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Asset liquidity and financial contracts: Evidence from aircraft leases ☆

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A B S T R A C T

Financial contracting theories agree that more-liquid assets decrease the expected cost of external financing, thus making leasing more attractive and reducing lessors' equilibrium return. However, the literature has ambiguous predictions about the effect of liquidity on the maturity of leases. These predictions are further complicated by the existence of two types of lease contracts—operating and capital—that differ in whether asset ownership transfers to the lessee at the end of the contract. Using data from commercial aircraft, I find that more-liquid assets (1) make leasing, operating leasing in particular, more likely; (2) have shorter operating leases; (3) have longer capital leases; and (4) command lower markups of operating lease rates.

1. Introduction

This paper uses data on commercial aircraft to investigate empirically how asset characteristics affect lease contracts. More precisely, it focuses on one characteristic that lies at the heart of a leasing contract and has received a lot of attention in incomplete-contract theories of financial contracting: the salvage/liquidation value of the asset. I empirically analyze how aircraft liquidity (see, e.g., Williamson, 1988; Shleifer and Vishny, 1992) affects whether an aircraft is leased or owned, the optimal maturity of aircraft lease contracts, and the markups of lease rates over aircraft prices.

Leasing contracts are extensively used in capital-equipment markets, and leasing is one of the major sources of financing for firms. In fact, 80% of U.S. companies lease capital equipment. Of the $668 billion spent by American businesses on productive assets in 2003, $208 billion was acquired through leasing, according to the Equipment Lease Foundation. Graham, Lemmon, and Schallheim (1998) report that operating leases, capital leases, and debt are 42%, 6%, and 52% of fixed claims, respectively, in the 1981–1992 Compustat data. Eisfeldt and Rampini (2009) document that leasing is the largest source of external finance for small firms.

In a typical lease contract, the owner of the asset (the lessor) grants to another party (the lessee) the exclusive right to use the asset for an agreed period of time, in return for periodic payments. Hence, the lessee takes the risks and returns from the use of the asset, and the lessor takes the risks and returns from ownership of the asset. As in any financial contract, the risk of default by the lessee is a primary element in the risk of ownership, with the liquidation value of the asset playing a key role if the lessee defaults.

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The previous general definition of a lease contract, however, masks an important difference between the two existing types of lease. In a *capital lease*, the lessee acquires ownership of the asset at the end of the lease's term, while in an *operating lease* the asset reverts to the lessor. Hence, in a capital lease, a single lessee provides the returns to the lessor, while in an operating lease, the lessor must arrange more than one transaction over the life of the asset in order to generate returns and to repay the capital investment.

Overall, theoretical arguments suggest that more-liquid assets make any type of leasing more attractive. The reason is that more-liquid assets are more *redeployable* (as in Shleifer and Vishny, 1992) and less *specific* (as in Williamson, 1975, 1979; Klein, Crawford, and Alchian, 1978), decreasing the expected costs of external financing. Moreover, since in an operating lease the lessor likely needs to redeploy the asset over time to several lessees, the liquidity of the asset plays a more relevant role in an operating lease than in a capital lease. Hence, we can expect that, as assets become more liquid, the share of assets under operating leases will increase more than the share of assets under capital leases.

Theoretical predictions of the effect of liquidity on the maturity of lease contracts are more intricate. Several influential papers have analyzed the determinants of the maturity of financing, with a special focus on the maturity of debt (Diamond, 1991; Hart and Moore, 1994; Berglöf and von Thadden, 1994). The structure of a capital lease is similar to the structure of a debt contract. At maturity, the lessor does not have any further claims on the asset, and the lessee (often) makes one larger payment. Thus, the theoretical predictions for debt contracts should apply to capital leases as well. According to Hart and Moore (1994), asset liquidity prolongs debt maturity since more-liquid assets have higher collateral value.[1] Berglöf and von Thadden investigate how the tradeoff between strategic default and inefficient liquidation affects the maturity of financing, and they suggest that more-liquid assets should have longer-term financing.

In contrast, the structure of operating leases—under which the asset returns to the lessor at the expiration of the contract—poorly fits the theoretical arguments developed for debt. Two considerations are particularly important for understanding what determines the maturity of operating leases. First, the lessor has to redeploy the asset after the leasing period; hence, the lessor should prefer a longer-term contract if liquidity is low. Second, specific assets require that the lessee and the lessor make some non-contractible investments. Repeatedly contracting over more-specific assets increases the likelihood of ex post holdup or opportunistic behavior. Ex ante, to mitigate ex post opportunistic behavior, parties choose to specify long-term contracts (Joskow, 1987). Hence, the lessee, too, should prefer longer-term contracts for less-liquid assets.

