties involved in the transaction, and generally not available in existing datasets.

Researchers have focused on the airlines industry to answer important questions regarding the estimation of the fire sale discount and other trading frictions (see for example, Pulvino (1998, 1999), Benmelech and Bergman (2008, 2011), Gavazza (2010, 2011a), and Bian (2020)). 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 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 well documented in the technical aviation literature, where maintenance and safety considerations have led to wide availability and high accuracy of aircraft level capacity utilisation data. We use the lower flying hours and reduced life expectancy of distress-affected aircraft, as proxies for the productivity of aircraft. The micro tracking of each aircraft at the airline level allows us to consistently trace aircraft reallocation from one user to another, and measure airline level productivity. The data are used to address 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 provide a more detailed description of these issues 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.[14] 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 which liquidated in Chapter 11, or emerged as a going concern. As a result, we might expect that the

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

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.[15] The dataset reports information of aircraft characteristics including the aircraft 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 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.[16]

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

[16] For 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.

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 utilisation using flying hours for the period from 1975 to 2015.[17] We have operational data on 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.[18] We show in Panel A for the full sample that an average aircraft flies for 2,171 hours annually. Conditional on not being parked, an average aircraft flies for 2,195 hours annually. We also report statistics for 3 subsamples: (i) aircraft sold by airlines in Chapter 7 bankruptcy, (ii) aircraft sold by airlines during Chapter 11 bankruptcy protection, and, (iii) aircraft that were sold outside bankruptcy. Aircraft that were sold by airlines that liquidated in Chapter 7 fly for 1,269 hours annually, while those sold in Chapter 11 fly for 1,979 hours annually. These levels of utilization are significantly below the average utilization of aircraft that were not exposed to bankruptcy.[19]

While, Panel A summarises data on flying hours, Panel B reports the characteristics of aircraft sales during our sample period, 1975 to 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, 252 aircraft were sold by airlines operating under Chapter 11, while 48 were sold by airlines operating under Chapter 7.[20] Using retirement dates in our database, we find that of the 4,235 aircraft 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 their cumulative hours flown 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 in Chapter 7 bankruptcy, (ii) sales by airlines during Chapter

[17] The aircraft utilization database comprises of all the aircraft types for which we have the transaction prices data.

[18] *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.

[19] Aircraft sold in Chapter 11 bankruptcy protection spend a slightly higher proportion of their time parked (1.5%); there is no significant difference in parking time for the 3 subsamples of aircraft.

[20] The average age of aircraft sold in Chapter 7 is 12 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.

[21] 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 reflects the fact that when an aircraft has zero flying hours for an entire year, it is described as being *parked* in the database.

11 bankruptcy protection, and, (iii) sales made by non-bankrupt airlines. We find that aircraft sold by airlines operating in bankruptcy have a lower median retirement age (27 years) compared with aircraft sold by non-bankrupt airlines (29 years). Also, the cumulative flying hours of aircraft sold by airlines in Chapter 7 are significantly less than aircraft sold by non-bankrupt airlines. The median cumulative flying hours of aircraft sold by airlines in Chapter 11 are around 4% lower than aircraft sold by non-bankrupt airlines. The difference between Chapter 11 sales and non-bankruptcy sales increases when we control for aircraft model and usage fixed effects. We explore these differences in retirement age and flying hours in detail in the next section.

In Panel C 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.[22] 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; these differences become more marked when we control for aircraft type and other characteristics.

3 Evidence on Aircraft Quality Impairment

As discussed earlier, the quality of transacted aircraft is an important omitted explanatory variable in the hedonic price regression. It is particularly important since it seems to be correlated with the financial health of an airline company, evidence of which was presented in the summary statistics in Table 1. We reported that both the retirement age and the cumulative flying hours were lower for aircraft that were sold by airlines in bankruptcy compared with aircraft that were sold by non-bankrupt airlines. Such a correlation would generate an upward bias in the estimated fire-sale discount. The descriptive statistics, however, were unconditional averages and did not include relevant control variables that could affect the pricing of aircraft. In this section, we conduct a more rigorous analysis to examine if there is indeed a quality impairment for aircraft that were sold by distressed airlines.

[22]We conjecture that the proportion of Chapter 7 sales greatly reduces post 1994 due to the increased effectiveness of Section 1110.

3.1 Cumulative Flying Hours and Retirement age

We begin by comparing the total flying hours of aircraft sold by distressed airlines with aircraft sold by non-distressed airlines. 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.

The results are reported in Table 2. The indicator variable *Distress* 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.[23] In columns (1) and (2), we report our results using aircraft type, aircraft usage and year of retirement fixed effects. The dependant variable is the natural logarithm of total flying hours. We find that aircraft exposed to distress fly approximately 8% less than similar aircraft sold by non-distressed sellers. We also find that the cumulative flying hours are lower for aircraft that were exposed to distress earlier in their economic life suggesting that 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 divide distressed sales into subsamples of sales made by airlines in Chapter 7 and Chapter 11, respectively. We find that an aircraft sold by an airline being liquidated in Chapter 7 is utilized around 15.4% 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 6.7% less than other similar aircraft not exposed to distress.

We also examine the retirement age and find similar patterns. Controlling for aircraft type, age at sale, and retirement year fixed effects, aircraft sold by distressed airlines have roughly 1.6 years shorter lifespan. On splitting distressed sales into Chapter 7 and Chapter 11 sales, we find that aircraft sold by airlines liquidating in Chapter 7 retire around 2.7 years before aircraft sold by non-distressed airlines. Similarly, aircraft sold in Chapter 11 have roughly 1.7 years shorter lifespan.[24] We also apply duration analysis to aircraft retirement age and calibrate the hazard function for an aircraft. Figure 1 plots the hazard rate and life expectancy for aircraft sold by airlines operating in bankruptcy relative to other transacted aircraft. It shows that aircraft exposed to bankruptcy have a lower life expectancy versus non-distressed aircraft.[25]

Thus, we find that aircraft sold by distressed airlines have lower total flying hours and retire earlier. Both these results suggest that distressed aircraft are effectively older than their chronological age. While

[23] The variable $Age - \overline{Age}$ *(at distress)* measures the difference between the age at distress (Age) for the aircraft sold by a distressed airline, and the average age ($\overline{Age}$) of all aircraft sold by distressed airlines.

[24] refer to Table IA.1.

[25] We discuss the details of Table IA.1 and the hazard model in Appendix B.

this evidence provides a strong link between distress and quality of aircraft, it might be the case that lower cumulative flying hours are an outcome of the aircraft being allocated to lower productivity users (Shleifer and Vishny (1992)). It is crucial to separate the quality channel from the misallocation channel. In the next subsection, we address this issue by shifting our analysis to annual flying hours, and analyzing the variation in flying hours of aircraft within a given operator's fleet.

3.2 Annual Flying Hours

Annual aircraft flying hours allow us to investigate whether aircraft sold by distressed airlines fly less while they are in use by the new operator. Our specification allows us to examine the utilization of aircraft within a given operator. In the language of fixed effects, this is equivalent to adding *operator* fixed effects. The effect of financial distress of the seller on the future utilization of an aircraft is estimated via the following equation:

$$\log(Hours)_{it} = \beta Distress_{it} + \beta_t + \beta_{Type \times Age} + \beta_{operator} + \gamma X_{it} + \epsilon_{it} \tag{1}$$

where, $\log(Hours)_{it}$ measures the yearly flying hours of aircraft i in year t, conditional on the aircraft not being parked.[26,27] $Distress_{it}$ is a dummy variable taking value 1 if the aircraft i was ever sold by a distressed airline 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 × Age ($\beta_{Type \times Age}$) 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.[28] Finally, operator fixed effects ($\beta_{operator}$) ensure that our results are not driven by any airline specific factor, for example, they reflect the management or operational priorities of an airline. The aircraft acquired from distressed airlines are compared with other similar aircraft operated by the *same* carrier. This comparison of buyer's utilization of the distressed aircraft with the utilization of other aircraft in its fleet allows us to isolate the under-maintenance effect. If the utilization of the distressed aircraft is

[26] The 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. To measure utilization we use the yearly flying hours of an aircraft, conditional on it not being parked. In Table 1 Panel A we show that there is no significant difference in parking time for aircraft sold in bankruptcy compared with other non-distressed aircraft. All our results are robust to including the aircraft-years spent in parking, i.e. using the (unconditional) yearly flying hours as a measure of aircraft utilization.

[27] In our main specification the standard errors are clustered by aircraft type. All our results are robust to clustering the standard errors by the aircraft operator.

[28] Using 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 × 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.

lower than other similar aircraft in the buyer's fleet then this is consistent with an under-maintenance effect. As a robustness check, we include additional controls for the number of same type of aircraft operating in the market in a given year, and operator fleet size (X_{it}).[29]

Table 3 Panel A, 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 buyer of the distressed aircraft. In column (3), we include aircraft operator × 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 productivity of post-sale operators.[30] In columns (4) to (6), we split our sample of distressed sales into 3 categories: sales made by airlines while operating in Chapter 7, Chapter 11, and in the 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 14.4% 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 7.6% 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.[31] If the flying hours of an ageing aircraft depreciate at 2.5% every year, then a 10% lower utilization translates into approximately 4 years of lower operating life. Thus, a 10 year old distressed aircraft is effectively older than its chronological age, and is instead being utilized as a 14 year old aircraft.

Notwithstanding, it maybe argued that the documented lower flying hours of a distressed aircraft reflects not their lower quality (under-maintenance), but rather their deployment say, to less profitable routes. This seems rather unlikely for several reasons. It is unclear why from a group of otherwise similar aircraft, the aircraft that is bought in a distressed transaction should be systematically chosen to be deployed to an inferior route. All aircraft should be equal contenders for such redeployment. To illustrate this point, we compare the utilization of non-distressed second-hand aircraft with the aircraft purchased from distressed airlines by the same buyer. In Table 3 Panel B, we split the fleet of the buyer into 3 samples: (i) aircraft purchased from distressed sellers, (ii) other second-hand aircraft purchased in regular sales in the same year the buyer purchases a distressed aircraft, and (iii) the remaining aircraft in the buyers' fleet. In columns (1) and (2) we find that distressed aircraft are utilized around 10% less than the other second-hand aircraft

[29] In commercial aircraft markets, Gavazza (2011b) documents that aircraft with a *thinner* market are less liquid and more difficult to sell, and this lowers their average productivity. This is because firms hold on longer to less redeployable assets amid profitability shocks, and as a result, the aircraft average productivity is lower in *thin* markets. To account for this, following Gavazza (2011b), we include controls for the number of same type of aircraft operating in the market in a given year, and operator fleet size.

[30] In Appendix B (Table IA.3), in a specification similar to Table 3, we include operator × type, operator × year, and type × 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.

[31] We 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.

purchased by the same buyer. In addition, the utilization of other non-distressed aircraft purchased in the same year in which the buyer purchased a distressed aircraft, is almost similar to other aircraft in the buyers' fleet (i.e. aircraft that were not transacted in that year). 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. In column (3) we show that this result is robust to controlling for time varying trends in the buyers' productivity (using operator × year fixed effect). 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.[32]

We further break down the aircraft utilization into three phases: (i) pre-distress period, (ii) during the distress period, and (iii) post-distress period. Prior to the distress event, we find no evidence of lower productivity of aircraft sold by distressed airlines.[33] However, in the post-distress period we see a significant drop in the utilization of these aircraft. We also restrict the analysis to the sample of aircraft for which we have transaction prices data (in Table 1 Panel C), which are used to measure the fire sale discount. We find that aircraft transacted by distressed airlines during 1978-1991 exhibit similar lower productivity post-sale.[34]

4 Empirical Methodology and Results

In the previous section we have documented evidence that the quality of an aircraft is negatively correlated with the financial distress of its seller, and therefore, a crucial challenge in calculating the fire sale discount is that it subsumes a quality discount. In this section we outline a simple methodology for isolating the quality discount from the raw fire sale discount and, present the quality-adjusted fire sale discounts for different intensities of financial distress.