Asset liquidity also affects the external financier's required return. More-liquid assets are easier to reallocate across lessees, and, in equilibrium, lessors command lower returns. Thus, the markups of lease rates over selling prices should be lower for more-liquid assets.

The commercial aircraft market provides an ideal candidate for general investigation of leasing issues. First, more than half of all commercial aircraft are currently leased (approximately one-third of the aircraft are under operating lease and one-sixth under capital lease, see Section 4.1). Second, there is an active secondary market for aircraft. All airlines in the world use the same types of aircraft, and aircraft can be redeployed to an operator anywhere in the world within a day. These characteristics mean that there is a single global market for aircraft, and the market is, in principle, thicker than markets for other capital equipment. Third, it is easy to obtain a valid proxy for the liquidity of a given aircraft. According to Lehman Brothers (1998), "[A]ircraft with a large number in current use across a wide array of users will obviously be easier to resell or re-lease than aircraft with limited production and usage." Thus, the stock of a specific type of aircraft is a very good proxy for the number of potential users and for the liquidity of an aircraft.

I find strong support for the hypothesis that asset liquidity affects aircraft lease contracts. More-liquid aircraft are more likely to be leased and, in particular, more likely to be under an operating lease. More-liquid aircraft also command lease rates with lower markups over prices. Moreover, asset liquidity differentially affects operating and capital leases. In particular, more-liquid aircraft have shorter operating leases but longer capital leases. These patterns emerge even after controlling for carriers, lessors, aircraft types, and year fixed-effects, thus relying on variation in liquidity within aircraft type and within year.[2] For example, lease contracts for the Boeing 737 had an average maturity of 100 months for an operating lease and 205 months for a capital lease if the contracts were signed in 1983, when there were approximately 1000 units. When there were approximately 4000 units (in 2003), the average maturity of an operating lease decreased to 80 months, while the average maturity of a capital lease increased to approximately 225 months, suggesting that operating and capital leases are substantially different contracts.

The mechanisms identified in this paper are not unique to the aircraft market and they help explain the role of leasing for a wide range of assets. Leasing has grown fast in recent years and is now extensively used in the market for corporate assets. Most of the literature that has investigated firms' decisions to lease capital assets has had a special focus on the role of taxes (Miller and Upton,

[1] Hart and Moore's model has somewhat ambiguous predictions depending on the interpretation of liquidity. In particular, if liquidity implies that assets are easier for the user (the lessee) to replace, then maturity should be shorter for more-liquid assets. The reason is that more replaceable assets provide the creditor with *less* security as the debtor's cost of repudiation is lower. However, this argument does not seem to apply to airlines. In particular, this kind of asset replacement would be very disruptive of airlines' business and, thus, very costly. I am not aware of any instance of such behavior in airlines' bankruptcies and reorganizations.

[2] Year fixed-effects capture aggregate economic conditions that can affect lease contracts. An interesting question, left for future research, is to investigate how the leasing decision and features of leasing contracts change over the business cycle.

1976; Myers, Dill, and Bautista, 1976). However, taxation provides only a partial explanation of which assets are owned or leased and of the provisions in lease contracts. This paper makes a number of contributions. First, it focuses on one aspect—asset liquidity—that plays a prominent role in the theory. Second, the units of observation are the assets and leases themselves, not firm-level aggregate measures of leasing intensity. Third, the paper explicitly shows how operating and capital leases have substantially different characteristics.

The paper is organized as follows. Section 2 presents institutional characteristics of lease contracts and briefly describes the market for aircraft. Section 3 lays out the theoretical hypotheses. The empirical analysis is performed in Section 4. Section 5 reviews the related literature. Section 6 concludes. An Appendix, which is closely based on Gavazza (2009), describes in more detail the aircraft leasing business.

2. Institutional characteristics

2.1. Equipment leasing

A lease is a contract between two parties by which the owner (lessor) grants the rights to possess and use the contracted equipment to the other party (lessee), and which sets forth the terms of payment and other conditions. Generally, the lessor is a professional leasing company that leases or arranges the lease of property and supplies all the financing. The vast majority of lessees are business concerns, accounting for more than 90% of all lease transactions. Public utilities and municipal governments each account for about 2% of all leasing (U.S. Department of Commerce, U.S. Industrial Outlook, various years).