4.1 Methodology

The fire sale discount is calculated using hedonic models. Essentially, the price of a transacted asset (aircraft here) is regressed on observable characteristics, and the estimated coefficients are then used to predict the true value of the asset. The fire sale discount is the difference between the actual price and the model

[32] There is also an opportunity cost of continuing to operate an aircraft sub optimally. A buyer of the distressed aircraft could always resell the aircraft at a price in the secondary market that reflects optimal use by another operator. Moreover, while we do not have information on which route that aircraft operates, it is well known that aircraft of a given type fly similar distance routes (see footnote 28). Our results are unaffected when we include different variants of aircraft model fixed effects.

[33] Refer to Table IA.2

[34] Refer to Table IA.4. As the coefficients reported in Table IA.4 and Table 3 Panel A are virtually identical, we perform our other utilization tests on the full sample of bankruptcies from 1975 to 2015.

predicted price.[35] In our empirical methodology, we make a simple adjustment to account for the fact that aircraft sold by distressed airlines are under-maintained. The quality correction relies on the insight that ex-ante differences in quality can be gauged from ex-post performance of the asset.

We propose a simple approach to capture the quality correction. The adjustment is motivated from the observation that aircraft sold by distressed airlines are effectively older than equivalent regular aircraft. We capture the quality effect through this aircraft effective age ($\tilde{Age}$). We assume (for sheer simplicity) that financial distress adds δ years to the aircraft's chronological age (Age). Given this, the effective age of an aircraft can be written as $\tilde{Age}_i = Age_i + \delta Distress_i$. We adjust the hedonic regression by substituting effective age ($\tilde{Age}_i$) of the aircraft instead of their actual age. This gives us the modified fire sale discount regression as:

$$p_i = \alpha_p + \beta_p X_i + \gamma_p \tilde{Age}_i + \lambda Distress_i + \epsilon_{p,i} \tag{2}$$

Equation 2 specifies the price p_i of an aircraft i, as a function of its characteristics. X_i is a vector of other physical characteristics, including the aircraft's model and engine noise characterization. The pricing equation includes in addition to the physical characteristics, a liquidity factor, with a coefficient λ, that measures the fire sale discount. We expect λ to be negative.

Our main quality adjustment is calibrated using the post-sale annual flying hours (h_i), though the results are similar if we use other metrics such as post-sale life expectancy or post-sale total flying hours.

Essentially, we estimate the following regression:

$$h_i = \alpha_h + \beta_h X_i + \gamma_h \tilde{Age}_i + \epsilon_{h,i} \tag{3}$$

We expect $\tilde{Age}$ to have a negative effect on the aircraft's price and performance (i.e $\gamma_p < 0$ and $\gamma_h < 0$). The error terms (ϵ) satisfy the usual conditions.

We rewrite equations 2 and 3 in the following reduced form setup:

$$p_i = \rho_0 + \rho_1 X_i + \rho_2 Age_i + \rho_3 Distress_i + \zeta_i \tag{4}$$

$$h_i = \phi_0 + \phi_1 X_i + \phi_2 Age_i + \phi_3 Distress_i + \xi_i \tag{5}$$

that allows us to solve for the structural parameters:

$$\hat{\delta} = \frac{\hat{\phi}_3}{\hat{\phi}_2}, \qquad \hat{\gamma}_p = \hat{\rho}_2, \qquad \hat{\lambda} = \hat{\rho}_3 - \hat{\gamma}_p \hat{\delta}$$

[35] It is important to highlight that unlike Pulvino (1998, 1999) who calculates the fire sale discount using a two-stage procedure, we do it all in one regression. We believe that our approach is econometrically more accurate. Both approaches, however, produce fairly similar raw fire sale discount results (see Appendix D).

The quality adjustment, δ maps the lower flying hours of distressed aircraft (ϕ_3) into an effective age measure, using the depreciation schedule of ageing aircraft (ϕ_2). To understand this, consider a 15 year old aircraft that was sold by a distressed airline. Assume that distressed aircraft have 8% lower flying hours compared with regular aircraft, and aircraft flying hours depreciate by 2.5% every year. The quality adjustment δ essentially changes the units from utilization rate (lower percentage flying hours) to years (higher effective age). Financial distress therefore has an effect equivalent to increasing the chronological age of the aircraft from 15 to $15 + \frac{8}{2.5} = 18.2$, with a respective effect on the aircraft's price. In this example, δ equals $\frac{8}{2.5} = 3.2$.[36]

For the quality correction, we first estimate δ from the post-sale flying hours of an aircraft. Next, we use it to calculate the aircraft's effective age ($\tilde{Age}_i = Age_i + \delta Distress_i$). Finally, we substitute the effective age ($\tilde{Age}_i$) in equation 2, to estimate the quality-adjusted fire sale discount λ.

In this subsection we have outlined a very simple methodology for isolating the quality discount from the raw fire sale discount. Here, we have illustrated the decomposition using effective age to measure the quality variation between distressed and non-distressed aircraft. The empirical analysis that follows is not limited to this specification, but is also robust to including other quality measures in the hedonic model. For example, instead of effective age, predicted aircraft flying hours can be included in the hedonic model, giving us very similar results for the quality adjusted fire sale discount.

4.2 Quality Adjusted Fire Sale Discount

As discussed in the previous subsection, the quality adjustment, δ estimates the number of years distress adds to the age of an aircraft. We estimate δ for varying degrees of financial distress, and different aircraft types using equation 5. Specifically, δ is estimated using the flying hours of aircraft exposed to distress (Table 3 Panel A column (6)). We find that on average an aircraft sold by distressed airlines is effectively 4.4 years older than an aircraft sold by a non-distressed airline.[37] Our estimate of δ using post-sale flying hours allows us to control for aircraft operator $\times$ year, and type $\times$ age fixed effects. This ensures that our estimate captures the quality of an aircraft, and is not biased by the productivity of the post-sale operator.

We report the raw fire sale discount in columns (1) and (2) of Table 4 Panel A. We regress the price of an aircraft on its observable characteristics (including fixed effects for aircraft model, size $\times$ year quarter,[38] engine noise category), age at sale, and incidence of distress of its seller. Fixed effects for aircraft size $\times$ calendar-quarter separately control for the time varying demand and liquidity factors associated with narrow bodied and wide bodied aircraft. Engine noise category fixed effects control for the noise stage of the aircraft

[36] Refer to Figure IA.1 for a graphical illustration of calibrating δ.
[37] In Table IA.5, we report our average estimates of the quality adjustment (δ) for varying degrees of financial distress.
[38] Aircraft size is grouped into narrow and wide body

engines.[39] Including seller fixed effects allows us to isolate the effect of bankruptcy on prices from the firm specific effects.[40] 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 discount of around 5% (in column (2)). In Appendix D, to make an exact comparison with Pulvino (1998), we estimate the raw fire sale discount replicating his two stage procedure, and find a 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. We measure the *effective age* of an aircraft using aircraft flying hours. The *effective age* of an aircraft is calculated by adding δ years to the age at sale of the distressed aircraft. In columns (3) and (4) of Panel A, we regress the price of an aircraft on its characteristics, effective age, and incidence of distress of its seller. We report that the quality adjusted fire sale discount is between 8% and 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.[41] Quality impairment therefore explains roughly 50% of the raw fire sale discount and, after controlling for quality, the fire sale discount declines to 8-9% for the sale of aircraft by distressed airlines.[42] 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 (4)). 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 6.

For columns (5) and (6), we calibrate δ using the flying hours of the sample of aircraft for which we have transaction prices data (Table IA.4 column (6)). This ensures that the quality correction is estimated on exactly the *same* sample of aircraft for which we have the transaction prices (i.e. aircraft that were sold by distressed airlines between 1978-1991). We again find a very similar quality adjusted fire sale discount of 8-9% on sales of aircraft by distressed airlines.

[39] A stricter specification might allow for aircraft model $\times$ time 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).

[40] Seller 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.

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

[42] To supplement our analysis, we have also used aircraft retirement age and cumulative flying hours to estimate the effective age of aircraft exposed to distress. The quality-adjusted fire sale discount is similar using either proxy, flying hours, or retirement age, or cumulative flying hours (results available on request). The high correlation between these quality impairment measures results in similar fire sale discount estimates with each of these measures.

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)).[43] Comparing columns (2) and (4), we find that the raw fire sale discount reduces by around 16 percentage points (or 57%) for Chapter 7 sales and, by about 9 percentage points (46%) for Chapter 11 sales, a reflection of the quality adjustment. The large difference in the quality adjustment between Chapter 7 and 11, reflects the lower life expectancy of aircraft sold in Chapter 7, and their substantially lower utilization i.e. lower flying hours, for their remaining lives after the sale; see Table 3 Panel A above. For sales made by an airline during the distress period prior to filing for bankruptcy, the raw fire sale discount reduces by around 7 percentage points 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, 12.7% and 11%, respectively.[44] The quality impairment on aircraft increases with the depth of distress, as proxied by the length of the 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. In 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.

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. In retrospect, it should not surprise that a 10% reduction in utilization of distressed aircraft owing to under maintenance, results in roughly a 10% quality impairment discount.[45] 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 utilization of the asset and its under-maintenance, and not to the attributes of the purchaser. The productivity of these aircraft is lower

[43] This 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.

[44] In 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.

[45] Our 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.

than the other aircraft operated by the non-distressed purchaser which have not been exposed to distress. In Table 5 we summarize the fire sale discounts for different definitions of financial distress. We find that after controlling for quality, financially distressed airlines sell aircraft at around 9% fire sale discounts. 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.

5 Evidence on Aircraft Misallocation

In the previous sections we have analyzed variations in the quality of distressed aircraft using within operator comparisons with other aircraft in the buyer's fleet. This has allowed us to isolate the quality impairment channel, while filtering out aircraft allocation considerations. In this section, we investigate the extent to which the quality-adjusted fire sale discount is attributable to the misallocation channel. To do this we devise a simple approach that can be best understood from the following example. Consider two aircraft A and B being transacted in the second-hand market at a given point in time. These aircraft A and B are otherwise identical in all respects, but aircraft A is sold in a distressed transaction whereas B is being transacted as a regular sale. We then compare the productivity of the buyers that are purchasing each of these aircraft. The productivity of the buyer of aircraft B provides us with the correct counterfactual to evaluate the extent of misallocation of aircraft A. We also supplement this analysis by examining the difference between buyer and seller productivity for each of these aircraft.

An alternative conjecture to the misallocation hypothesis, particularly relevant in the presence of Chapter 11 type procedures, 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, we begin by identifying the operators and status of aircraft post their sale. 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.[46] 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 both parking and flying hours. Parking indicates that an aircraft is inactive and involves costly downtime. We might expect that since aircraft are often sold to leasing companies and other financial intermediaries, parking would be higher for aircraft purchased from distressed sellers. Rather,

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

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, 14.6% aircraft sold by distressed airlines are parked by their new users, as opposed to 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.[47] This suggests that most aircraft sold by distressed airlines are quickly redeployed to operational use.

5.1 Reallocation of aircraft sold by distressed airlines

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 airlines' productivity (Gavazza (2011a,b), Benmelech and Bergman (2011) and Bian (2020)). In the next subsection, we also use financial measures as a proxy for productivity to test the robustness of our analysis. Whereas financial measures are only available for listed airlines the productivity data are available for both listed and non-listed US airlines.

Following Gavazza (2011a,b) and Bian (2020), we use aircraft flying hours aggregated at the airline level to measure the airline's productivity. Our sample includes all U.S. operators.[48] Flying hours of an airline's fleet are measured after controlling for the differences in aircraft type, aircraft age, aircraft usage, and other macro trends affecting aircraft utilization. More specifically, for aircraft i flown by operator j in year t:

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

where, $\log(Hours)_{ijt}$ measures the annual flying hours of an aircraft i, flown by operator j, in year t. From the above regression we calculate the residuals (ϵ_{ijt}), after partialling out aircraft specific factors ($\beta_{Type\times Age}$), usage category (β_{Usage}),[49] and year specific trends (β_t) in aircraft productivity. Post sale, both in the case of distressed and non-distressed aircraft sales, 82% of the aircraft are used as passenger aircraft, while the rest are used by cargo airlines.[50] The unexplained difference in flying hours of the above regression captures the productivity of the operator. Therefore, the airline productivity is calculated by averaging the residuals (ϵ_{ijt}) across all the aircraft that are flown by the operator j.