The two basic types of lease—the operating lease and the capital lease—have important differences. Generally speaking, if ownership of the leased asset is transferred to the lessee at the end of the lease term following payments that represent the full value of the asset, it is a capital lease; otherwise, it is an operating lease. The precise classification changes slightly for legal, taxation, and accounting purposes, but the main idea is that the greater the extent to which the lessee acquires control and residual claims on the asset, the more likely it is that the lease is classified as a capital lease (Sharpe and Nguyen, 1995; Eisfeldt and Rampini, 2009). In the United States, if (1) the lease term exceeds 75% of the anticipated economic life of the asset; or (2) the present discounted value of the required lease payments exceeds 90% of the cost of the equipment; or (3) the lease transfers ownership of the equipment to the lessee at or before the end of the lease term; or (4) the lease contains a bargain purchase option, then the lease is treated as a capital lease. If none of the above conditions is satisfied, then the lease is treated as an operating lease. In many other countries, the accounting and fiscal rules are very similar (see Littlejohns and McGairl, 1998, Chapters 8–14).

The difference between capital and operating leases has important implications for which party is treated as the owner of the asset in bankruptcy. Roughly speaking, with an operating lease, the lessor is treated as the owner of the asset. This means, for example, that the asset can be repossessed if the lessee enters Chapter 11 protection and rejects the lease. In contrast, with a capital lease, the lessee is treated as the owner of the asset and the lease is intended as security. In Chapter 11, the lessor is treated as a secured lender. The general bankruptcy rules are slightly different for aircraft, however. The U.S. Bankruptcy Code provides financiers (hence, lessors) stronger claims on aircraft than on any other asset in bankruptcy. In particular, according to Section 1110, aircraft are not subject to automatic stays, and lessors can foreclose an aircraft if the lessee fails to make lease payments within 60 days.[3]

The difference between operating and capital leases also affects the nature of companies offering one contract versus the other. For expensive equipment, lessors tend to specialize in either operating leases or capital leases. Operating lessors are usually companies with specific knowledge of the market for the assets they lease, while capital lessors are banks or financial institutions that provide secured lending to firms.

The Appendix discusses in detail some characteristics of the aircraft leasing market.

2.2. Liquidity of commercial aircraft

The market for used commercial aircraft might seem relatively liquid compared to the market for other, more specialized equipment. All airlines around the world use the same types of aircraft, and there are relatively few types. Sometimes governments and air-cargo companies purchase aircraft, but the major players are airlines and lessors. Also, aircraft are the only form of capital equipment that can be delivered to a buyer or operator anywhere in the world within a day and get there under their own power. Thus, the secondary market for aircraft is a single, worldwide market.

However, the absolute number of transactions remains very small compared to financial markets and other equipment markets. For example, in the 12-month period from May 2002 through April 2003, of the total stock of 12,409 commercial aircraft used for passenger transportation and older than two years, only 720 (5.8%) were traded.

Moreover, the market is organized around privately negotiated transactions. This is one characteristic that Rauch (1999) uses to measure asset-specificity. The idea is that if an asset is sold on an organized exchange, then the market for this asset is thick and, hence, the asset is less specific to the transaction. Most major carriers have staff devoted to the acquisition and disposition of aircraft, and independent brokers are sometimes used to match buyers and sellers. Aircraft are seldom sold at auctions. Pulvino (1998) reports that in one of the first auctions, organized

[3] Section 1110 applies only to a reorganization under Chapter 11 and does not apply when the debtor seeks to liquidate under Chapter 7 of the Bankruptcy Code.

in 1994 to enhance the liquidity of the market, only nine aircraft sold from the 35 offered for sale. Some subsequent auctions have ended without a single sale. Hence, prices are very sensitive to a party's individual shocks, and the bargaining power of sellers and buyers is an important determinant of transaction prices. For example, Pulvino finds that sellers whose financial status is poor sell aircraft at a 14% discount relative to the average market price.

Furthermore, aircraft are differentiated products, and product differentiation generates economic rents. Each type of aircraft requires human-capital investments in specific skills for pilots, crew, and mechanics that increase the degree of physical differentiation. As a result, carriers tend to minimize the number of types of aircraft they operate. Product differentiation also implies that aircraft are imperfect substitutes for one another, and this has important implications for the differential liquidity of different aircraft types. Different types are designed to serve different markets and different ranges. For example, a Boeing 747 is suited to markets in which both demand *and* distance are large. Thus, the differential size and number of different airline markets imply that different aircraft types have differential liquidity, and a carrier could choose to operate a rather illiquid aircraft that better suits its route structure. For a given aircraft type, the number of annual transactions can be small. For example, only 21 Boeing 747s traded in the 12-month period ending April 2003. Clearly, the liquidity of a given aircraft type also varies over time, as aircraft follow the typical life cycle of products. Thus, two main factors affect the liquidity of aircraft types over time: the production of new units and the retirement of old units. For example, the Boeing 727 was the most popular and liquid commercial aircraft during the 1970s, when production rates were high, but it is rather illiquid today, as it has been phased out of production and many units have been retired.