[47] Also, we find no evidence that aircraft sold by bankrupt airlines have a higher probability of being parked post sale. At the end of the same year as the sale, 11% aircraft sold by bankrupt airlines are parked with their new users. By the end of the next year following the sale 2% of the aircraft sold by bankrupt airlines are parked.

[48] Post sale, 95% aircraft sold by distressed operators are flown by U.S. operators. In 78% of sales by non-distressed owners, the aircraft are used by U.S. operators post sale.

[49] Aircraft usage category is grouped into passenger or cargo aircraft.

[50] Both 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.

In Table 3 Panel A column (6), we measure the productivity of an airline in a given year using the *Operator* × *Year* fixed effects; we also partial out aircraft specific factors (*Type* × *Age*), usage category, and year specific trends affecting the aircraft utilization of its fleet.[51]

We test the misallocation hypothesis 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 are allocated to less productive buyers, and thereby, the productivity of the buyer (or user) is lower than that of the seller. In our sample, we test this hypothesis empirically by comparing the differential productivity across the buyer and seller of the asset around the year of its sale. If the difference is positive the productivity of the buyer is higher than that of the seller. Figure 2 Panel A, plots the distribution of this difference for aircraft sold by distressed airlines (blue curve), and for aircraft sold during other transactions (red curve). As buyer minus seller productivity is positive in the majority of the sales made by distressed operators, we can conclude that post their sale, these aircraft are operated by more productive buyers. There is an economically large and statistically significant difference between buyer and seller productivity for distressed sale.[52]

We have argued earlier that although the buyer is more productive than the seller, the distressed aircraft might have been allocated to a buyer whose productivity is below the average for the industry, and that it would have been allocated to an even more productive user if it had not been sold in a fire sale. To test this hypothesis, we assess aircraft redeployment by using a comparison of post-sale users of distressed aircraft with post-sale users of non-distressed aircraft. Figure 2 Panel B, plots the kernel density of operator productivity for post-sale users of the distressed and non-distressed aircraft. These distributions are virtually identical, and confirm that the buyers of the distress-affected aircraft are not on average less productive than other buyers of second-hand aircraft.

In Figure 3 Panel A, we plot the mean difference in productivity of the buyer and seller of distressed aircraft for 3 years prior to the year of aircraft sale. The event year (from -1 to 0) is defined as the year in which the aircraft was transacted. We choose 3 years because the average distress period is roughly 2.4 years.[53] If distress is the cause of the lower productivity of the seller then we would expect that the difference in buyer-seller productivity would be low or zero early on in the distress period and increase as the period of distress progresses. We find exactly this pattern: the average productivity difference between the buyer and seller increases with event time, and the difference is virtually zero at the beginning of year -3,[54] and reaches

[51]There is a only a marginal difference between the two approaches that we are discussed for measuring airline productivity. Using *Operator* × *Year* fixed effects from Table 3 allows us to measure the productivity of an airline in a single stage regression. While by averaging the residuals obtained in equation 6, the productivity of an airline is calculated in 2 stages. We find that all the results reported in this section are highly robust to using either measure of operator productivity. (Results from using the 2 stage approach of equation 6 are available on request.)

[52]The evidence is consistent with the finding that markets for used capital reallocate assets from less productive to more productive firms (Maksimovic and Phillips (2001)).

[53]Distress period is defined as spanning the bond downgrade (prior to filing for bankruptcy) to the sale of the aircraft.

[54]this difference is also virtually zero at the beginning of years -4 and -5.

its maximum in the year of aircraft sale; buyers of aircraft sold by distressed airlines are almost 17% more productive than the sellers.[55] These differences are both economically large and statistically significant.

In the same specification we also compare the productivity of the buyers of distressed aircraft with other buyers of non-distressed aircraft of a similar vintage. This allows us to test whether these two sets of buyers are similar or are drawn from two different groups of operators. If airlines that are buyers of distressed aircraft are generally of low productivity while other airlines of higher productivity avoid this market, then we might observe a segmented market for distressed aircraft sales where buyers typically have lower productivity than other buyers of non-distressed aircraft; this would be suggestive of misallocation. In Figure 3 Panel B, we analyse a 5 year period straddling the year of the sales transaction. We find that the productivity of buyers of distressed aircraft are almost the same as the productivity of other buyers in the second-hand aircraft market. There is no economically or statistically significant difference in productivity between these two sets of buyers during the 5 year event window around the aircraft sale.[56]

To augment our analysis, in Table 6 we test for differences in productivity between buyers and sellers of aircraft, 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. 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* × *Buyer* equals 1 for the buyers of distressed aircraft. In column (1), we report that the difference between buyer and seller productivity in distressed aircraft sales is 19%, 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)-(4), we control for aircraft characteristics at sale, that might influence the kind of buyers that purchase these aircraft. For example, in column (4), 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 there is a significant difference of 16% between buyer and seller productivity in distressed aircraft sales, and the productivity of the buyer of distressed aircraft is almost similar to the productivity of the buyer of non-distressed aircraft.[57]

[55] The comparison in Panel A stops in year 0 as most of the distressed sellers ceased to operate shortly after liquidating their aircraft in bankruptcy.

[56] Our results are robust to choosing a 7 years event window around the aircraft sale.

[57] In Table 6 column (4), the average productivity of the seller of distressed aircraft is -21.2%, while the productivity of buyers of distressed aircraft is -5.4% (= -0.212-0.067+0.225). The productivity difference of 15.8% between the buyers and sellers of distressed aircraft is significant (p-value is 0.0034). The average productivity of the buyers of non-distressed aircraft is -6.7%, and the productivity of buyers of distressed aircraft is -5.4%. The difference of 1.3% between the buyers of distressed and non-distressed aircraft is insignificant (p-value is 0.8084).

5.2 Alternate measures of aircraft reallocation

We use financial variables of the airlines to test whether aircraft sold by distressed airlines are misallocated. 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 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. Another 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.[58] $Log(MPK)$ 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, with the post-sale users of aircraft sold by non-distressed airlines.

Table 7 Panel A reports our results. Using measures of *Tobin's Q*, $log(MPK)$, and $Profitability$ we can conclude that the users operating distress-affected aircraft are at least as efficient as other users of non-distressed aircraft. Our comparison using Tobin's Q suggests that buyers of distressed aircraft have a higher average Tobin's Q of 1.31, than the average of other users' at 1.16. 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.[59] 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 7 Panel B. Our analysis 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.

A selection concern may arise because we only have financial data for roughly half of our sample of companies; as a result, there is a concern that this subsample of listed companies may be more profitable and have higher productivity than the subsample of unlisted companies. Since we are concerned with differences

[58] Cong et al. (2019) present a model of resource misallocation based on Hsieh and Klenow (2009). The measure 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.

[59] The 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).

between the distressed and the non-distressed sales, in Panel C we compare our previously defined measures of productivity for the distressed and non-distressed buyers for the subsample of unlisted companies. These differences are not statistically significantly different from zero, suggesting that similarities in productivity for the different subsamples of both listed and unlisted companies are consistent with similar levels of profitability.

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 8 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 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* × *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* × *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 8, 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). 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. 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.

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.

6 Additional Results and Discussion

6.1 How fire sale discounts are affected by bankruptcy procedures

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; all the remaining aircraft were sold by airlines that did not have bond ratings.

Of the 46 airlines that entered bankruptcy, 34 sold all their aircraft in Chapter 11, while another 4 sold aircraft in both Chapter 11 and Chapter 7.[60] In all cases where operators sold aircraft in Chapter 7 they previously filed and sold aircraft in Chapter 11. In addition to the 34 operators, another 8 entered Chapter 11 and emerged as going concerns; the other 34 were liquidated. We find a sharp difference in the average time spent in distress for operators that sell aircraft in Chapter 11 only, compared with those operators that sell aircraft in both Chapter 11 and Chapter 7. Defining the period of distress as spanning the bond downgrade (prior to filing for bankruptcy) to the sale of the aircraft, we find it is 2 years for aircraft sold by operators in Chapter 11 only, and 3.9 years for operators that sold aircraft in Chapter 11 and Chapter 7.[61] We would predict that aircraft sold in Chapter 7 are owned by operators that under maintain their fleet more than those operators which only sold aircraft in Chapter 11; the former 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 3.1%, 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 sales, 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 broadly similar to the under-maintenance effects reported in Table 3 Panel A. It appears that much of the under

[60] Of these 34 airlines, 12 filed for Chapter 7 but did not sell any aircraft in Chapter 7.

[61] For Chapter 11 sales the distress period for operators prior to filing is 1.2 years, and 1.9 years for operators filing for Chapter 7. For operators that only filed for Chapter 11 their average period in bankruptcy prior to sale of the aircraft is 0.8 years, while it is 1.8 years for those aircraft sold by operators that subsequently filed for Chapter 7. Aircraft sold in Chapter 7 spend only a very short time, averaging 2.8 months in Chapter 7, after the Chapter 11 bankruptcy case is converted into Chapter 7.

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.

Our findings suggest that the apparent difference between the fire sale discounts in Chapter 7 and Chapter 11 sales, as estimated by Pulvino (1999), does not depend on the particular bankruptcy procedure, but rather reflects the intensity of distress of the seller of the asset; and as we show is related to an under-maintenance effect. After adjusting for this under-maintenance effect the fire sale discounts are almost identical for these two procedures. This may be less surprising than it seems, because the aircraft sold in Chapter 7 spend so little time in this procedure prior to sale. Thus, we believe that aircraft sale prices are largely determined by the provisions of Chapter 11.

This test further corroborates our evidence that the lower utilization of distressed aircraft post-sale is attributable to their under-maintenance by the distressed seller. It addresses the issue that the lower utilization of these aircraft is not due to the buyer misallocating them to inferior routes. This is because, as time in distress increases, the aircraft is more likely to be transacted in a patient sale, and therefore, there is a lower likelihood of it being misallocated. We find that as the length of distress period increases, the future utilization of an aircraft decreases. This is consistent with the under-maintenance channel (and not the misallocation channel), that we have identified in our analysis.

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.[62] In Table 10 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 3. We find that the additional fire sale discount for distressed aircraft sold during recessions reduces to almost 11% (in column (4)) once we control for the

[62] During 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.

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.[63]

In Figure 5, we test if distressed aircraft sold during recessions are misallocated to lower quality buyers. In a setting similar to Figure 3, we investigate whether there is evidence of misallocation during recessions. We compare the operator-level time varying productivity of the sellers and buyers of distressed aircraft that are sold during recession periods. In Panel A of Figure 5 we report that in the year of sale (year 0), for sales made during recessions the buyer is around 11% more productive than the seller of distressed aircraft. Further, Panel B reports that the productivity of buyers of distressed aircraft is slightly higher than the productivity of other buyers in the second-hand aircraft market during recessions. This suggests that there is not any misallocation of distressed aircraft to lower productivity users, compared with non-distressed aircraft sold during recessions.[64] We also restrict our sample to the transactions for the shorter period where we have price data, 1978 to 1991, comparing the productivity of the sellers and buyers of distressed aircraft during recessions, and find that distressed aircraft do not appear to be misallocated during recessions.[65]

In summary, 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 17% in recessions, compared with around 7% in non-recession periods. Since we find no evidence of differential misallocation of distressed aircraft compared with non-distressed aircraft during recessions, we attribute the higher fire sale discount in recessions to the greater need for immediacy.[66]

6.3 Productivity of airlines emerging from Chapter 11

In the previous sections we have focused on aircraft that are transacted by airlines. The large majority of these transactions are made by airlines that were liquidated in bankruptcy, either in Chapter 11 or Chapter 7. However, it is possible that airlines that emerged from Chapter 11 as a going concern, did not sell aircraft to avoid potentially large fire sale discounts. 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 filed for Chapter 11 and subsequently emerged as going concerns. The analysis of productivity of airlines emerging from Chapter 11 allows us to

[63] 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. We find 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.

[64] It is possible that capital reallocation is costly due to the higher cost of liquidity during recessions, and therefore, some assets might spend a longer period with distressed operators in recessions (see Eisfeldt and Rampini (2006)).

[65] Refer to Table IA.7.

[66] One 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.

examine the impact of bankruptcy procedures, particularly those permitting de-contracting, on the operating performance of the airline.

In Figure 6 Panel A, we plot the productivity of airlines that emerged from Chapter 11 as going concerns. The event year is defined as the year in which the airline emerged from bankruptcy. This specification allows us to measure and compare the productivity of airlines that survived Chapter 11 over the cycle of distress. In the 2 years before emergence, the productivity of airlines surviving Chapter 11 is not significantly different from the industry average. However, their productivity is almost 20% higher than the industry average after emerging from bankruptcy. This indicates that the aircraft that were retained by airlines that survived bankruptcy perform better than other similar aircraft in the industry.[67]

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. 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 Northwest 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 their $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 airline-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, quite different from the predictions of the misallocation hypothesis.[68]

6.4 Productivity of airlines involved in distressed exchanges

It can be argued that all of our airlines, by filing for bankruptcy, were to a varying extent economically distressed. Airlines that liquidated in Chapter 11 or 7, were at the extreme end of economic distress, while those that emerged from Chapter 11 were still economically distressed, albeit less so than the liquidated sample. Their economic distress is evidenced by them taking advantage of the decontracting provisions to

[67] Our findings are consistent with Eckbo and Thorburn (2003, 2008), who report that restructured firms in Sweden have a post-bankruptcy operating performance on a par with those of non-bankrupt industry rivals.

[68] 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.

restructure in Chapter 11. However, the misallocation hypothesis, as described by Shleifer and Vishny (1992), might be interpreted as relating largely to 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) and Gilson et al. (1990). In our sample period of 1975-2015, 8 airlines engaged in distressed exchanges. In Panels B and C of Figure 6, we analyse the 4 financially constrained airlines that both engaged in distressed exchanges, 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.[69] None of these airlines filed for bankruptcy within 5 years of the distressed exchange.

To test the misallocation hypothesis, we plot the mean difference in productivity between the buyer and seller of aircraft sold by financially constrained firms, in the 5 year event window around the aircraft sale. In Panel B of Figure 6, we report that there is no significant difference in productivity of the buyers and sellers of aircraft sold by financially constrained firms. We also compare the productivity of buyers of aircraft sold by financially constrained firms with the productivity of other buyers in the second-hand aircraft market. In Panel C, we report that on average the buyers of aircraft sold by financially constrained airlines are just as productive as the other buyers in the second-hand aircraft market. The differences between their productivity are not economically or statistically significant in the 5 year event window around the sale of the aircraft. Our results indicate that aircraft sold by financially constrained airlines are not misallocated.

6.5 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, there are 153 leasing companies and, roughly 41% of the global fleet is leased.[70] 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.

[69]The remaining 4 airlines made distressed exchanges, but did not sell any aircraft in distress.

[70]Refer to Current Aircraft Finance Market Outlook by Boeing (2019).

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% in 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, 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* × *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.[71] We find that in the year before aircraft sale, 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* × *Financial Buyer*). The results are similar when we control for operator fixed effects in columns (3) and (4). 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 (Figure 3). We find that there is no difference in productivity of users, for distressed aircraft purchased by financial buyers versus

[71] The 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.

those purchased by non-financial buyers (results available on request). 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.

A related 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.[72] 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.[73] Our price discount of around 6% for sales to financial buyers, in the combined sample of narrow and wide body aircraft transactions, is consistent with 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.

7 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, it is not easily observable in public databases, 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.

[72] In 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.

[73] In 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 $\tau = 0.1583$.

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 18%, and the quality impairment component is 9%, giving a quality-adjusted discount rate of 9%. The quality impairment component is higher at 16% for aircraft sold in Chapter 7, versus 9% 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 operators that sell aircraft in Chapter 7 compared with those operators that sell aircraft in Chapter 11 only, 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, 12.7% and 11%, respectively.

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%, and even larger during recessions. 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 has 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.

References

Acharya, V. V., S. T. Bharath, and A. Srinivasan (2007). Does industry-wide distress affect defaulted firms? evidence from creditor recoveries. *Journal of Financial Economics 85*(3), 787–821.

Allen, F. and D. Gale (1994). Limited market participation and volatility of asset prices. *The American Economic Review*, 933–955.

Andersen, S. and K. M. Nielsen (2017). Fire sales and house prices: Evidence from estate sales due to sudden death. *Management Science 63*(1), 201–212.

Bartelsman, E., J. Haltiwanger, and S. Scarpetta (2013). Cross-country differences in productivity: The role of allocation and selection. *American Economic Review 103*(1), 305–34.

Benmelech, E. and N. K. Bergman (2008). Liquidation values and the credibility of financial contract renegotiation: Evidence from us airlines. *The Quarterly Journal of Economics 123*(4), 1635–1677.

Benmelech, E. and N. K. Bergman (2011). Vintage capital and creditor protection. *Journal of Financial Economics 99*(2), 308–332.

Bernstein, S., E. Colonnelli, and B. Iverson (2019). Asset allocation in bankruptcy. *The Journal of Finance 74*(1), 5–53.

Bian, B. (2020). Globally consistent creditor protection, reallocation, and productivity. *Working Paper*.

Bris, A., I. Welch, and N. Zhu (2006). The costs of bankruptcy: Chapter 7 liquidation versus chapter 11 reorganization. *The journal of finance 61*(3), 1253–1303.

Brunnermeier, M. K. and L. H. Pedersen (2009). Market liquidity and funding liquidity. *The Review of Financial Studies 22*(6), 2201–2238.

Caballero, R. J. and M. L. Hammour (1994). The cleansing effect of recessions. *American Economic Review 84*(5), 1350–1368.

Campbell, J. Y., S. Giglio, and P. Pathak (2011). Forced sales and house prices. *American Economic Review 101*(5), 2108–31.

Ciliberto, F. and C. Schenone (2012). Bankruptcy and product-market competition: Evidence from the airline industry. *International Journal of Industrial Organization 30*(6), 564–577.

Cong, L. W., H. Gao, J. Ponticelli, and X. Yang (2019). Credit allocation under economic stimulus: Evidence from china. *The Review of Financial Studies 32*(9), 3412–3460.

Coval, J. and E. Stafford (2007). Asset fire sales (and purchases) in equity markets. *Journal of Financial Economics 86*(2), 479–512.

Dow, J. and J. Han (2018). The paradox of financial fire sales: The role of arbitrage capital in determining liquidity. *The Journal of Finance 73*(1), 229–274.

Duffie, D. (2010). Asset price dynamics with slow-moving capital. *The Journal of Finance 65*(4), 1237–1267.

Eckbo, B. E. and K. S. Thorburn (2003). Control benefits and ceo discipline in automatic bankruptcy auctions. *Journal of Financial Economics 69*(1), 227–258.

Eckbo, B. E. and S. K. Thorburn (2008). Automatic bankruptcy auctions and fire-sales. *Journal of Financial Economics 89*(3), 404–422.

Eisenbach, T., F. Duarte, et al. (2014). Fire-sale spillovers and systemic risk. In *2014 Meeting Papers*, Number 541. Society for Economic Dynamics.

Eisfeldt, A. L. and A. A. Rampini (2006). Capital reallocation and liquidity. *Journal of monetary Economics 53*(3), 369–399.

Ellul, A., C. Jotikasthira, and C. T. Lundblad (2011). Regulatory pressure and fire sales in the corporate bond market. *Journal of Financial Economics 101*(3), 596–620.

Franks, J. R., G. Seth, O. Sussman, and V. Vig (2020). The privatization of bankruptcy: evidence from financial distress in the shipping industry. *Working Paper*.

Franks, J. R. and W. N. Torous (1994). A comparison of financial recontracting in distressed exchanges and chapter 11 reorganizations. *Journal of Financial Economics 35*(3), 349–370.

Gavazza, A. (2010). Asset liquidity and financial contracts: Evidence from aircraft leases. *Journal of Financial Economics 95*(1), 62–84.

Gavazza, A. (2011a). Leasing and secondary markets: Theory and evidence from commercial aircraft. *Journal of Political Economy 119*(2), 325–377.

Gavazza, A. (2011b). The role of trading frictions in real asset markets. *American Economic Review 101*(4), 1106–43.

Geanakoplos, J. (2003). Liquidity, default, and crashes. In *Advances in economics and econometrics: theory and applications: eighth World Congress.*

Gilligan, T. W. (2004). Lemons and leases in the used business aircraft market. *Journal of Political Economy 112*(5), 1157–1180.

Gilson, S. C., K. John, and L. H. Lang (1990). Troubled debt restructurings: An empirical study of private reorganization of firms in default. *Journal of Financial Economics 27*(2), 315–353.

Gray, D., J. MacIntyre, and J. Wool (2015). The interaction between cape town convention repossession remedies and local procedural law: a civil law case study. In *Cape Town Convention Journal*, Volume 4, pp. 17–52. Taylor & Francis.

Greenwood, R., A. Landier, and D. Thesmar (2015). Vulnerable banks. *Journal of Financial Economics 115*(3), 471–485.

Gromb, D. and D. Vayanos (2002). Equilibrium and welfare in markets with financially constrained arbitrageurs. *Journal of Financial Economics 66*(2-3), 361–407.

Hsieh, C.-T. and P. J. Klenow (2009). Misallocation and manufacturing tfp in china and india. *The Quarterly Journal of Economics 124*(4), 1403–1448.

Jotikasthira, C., C. Lundblad, and T. Ramadorai (2012). Asset fire sales and purchases and the international transmission of funding shocks. *The Journal of Finance 67*(6), 2015–2050.

Kaplan, S. N. and L. Zingales (1997). Do investment-cash flow sensitivities provide useful measures of financing constraints? *The Quarterly Journal of Economics 112*(1), 169–215.

Kiyotaki, N. and J. Moore (1997). Credit cycles. *Journal of Political Economy 105*(2), 211–248.

Krishnamurthy, A. (2010). Amplification mechanisms in liquidity crises. *American Economic Journal: Macroeconomics 2*(3), 1–30.

LoPucki, L. M. and J. W. Doherty (2007). Bankruptcy fire sales. *Mich. L. Rev. 106*, 1.

Maksimovic, V. and G. Phillips (2001). The market for corporate assets: Who engages in mergers and asset sales and are there efficiency gains? *The Journal of Finance 56*(6), 2019–2065.

Meier, J.-M. and H. Servaes (2019). The bright side of fire sales. *The Review of Financial Studies 32*(11), 4228–4270.

Melzer, B. T. (2017). Mortgage debt overhang: Reduced investment by homeowners at risk of default. *The Journal of Finance 72*(2), 575–612.

Merrill, C. B., T. Nadauld, R. M. Stulz, and S. M. Sherlund (2014). Were there fire sales in the rmbs market? *Charles A. Dice Center Working Paper* (2014-09).

Mian, A., A. Sufi, and F. Trebbi (2015). Foreclosures, house prices, and the real economy. *The Journal of Finance 70*(6), 2587–2634.

Mitchell, M. and T. Pulvino (2012). Arbitrage crashes and the speed of capital. *Journal of Financial Economics 104*(3), 469–490.

Myers, S. C. (1977). Determinants of corporate borrowing. *Journal of Financial Economics 5*(2), 147–175.

Nowak, A. D. and P. S. Smith (2020). Quality-adjusted house price indexes. *American Economic Review: Insights 2*(3), 339–56.

Ozbas, O. and D. S. Scharfstein (2010). Evidence on the dark side of internal capital markets. *The Review of Financial Studies 23*(2), 581–599.

Phillips, G. and G. Sertsios (2013). How do firm financial conditions affect product quality and pricing? *Management Science 59*(8), 1764–1782.

Pulvino, T. C. (1998). Do asset fire sales exist? an empirical investigation of commercial aircraft transactions. *The Journal of Finance 53*(3), 939–978.

Pulvino, T. C. (1999). Effects of bankruptcy court protection on asset sales. *Journal of Financial Economics 52*(2), 151–186.

Ripple, G. P. (2002). Special protection in the airline industry: The historical development of section 1110 of the bankruptcy code. *Notre Dame L. Rev. 78*, 281.

Scheinberg, R. (2017). *The Commercial Aircraft Finance Handbook*. Routledge.

Schlingemann, F. P., R. M. Stulz, and R. A. Walkling (2002). Divestitures and the liquidity of the market for corporate assets. *Journal of Financial Economics 64*(1), 117–144.

Shleifer, A. and L. H. Summers (1988). Breach of trust in hostile takeovers. In *Corporate takeovers: Causes and consequences*, pp. 33–68. University of Chicago Press.

Shleifer, A. and R. Vishny (2011). Fire sales in finance and macroeconomics. *Journal of Economic Perspectives 25*(1), 29–48.

Shleifer, A. and R. W. Vishny (1992). Liquidation values and debt capacity: A market equilibrium approach. *The Journal of Finance 47*(4), 1343–1366.

Shleifer, A. and R. W. Vishny (1997). The limits of arbitrage. *The Journal of Finance 52*(1), 35–55.

Strömberg, P. (2000). Conflicts of interest and market illiquidity in bankruptcy auctions: Theory and tests. *The Journal of Finance 55*(6), 2641–2692.

Weiss, L. A. and K. H. Wruck (1998). Information problems, conflicts of interest, and asset stripping:: Chapter 11's failure in the case of eastern airlines. *Journal of Financial Economics 48*(1), 55–97.

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.

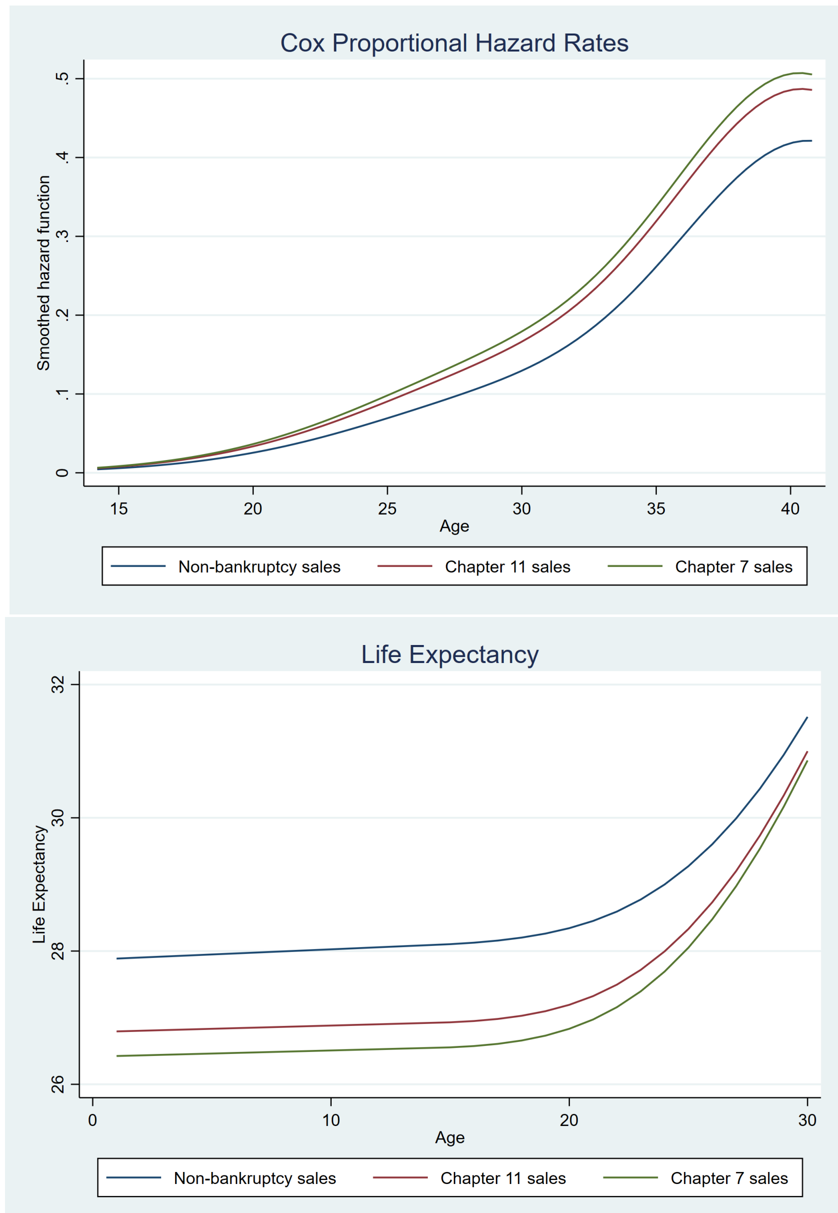
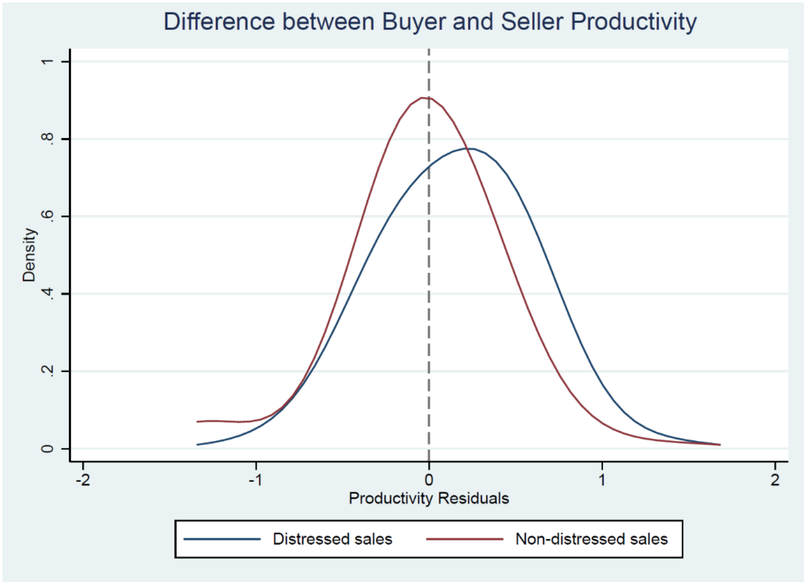


Figure 2: Efficient reallocation of aircraft sold by distressed airlines

In Panel A, we plot the kernel density for the difference in productivity of the buyer and seller of the aircraft in the year of its sale. The average operator productivity is computed using the *Operator* × *Year* fixed effects in Table 3 Panel A column (6). The difference plotted in Panel A is calculated by subtracting the seller's productivity from the buyer's productivity for a given aircraft. In Panel B, we plot the kernel density of operator productivity for post-sale users of distress-affected aircraft and non-distressed aircraft in the year of the aircraft's sale.

Panel A



Panel B

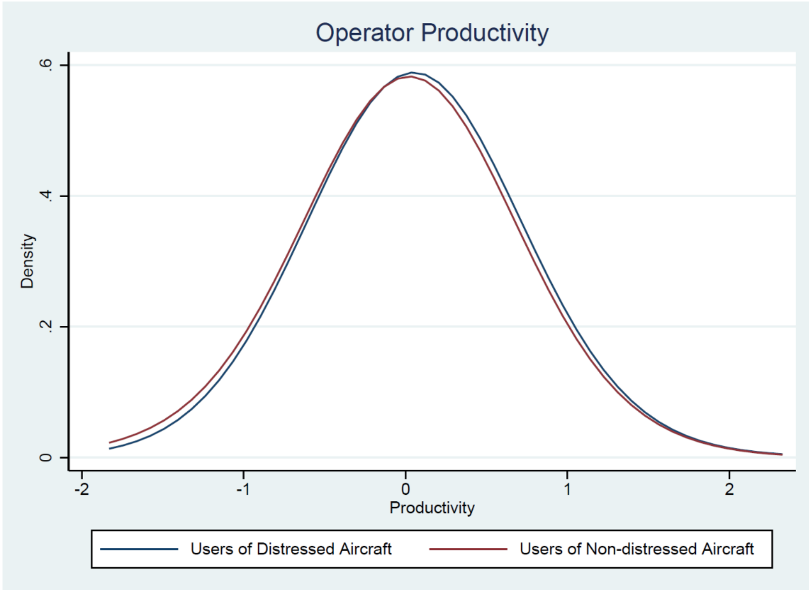
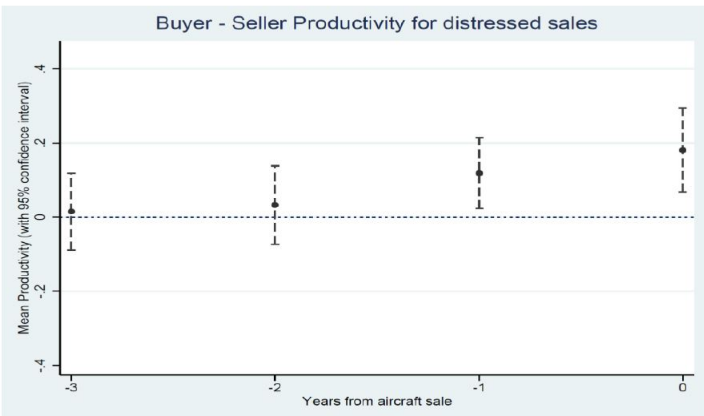


Figure 3: Productivity of operators around aircraft sale

The average operator productivity is computed using the *Operator* × *Year* fixed effects in Table 3 Panel A column (6). In Panel A, we plot the difference in productivity of the buyer and seller of the distressed aircraft. In Panel B, we plot the difference in productivity of post-sale users of distress-affected aircraft and non-distressed aircraft. Year 0 is the year in which the aircraft was transacted.

Panel A



Panel B

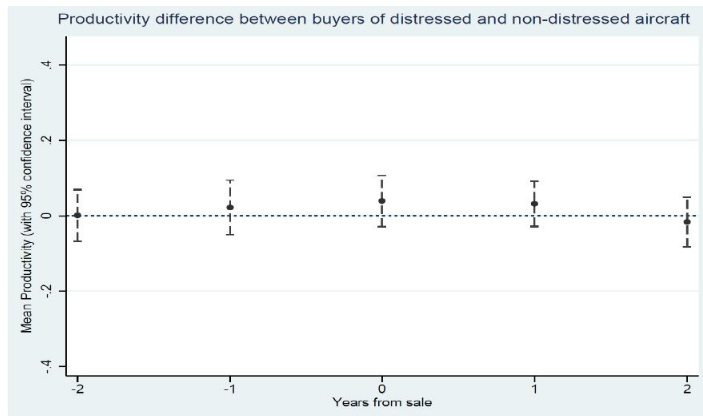


Figure 4: Tobin's Q for Post-Sales Users of Aircraft

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.

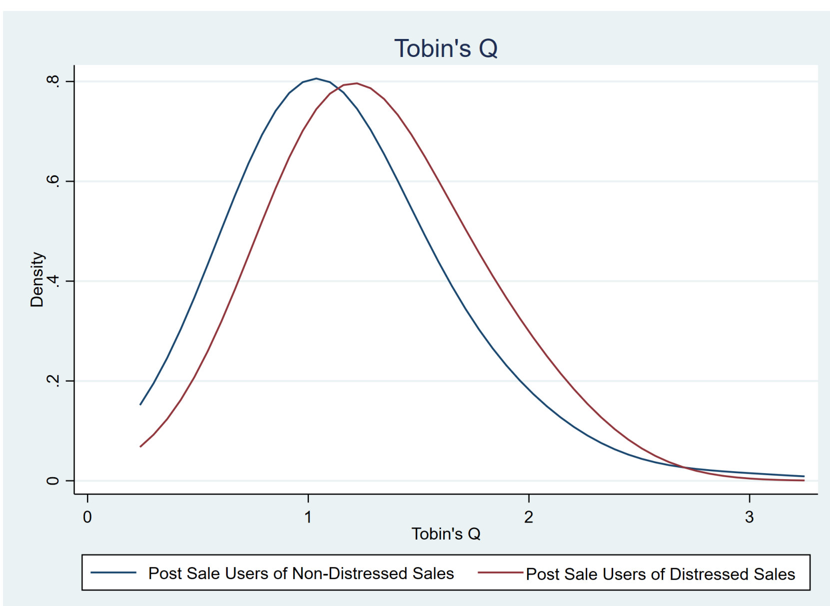
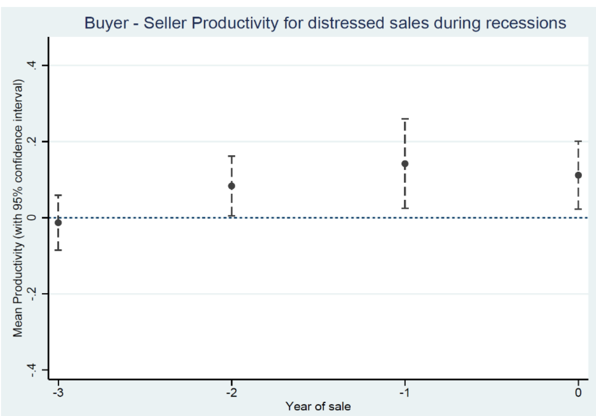


Figure 5: MISALLOCATION DURING BUSINESS CYCLES

The average operator productivity is computed using the *Operator* × *Year* fixed effects in Table 3 Panel A column (6). In Panel A, we plot the difference in productivity of the buyer and seller of the distressed aircraft sales made during recessions. In Panel B, we plot the difference in productivity of post-sale users of distress-affected aircraft and non-distressed aircraft sales made during recession periods. Year 0 is the year in which the aircraft was transacted.

Panel A



Panel B

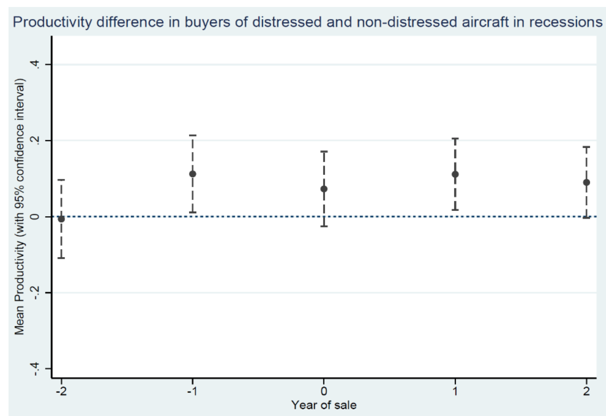
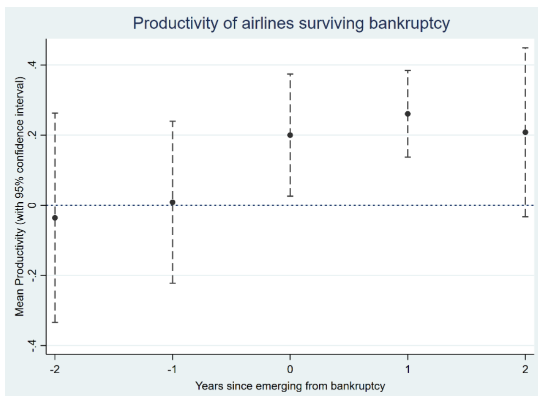


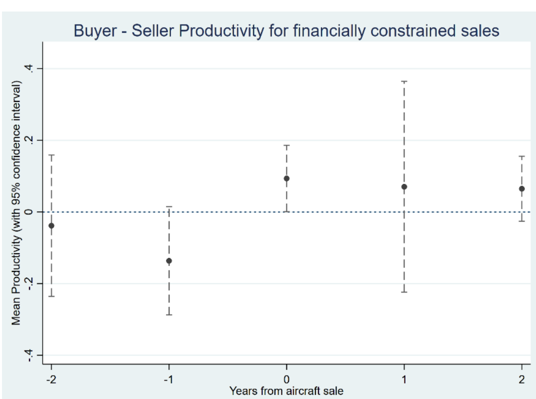
Figure 6: Productivity of operators around aircraft sale

The average operator productivity is computed using the *Operator* × *Year* fixed effects in Table 3 Panel A column (6). In Panel A, we plot the productivity of airlines that emerged from Chapter 11 as going concerns. Year 0 is the year in which the airline emerged from bankruptcy. In Panel B, we plot the difference in productivity of the buyer and seller of aircraft sold by financially constrained airlines. Year 0 is the year in which the aircraft was transacted. In Panel C, we plot the difference in productivity of post-sale users of aircraft sold by financially constrained airlines and non-constrained airlines. Year 0 is the year in which the aircraft was transacted.

Panel A



Panel B



Panel C

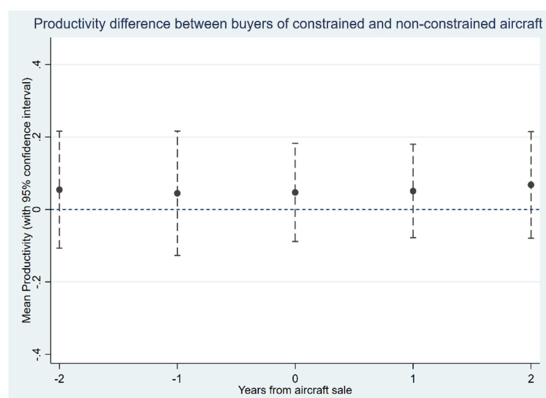


Table 1: Summary Statistics

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	2,226	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)				19.97	20	8.98			
Retirement Age (years)				29.03	29	6.10			
Cumulative flying hours				64,820	64,602	16,042			
	Sold in Ch 7 (N=48)			**Sold in Ch 11** (N=252)			**Non bankruptcy** (N=3,945)		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Age at sale (years)	11.63	10	6.26	18.09	20	6.62	20.09	20	9.07
Retirement Age (years)	27.63	27	4.42	28.13	27	6.21	29.17	29	6.10
Cumulative flying hours	49,224	44,683	11,472	64,127	62,693	15,449	65,244	65,505	16,038
Panel C: Sample of Transactions with Prices (1978-1991) (N = 1,333 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

The table shows how a distress event affects the total flying hours 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(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	-0.076***	-0.080***		
	(0.014)	(0.013)		
Chapter 7			-0.179***	-0.154***
			(0.037)	(0.035)
Chapter 11			-0.059***	-0.067***
			(0.015)	(0.014)
$Age - \overline{Age}$ (at distress)	0.009***	0.010***	0.007***	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)
Aircraft Type FE	YES	YES	YES	YES
Aircraft Usage FE	YES	YES	YES	YES
Year of Retirement FE	NO	YES	NO	YES
Observations	1,920	1,920	1,920	1,920
Adjusted R^2	0.429	0.506	0.432	0.508

Table 3: Annual flying hours

Panel A: Utilization of Aircraft sold by Distressed Airlines

The table shows how a history of distress affects the future productivity of an aircraft. *Distress* is an indicator variable that equals 1 from the year after an aircraft is 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 in the years after the aircraft is sold by an airline liquidating in Chapter 7. *Chapter 11* is an indicator that equals 1 for the years after the aircraft is sold by an airline operating in Chapter 11 protection. *Pre-filing (in distress)* is an indicator variable that equals 1 for the years after 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(Fleet Size)*), and the number of same model aircraft operating during that time period (*ln(#type aircraft)*). Aircraft type × age, aircraft operator, and year fixed effects are included in all specifications. Additionally, aircraft operator × 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	-0.104***	-0.105***	-0.099***			
	(0.017)	(0.017)	(0.014)			
Chapter 7				-0.144***	-0.138***	-0.133***
				(0.029)	(0.030)	(0.031)
Chapter 11				-0.100***	-0.102***	-0.096***
				(0.020)	(0.022)	(0.026)
Pre-filing (in distress)				-0.076*	-0.083**	-0.074*
				(0.033)	(0.035)	(0.035)
ln(#type aircraft)		0.129	0.101		0.128	0.100
		(0.092)	(0.069)		(0.092)	(0.069)
ln(Fleet Size)		0.042			0.042	
		(0.024)			(0.024)	
Year FE	YES	YES	-	YES	YES	-
Type × Age FE	YES	YES	YES	YES	YES	YES
Operator FE	YES	YES	-	YES	YES	-
Operator × Year FE	NO	NO	YES	NO	NO	YES
Observations	58,844	58,844	57,269	58,844	58,844	57,269
Adjusted R^2	0.595	0.596	0.633	0.595	0.596	0.633

Panel B: 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 from the year after an aircraft is sold by an airline operating in bankruptcy or during the distress period prior to filing for bankruptcy. *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(Fleet Size)*), and the number of same model aircraft operating during that time period (*ln(#type aircraft)*). Aircraft type × age, aircraft operator, and year fixed effects are included in all specifications. Additionally, aircraft operator × year fixed effects are included in column (3). 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)
Distress	-0.104***	-0.105***	-0.097***
	(0.017)	(0.017)	(0.014)
Other second-hand aircraft (in purchase year)	0.011	0.007	0.031
	(0.030)	(0.032)	(0.032)
ln(#type aircraft)		0.129	0.100
		(0.092)	(0.069)
ln(Fleet Size)		0.042	
		(0.024)	
Year FE	YES	YES	-
Type × Age FE	YES	YES	YES
Operator FE	YES	YES	-
Operator × Year FE	NO	NO	YES
Observations	58,844	58,844	57,269
Adjusted R^2	0.595	0.596	0.633

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 $log(SalePrice)$ on its Age at sale 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 the *effective* age of an aircraft in the specification. *Effective Age* equals $Age + \delta Distress$, and adds δ years to the age at sale of distressed aircraft (the average estimates of δ are reported in Table IA.5). In columns (3) and (4), *Quality* measures the effective age using the post-sale flying hours of an aircraft in the full sample. In columns (5) and (6), *Quality* measures the effective age by restricting the post-sale flying hours to the aircraft for which we transaction prices (i.e. aircraft transacted between 1978-1991). Fixed effects for aircraft characteristics - aircraft model, noise level(stage), and year quarter × 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* Discount (Full Sample)		*Quality* Discount (1978-1991 Sample)	
	(1)	(2)	(3)	(4)	(5)	(6)
Distress	-0.174***	-0.183***	-0.081***	-0.089***	-0.080***	-0.088***
	(0.054)	(0.033)	(0.027)	(0.025)	(0.029)	(0.026)
Financial Buyer		-0.050*		-0.050*		-0.050*
		(0.030)		(0.028)		(0.028)
Age	-0.030***	-0.030***				
	(0.006)	(0.006)				
Effective Age			-0.023***	-0.023***	-0.020***	-0.021***
			(0.007)	(0.007)	(0.007)	(0.007)
Aircraft Model FE	YES	YES	YES	YES	YES	YES
Aircraft Stage FE	YES	YES	YES	YES	YES	YES
Year Quarter × 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	0.865	0.866

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 the *effective* age of an aircraft in the specification. *Effective Age* equals $Age + \delta Distress$, and adds δ years to the age at sale of distressed aircraft. In columns (3) and (4), $Quality$ measures the effective age using the post-sale flying hours of an aircraft in the full sample. In columns (5) and (6), $Quality$ measures the effective age by restricting the post-sale flying hours to the aircraft for which we transaction prices (i.e. aircraft transacted between 1978-1991). Fixed effects for aircraft characteristics - aircraft model, noise level(stage), and year quarter × 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		$Quality$ Discount (Full Sample)		$Quality$ Discount (1978-1991 Sample)	
	(1)	(2)	(3)	(4)	(5)	(6)
Chapter 7	-0.268***	-0.293***	-0.104**	-0.127***	-0.115**	-0.137***
	(0.068)	(0.070)	(0.053)	(0.047)	(0.045)	(0.046)
Chapter 11	-0.194***	-0.204***	-0.100***	-0.110***	-0.080***	-0.089***
	(0.072)	(0.071)	(0.021)	(0.022)	(0.029)	(0.030)
Pre-filing (in distress)	-0.115**	-0.121**	-0.045	-0.050	-0.076	-0.081
	(0.057)	(0.033)	(0.078)	(0.070)	(0.065)	(0.057)
Financial Buyer		-0.053*		-0.051**		-0.051**
		(0.032)		(0.022)		(0.021)
Age	-0.031***	-0.031***				
	(0.006)	(0.006)				
Effective Age			-0.023***	-0.023***	-0.020**	-0.020**
			(0.008)	(0.008)	(0.008)	(0.009)
Aircraft Model FE	YES	YES	YES	YES	YES	YES
Aircraft Stage FE	YES	YES	YES	YES	YES	YES
Year Quarter × 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	0.866	0.865	0.865

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 (4) report the fire sale discounts on sale of aircraft by airlines operating under *Distress*. Table 4 Panel B columns (2) and (4) 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) Raw Fire Sale Discount	(2) Quality-Adjusted Fire Sale Discount	(3) Quality Discount
Distressed	18%	9%	9%
Chapter 7	29%	13%	16%
Chapter 11	20%	11%	9%
Pre-filing (in distress)	12%	5%	7%

Table 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*, that is computed by averaging the flying hours residuals of all aircraft flown by the operator. The flying hours residuals for an aircraft are calculated by regressing the log(Flying Hours) of an aircraft on aircraft type × age, year and usage category fixed effects. *Distressed Transaction* equals 1 for the buyer and seller of distressed aircraft. *Buyer* equals 1 for the buyers of aircraft. *Distressed Transaction* × *Buyer* equals 1 for the buyer of distressed aircraft. *Age at Sale* equals the age at which the aircraft was transacted. Aircraft type fixed effects are included in columns (2)-(4), and year of sale fixed effects are included in column (3) and (4). Robust standard errors are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	Operator Productivity			
	(1)	(2)	(3)	(4)
Distressed Transaction	-0.172***	-0.196***	-0.207***	-0.212***
	(0.022)	(0.022)	(0.026)	(0.026)
Buyer	0.007	-0.000	-0.065***	-0.067***
	(0.020)	(0.019)	(0.018)	(0.019)
Distressed Transaction × Buyer	0.196**	0.196***	0.236***	0.225***
	(0.052)	(0.052)	(0.054)	(0.054)
Age at Sale				-0.008***
				(0.002)
Aircraft Type FE	NO	YES	YES	YES
Year of Sale FE	NO	NO	YES	YES
Observations	3,234	3,234	3,234	3,234
Adjusted R^2	0.012	0.029	0.254	0.259

Table 7: Comparison of Financial Variables across Buyers 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. *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. Panel C reports the differences in average operator 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. The average *Productivity* for an operator is computed using the *Operator* × *Year* fixed effects in Table 3 Panel A column (6).

	Panel A: Financial Variables						
	Non-Distressed Sales			Distressed Sales			Difference
	Obs.	Mean	SD	Obs.	Mean	SD	p-value
Tobin's Q	885	1.16	0.015	108	1.31	0.033	0.0000
Log(MPK)	993	0.48	0.011	126	0.56	0.030	0.0214
Profitability	971	0.15	0.003	112	0.14	0.008	0.2874
	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	885	-0.05	0.014	108	0.05	0.029	0.0019
Log(MPK)	993	-0.18	0.010	126	-0.13	0.025	0.0532
Profitability	971	0.02	0.003	112	0.04	0.007	0.0036
	Panel C: Subsample of Buyers with (and without) financial data						
	Non-Distressed Sales			Distressed Sales			Difference
	Obs.	Mean	SD	Obs.	Mean	SD	p-value
Without financial data: Productivity	468	-0.10	0.030	58	-0.05	0.095	0.6081
With financial data: Productivity	717	0.05	0.010	91	0.09	0.023	0.2472

Table 8: 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(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. *Productivity* × *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). *Productivity* × *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(Fleet Size)	Fleet Age	Fleet Tech Age
Productivity	0.715***	-1.623***	-1.012***
	(0.030)	(0.114)	(0.094)
Productivity × Buyer of Distressed Aircraft	0.242***	-0.201*	-0.081
	(0.042)	(0.115)	(0.061)
Productivity × Buyer of Non-Distressed Aircraft	0.200***	-0.110***	-0.081**
	(0.015)	(0.042)	(0.036)
Year FE	YES	YES	YES
Observations	1,671	1,671	1,671
Adjusted R^2	0.385	0.503	0.632
(Productivity × Buyer of Distressed Aircraft) versus (Productivity × Buyer of Non-Distressed Aircraft) t-test			
p-value	0.3481	0.4544	0.9945

Table 9: Time 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* × *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* × *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(Fleet Size)*), and the number of same model aircraft operating during that time period (*ln(#type aircraft)*). Aircraft type × 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***	-0.0304***				
	(0.005)	(0.006)				
Time in distress × Chapter 11			-0.0304***	-0.0298***		
			(0.005)	(0.006)		
Time in distress × Chapter 7			-0.0325***	-0.0310***		
			(0.007)	(0.007)		
Time before bankruptcy filing (years)					-0.0493***	-0.0450***
					(0.013)	(0.013)
Time after bankruptcy filing (years)					-0.0108	-0.0133
					(0.022)	(0.022)
ln(#type aircraft)		0.125		0.125		0.124
		(0.091)		(0.092)		(0.091)
ln(Fleet Size)		0.0414		0.0414		0.0414
		(0.024)		(0.024)		(0.024)
Year FE	YES	YES	YES	YES	YES	YES
Type × 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 10: 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 $log(SalePrice)$ on Age, *Distress* and *Distress* × *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. *Distress* × *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 the *effective* age of an aircraft in the specification. *Effective Age* equals $Age + \delta Distress$, and adds δ years to the age at sale of distressed aircraft. In columns (3) and (4), *Quality* measures the effective age using the post-sale flying hours of an aircraft in the full sample. In columns (5) and (6), *Quality* measures the effective age by restricting the post-sale flying hours to the aircraft for which we transaction prices (i.e. aircraft transacted between 1978-1991). Fixed effects for aircraft characteristics - aircraft model, noise level(stage), and year quarter × 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* Discount (Full Sample)		*Quality* Discount (1978-1991 Sample)	
	(1)	(2)	(3)	(4)	(5)	(6)
Distress	-0.126*	-0.135*	-0.061	-0.069	-0.047	-0.055
	(0.071)	(0.070)	(0.092)	(0.089)	(0.100)	(0.102)
Distress × Recession	-0.179***	-0.181***	-0.107***	-0.108***	-0.081***	-0.082***
	(0.013)	(0.019)	(0.012)	(0.008)	(0.025)	(0.023)
Financial Buyer		-0.051**		-0.049**		-0.048**
		(0.023)		(0.024)		(0.024)
Age	-0.031***	-0.032***				
	(0.009)	(0.009)				
Effective Age			-0.023***	-0.024***	-0.018***	-0.018***
			(0.007)	(0.008)	(0.006)	(0.007)
Aircraft Model FE	YES	YES	YES	YES	YES	YES
Aircraft Stage FE	YES	YES	YES	YES	YES	YES
Year Quarter × 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	0.865	0.865

Table 11: Financial Buyers and Utilization 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(Fleet Size)*), and the number of same model aircraft operating during that time period (*ln(#type aircraft)*). Aircraft type × 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***	-0.0876***	-0.169***	-0.163***
	(0.030)	(0.030)	(0.029)	(0.028)
Pre-sale × Financial buyer	0.129***	0.140***	0.120***	0.114***
	(0.047)	(0.047)	(0.044)	(0.044)
Distressed aircraft pre-sale (last year with distressed seller)	-0.426***	-0.412***	-0.351***	-0.343***
	(0.073)	(0.073)	(0.070)	(0.070)
Distressed aircraft pre-sale × Financial buyer	0.334***	0.332***	0.335***	0.339***
	(0.090)	(0.090)	(0.088)	(0.088)
ln(#type aircraft)		0.0920***		0.115***
		(0.020)		(0.019)
ln(Fleet Size)		0.0531***		0.0320***
		(0.004)		(0.009)
Year FE	YES	YES	YES	YES
Type × 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

Internet 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 and 2000 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.[74] 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.[75] 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.[76]

[74] For 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

[75] Gray 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.

[76] Before 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.

B. Aircraft Retirement Age

To reinforce our analysis of 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. As distressed aircraft are effectively older than their chronological age we would expect them to retire earlier. In Table IA.1, 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 age at sale. Controlling for these variations in aircraft life, our results in column (1) indicate that aircraft sold by distressed airlines have roughly 1.6 years lower lifespan. This difference translates into around 10% lower remaining life expectancy for aircraft transacted in distress.[77] In column (2) we report that an average aircraft sold by an airline liquidating in Chapter 7 retires around 2.7 years before an aircraft sold by a non-distressed airline. Similarly, aircraft sold in Chapter 11 have roughly 1.7 years lower lifespan.

As the retirement data ends in 2016, we do not have the retirement age for aircraft that did not retire by the end of 2016, and it might be a concern that censoring could affect our results.[78] To address this concern, in columns (3)-(6) of Table IA.1 we report that our results are robust to using all the retired and non-retired aircraft that were transacted in our sample. In columns (3) and (4), we apply duration analysis to calibrate the hazard function for an aircraft.[79] 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, and report 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-distressed airlines.

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:

[77] In Table 1 Panel C, we report that the average age at sale of an aircraft is 14 years and its average retirement age is 29 years, that implies an average remaining life of 15 years post sale. 1.6 years of lower lifetime reflect 10.7% lower remaining life.

[78] We do not observe a higher survival rate of distressed aircraft compared with non-distressed aircraft by the end of 2016. 8% of aircraft sold by distressed airlines have not retired by the end of 2016, compared with 16% of aircraft sold by non-distressed airlines.

[79] While estimating the survival function of an aircraft, the analysis time records the retirement age for the aircraft that have retired from service (*failure* = 1). For the aircraft that have not retired by the end of 2016 (*failure* = 0), the analysis time records the age of the aircraft in 2016.

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

Using the above method, we calculate the life expectancy separately for aircraft sold by airlines in Chapter 7, Chapter 11 and non-bankrupt airlines.[80] Figure 1 plots the life expectancy of aircraft, conditional on being alive at a given age. It shows that aircraft exposed to bankruptcy have a lower life expectancy versus non-distressed aircraft.

In columns (5) and (6) of Table IA.1, we report the probability of an aircraft being retired at a given age using the panel of aircraft-years. The dependent variable *Retirement* is 1 for the age at which the aircraft retires, and is 0 otherwise.[81] We run stacked regressions controlling for aircraft type × age fixed effects, and find that aircraft transacted in distress have a significantly higher probability of being retired, than similar type aircraft transacted by non-distressed airlines.

C. Robustness tests on the utilization of distressed aircraft

We have established that aircraft sold by distressed airlines have lower productivity while they are in use. In this appendix we show that our results are robust to alternate explanations.

We have 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. In Appendix Table IA.2, 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. During the distress period, these transacted aircraft fly 6% less than other similar aircraft operated by the distressed carrier.[82] 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.

[80] In 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.

[81] The aircraft-year observations are higher than the observations in Table 3, as the flying hours database reports the flying hours of aircraft during the years they operate in the US, while the retirement age is available for aircraft that were retired outside US.

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

A 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 Table IA.3, we attempt to resolve this concern by including aircraft operator × 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 (2), 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 9% and 8.3% lower utilization, respectively, than other similar aircraft models operated by the new carrier.[83] 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.

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 IA.4, we check whether the 131 aircraft transacted in bankruptcy during 1978-1991 (in Table 1 Panel C), exhibit similar lower productivity post-sale. Since, the coefficients reported in Table IA.4 and Table 3 Panel A are virtually identical, the tests in our paper are performed on the full sample of bankruptcies from 1975-2015.

D. 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:

$$log(PRICE)_{ijt} = \beta_{Age} log(1 + Age_i) + \beta_t + \beta_{Model} + \beta_{Stage} + \epsilon_{ijt} \tag{A-2}$$

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}), 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.[84]

We regress the residuals obtained from the first stage hedonic regression ($RESID$), described above on variables measuring the sellers' financial health.[85] More specifically, to quantify the raw fire sales discount,

[83] In a specification similar to Table IA.3, we also include both operator × year × type, and type × 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.

[84] As 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.

[85] We 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.

we regress:

$$RESID = \beta_1 Chapter7 + \beta_2 Chapter11 + \beta_3 PreFiling + \beta_4 FinancialBuyer + \beta_{Seller} + \eta \qquad \text{(A-3)}$$

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 IA.6, 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 IA.6, 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)).[86]

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.[87] 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, for which financial data are available for the quarter preceding the transaction (see Pulvino (1998)). 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 quarter[88]; *Q* equals (Market value of assets/Book value of assets)[89]; *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). 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

[86] This 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.

[87] These sales are identical to the *CAPLO* sales in Pulvino (1998).

[88] Leverage 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.

[89] 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

COGS/ASM).[90] 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 IA.6, 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)).

[90] To 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.

Figure IA.1: Illustration of the quality adjustment estimation

This figure illustrates how we estimate the quality adjustment (δ) from the flying hours of an aircraft. The blue line plots the depreciation of flying hours with age for aircraft sold by non-distressed airlines, while the red line plots the same for aircraft sold by distressed airlines. The slope of the depreciation schedule is γ_h. The *effective age* of an aircraft is calculated by adding δ years to the chronological age (or age at sale) of a distressed aircraft.

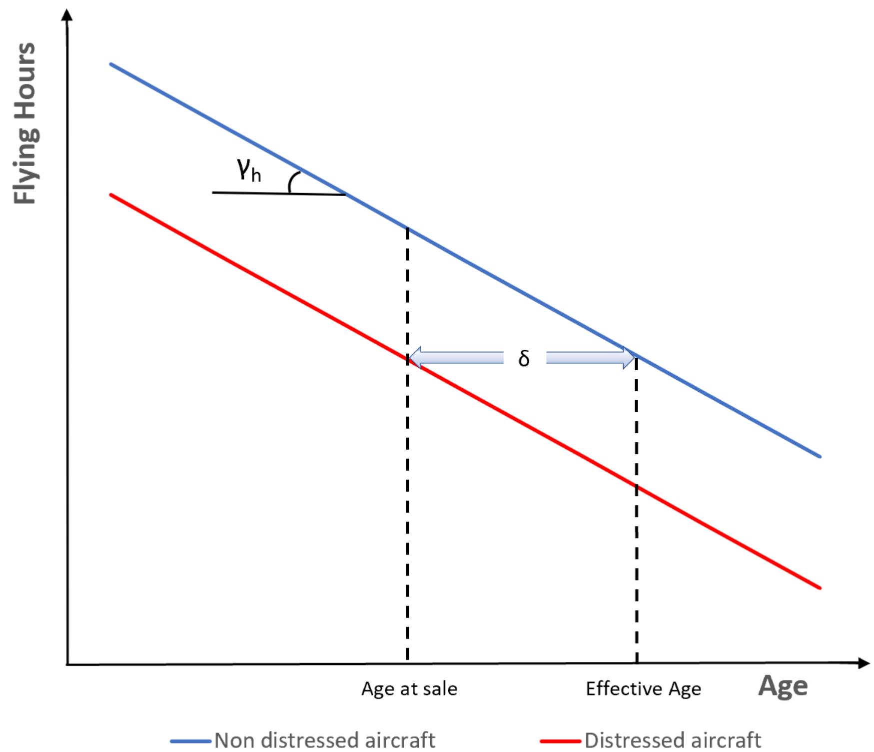


Table IA.1: Retirement Age and Distress History

The table shows how a history of distress affects the retirement age of an aircraft. *Distress* is an indicator variable that equals 1 if an aircraft is 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 when the aircraft is sold by an airline liquidating in Chapter 7. *Chapter 11* is an indicator that equals 1 when the aircraft is 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. In columns (1) and (2), we report the results of an OLS regression of *Retirement Age* of aircraft that were transacted on variables indicating distress. Fixed effects for aircraft type, age at sale, and year of retirement are included. In columns (3) and (4), we report the Cox Proportional Hazard rates for aircraft that were transacted in our sample. Fixed effects for aircraft type, and its age at sale are included. In columns (5) and (6), we run a stacked regression on a panel of aircraft-years for aircraft that were transacted in our sample. The dependent variable *Retirement* equals 1 in the year the aircraft is retired, and 0 otherwise. Fixed effects for aircraft type × age are included. The unit of observation in columns (1) to (4) is an aircraft. In columns (5) and (6) the unit of observation is aircraft-year. Robust standard errors are denoted in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

	Retirement					
	OLS regression		Cox Hazard		Stacked regression	
	(1)	(2)	(3)	(4)	(5)	(6)
Distress	-1.613 ***		0.311***		0.009***	
	(0.275)		(0.061)		(0.002)	
Chapter 7		-2.664***		0.444***		0.015***
		(0.632)		(0.153)		(0.005)
Chapter 11		-1.699***		0.318***		0.010***
		(0.309)		(0.069)		(0.002)
Pre-Filing (in distress)		-0.275		0.179		0.004
		(0.702)		(0.144)		(0.004)
Observations	2,289	2,289	2,695	2,695	81,672	81,672
Adjusted R^2	0.522	0.523			0.085	0.085
Type FE	YES	YES	YES	YES	NO	NO
Age at Sale FE	YES	YES	YES	YES	NO	NO
Retirement Year FE	YES	YES	NO	NO	NO	NO
Type × Age FE	NO	NO	NO	NO	YES	YES

Table IA.2: 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(Fleet Size)*), and the number of same model aircraft operating during that time period (*ln(#type aircraft)*). Aircraft type × 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	-0.005		
	(0.012)	(0.012)		
Pre Distress: Chapter 7 sale			0.062	0.063
			(0.047)	(0.047)
Pre Distress: Chapter 11 sale			-0.008	-0.008
			(0.012)	(0.012)
During distress (and bankruptcy)	-0.062***	-0.054***	-0.062***	-0.054***
	(0.009)	(0.010)	(0.009)	(0.010)
Post Sale (Distressed aircraft with new operator)	-0.103***	-0.104***		
	(0.015)	(0.015)		
Post Sale: Chapter 7 sale			-0.140***	-0.133***
			(0.024)	(0.025)
Post Sale: Chapter 11 sale			-0.097***	-0.099***
			(0.023)	(0.023)
ln(#type aircraft)		0.128***		0.125***
		(0.019)		(0.019)
ln(Fleet Size)		0.035***		0.035***
		(0.009)		(0.009)
Year FE	YES	YES	YES	YES
Type × 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 IA.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 from the year after an aircraft is 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 in the years after the aircraft is sold by an airline liquidating in Chapter 7. *Chapter 11* is an indicator that equals 1 for the years after the aircraft is sold by an airline operating in Chapter 11 protection. *Pre-filing (in distress)* is an indicator variable that equals 1 for the years after 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 number of same model aircraft operating during that time period (*ln(#type aircraft)*). Aircraft type × age, operator × type, and aircraft operator × year fixed effects are included. 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)
Distress	-0.072***	
	(0.014)	
Chapter 7		-0.090***
		(0.020)
Chapter 11		-0.083**
		(0.029)
Pre-filing (in distress)		-0.032
		(0.029)
ln(#type aircraft)	0.199*	0.199*
	(0.096)	(0.096)
Type × Age FE	YES	YES
Operator × Year FE	YES	YES
Operator × Type FE	YES	YES
Observations	57,190	57,190
Adjusted R^2	0.655	0.655

Table IA.4: Productivity and Distress History (of aircraft transacted between 1978-1991)

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(Fleet Size)*), and the number of same model aircraft operating during that time period (*ln(#type aircraft)*). Aircraft type × age, aircraft operator, and year fixed effects are included in all specifications. Additionally, aircraft operator × 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%.

	log(Flying Hours)					
	(1)	(2)	(3)	(4)	(5)	(6)
Distress	-0.115***	-0.117***	-0.098***			
	(0.027)	(0.028)	(0.025)			
Chapter 7				-0.135***	-0.129***	-0.123***
				(0.029)	(0.031)	(0.031)
Chapter 11				-0.117**	-0.122**	-0.109**
				(0.050)	(0.051)	(0.048)
Pre-Filing (in distress)				-0.083*	-0.093*	-0.046
				(0.041)	(0.043)	(0.035)
ln(#type aircraft)		0.128	0.095		0.127	0.093
		(0.091)	(0.069)		(0.092)	(0.069)
ln(Fleet Size)		0.041			0.041	
		(0.023)			(0.023)	
Year FE	YES	YES	-	YES	YES	-
Type × Age FE	YES	YES	YES	YES	YES	YES
Operator FE	YES	YES	-	YES	YES	-
Operator × Year FE	NO	NO	YES	NO	NO	YES
Observations	57,871	57,871	56,324	57,871	57,871	56,324
Adjusted R^2	0.596	0.597	0.632	0.596	0.597	0.632

Table IA.5: Estimating Quality Adjustment

In this table we report our estimates of quality adjustment (or δ) for different degrees of financial distress. The quality adjustment, δ estimates the number of years distress adds to the age of an aircraft. $\delta_{Distress}$ reports the average number of years an aircraft that is sold by an airline operating in bankruptcy or during the distress period prior to filing for bankruptcy, is effectively older than a similar type aircraft transacted by a non-distressed airline. $\delta_{Chapter7}$ reports the average number of years an aircraft sold by an airline liquidating in Chapter 7 is effectively older than an aircraft transacted by a non-distressed airline. $\delta_{Chapter11}$ reports the average number of years an aircraft sold by an airline operating in Chapter 11 protection is effectively older than an aircraft transacted by a non-distressed airline. $\delta_{PreFiling}$ reports the average number of years an aircraft sold by an airline during the distress period prior to filing for bankruptcy is effectively older than an aircraft transacted by a non-distressed airline. In column (1), δ is estimated using the lower flying hours of aircraft exposed to distress (from Table 3 column (6)). Standard errors are denoted in parentheses.

	Flying Hours
	(1)
$\delta_{Distress}$	4.432
	(1.925)
$\delta_{Chapter7}$	6.761
	(1.261)
$\delta_{Chapter11}$	3.875
	(1.534)
$\delta_{PreFiling}$	3.145
	(0.978)

Table IA.6: 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) Discount	(2) Discount	(3) Discount	(4) Discount
Distress	-0.159***	-0.158***		
	(0.034)	(0.033)		
Chapter 7			-0.255***	-0.282***
			(0.040)	(0.041)
Chapter 11			-0.157***	-0.159***
			(0.039)	(0.039)
Pre-filing (in distress)			-0.128***	-0.110***
			(0.041)	(0.041)
Financial Buyer		-0.090***		-0.097***
		(0.034)		(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. Robust standard errors are reported in parentheses. *** denotes significance at 1%, ** at 5%, and * at 10%.

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

Table IA.7: 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*. For an operator, *Operator Productivity* averages residuals across all aircraft flown by the operator, where the residuals are obtained by regressing log flying hours on aircraft *Type* × *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* × *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* × *Recessions* equals 1 for the distressed seller and the buyer of these aircraft, if the distressed aircraft is sold during recession periods. *Buyer* × *Recession* equals 1 if the buyer purchases an aircraft during recessions. *Distressed Transaction* × *Buyer* × *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		
	(1)	(2)	(3)
Distressed Transaction	-0.196***	-0.190***	-0.180***
	(0.012)	(0.016)	(0.017)
Buyer	0.030*	0.019	0.025
	(0.016)	(0.018)	(0.017)
Recession	-0.010		
	(0.010)		
Distressed Transaction × Buyer	0.126***	0.127***	0.122***
	(0.037)	(0.033)	(0.033)
Distressed Transaction × Recession	0.102***	0.104***	0.055*
	(0.020)	(0.027)	(0.032)
Buyer × Recession	-0.069**	-0.072**	-0.086***
	(0.031)	(0.033)	(0.033)
Distressed Transaction × Buyer × Recession	0.114**	0.127**	0.140***
	(0.055)	(0.051)	(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

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