Overall, these characteristics seem to indicate that aircraft are less liquid than cursory evidence might suggest. It is, therefore, likely that illiquidity entails some costs. The next section looks closely at how we expect parties to anticipate these costs when writing lease contracts.

3. Main hypotheses

A large body of theoretical literature has investigated the role of asset liquidation values in financial contracts. Williamson (1988) identifies an asset liquidation value with the asset's redeployability—or its value in its next-best use—and Shleifer and Vishny (1992) argue that a larger number of potential users increases an asset's liquidation value. The main idea of these theories of financial contracting is that, in some states of the world, the current user of the asset needs to liquidate. Thus, the costs of liquidation determine the costs of a financial contract—and the lower are the costs of liquidation, the more liquid is the asset.

Williamson (1988) argues that leasing is the least-cost form of finance for assets such as aircraft. The reason is that, absent moral-hazard issues, there is no need for the owner and the user of the asset to be the same. Moreover, a lessor enjoys stronger claims than a secured lender when default is outside bankruptcy, in both U.S. and non-U.S. bankruptcies. In particular, in the event of default on a lease prior to bankruptcy, a lessor can seize the aircraft more easily than a secured lender can (Krishnan and Moyer, 1994; Habib and Johnsen, 1999). In U.S.-based Chapter 7 bankruptcies and in most non-U.S. bankruptcies, a lessor can repossess the asset more rapidly than a debt holder (Littlejohns and McGairl, 1998). In U.S.-based Chapter 11 bankruptcies, Section 1110 treats lessors and all other secured lenders equally in allowing foreclosure on an aircraft in the event of bankruptcy. However, the bankruptcy code establishes that other claims of secured creditors are diluted considerably more than comparable claims of lessors. For example, in an interesting case, Continental Airlines sought to have over $100 million of its lease obligations treated as debt during its reorganization under Chapter 11 bankruptcy in 1991 (Krishnan and Moyer, 1994). The lessors did not agree, and the court ruled in the lessors' favor. This episode suggests that, in a U.S.-based Chapter 11 bankruptcy, aircraft lessors enjoy stronger claims than secured lenders do.

On the other hand, Shleifer and Vishny (1992) suggest that specialized owners (and, hence, lessors) tend to be lower-value users of capital, and Pulvino (1998) finds evidence consistent with this idea in the market for aircraft. They argue that while carriers might put the aircraft in use and generate revenue, lessors need to find lessees willing to take the aircraft. In periods of high demand and for some popular types, this is an easy task. But in periods of low demand and for some aircraft types that have few potential users, redeploying aircraft becomes difficult (Habib and Johnsen, 1999). Adding to this difficulty is the fact that it is precisely in periods of low demand that lessors need to redeploy more aircraft because airlines are more likely to return aircraft to lessors. According to Wachovia Securities (2005), "From a lessor's perspective, a good leasing asset is one of which, 'if I get this aircraft back, I want a lot of people that I can talk to about the plane...' " Similarly, BCI Aircraft Leasing—a medium-sized operating lessor—describes its corporate strategy as follows: "BCI looks for aircraft that are liquid."[4]

Furthermore, more-liquid aircraft are less *specific* assets, in the language of Williamson (1975, 1979) and the literature on incomplete contracts. According to this literature, contracting with regard to specific assets might create ex post holdup or opportunistic incentives. To mitigate this ex post opportunistic behavior, parties choose ex ante to own assets that are more specific. Hence, Smith and Wakeman (1985) argue that leasing of specific assets is unlikely. Illiquid aircraft provide several possibilities for opportunistic behavior. For example, a lessee could refuse to renew a lease or demand lower lease payments when few other carriers are using the

[4] See http://bciaircraft.com/.

same type of aircraft (Benmelech and Bergman, 2009). Similarly, a lessor can demand a high lease payment if the lessee wants to renew a lease and has previously made non-contractible, asset-specific investments in pilots, mechanics, and crews.

In summary, the main tradeoff between leasing and other forms of secured lending is between the costs of default and the costs of non-redeployable/specific assets. Since the costs of non-redeployable/specific assets are lower for more-liquid aircraft, we thus expect the following:

H1. The share of leased aircraft is larger for more-liquid types.

As discussed in Section 2.1, there is a fundamental difference between operating and capital leases. In an operating lease, the lessor must arrange several transactions over the life of the asset in order to generate returns and repay its capital investment. In a normal capital lease, a single lessee provides all the returns to the lessor. In both contracts, the liquidity of the asset matters if the lessee defaults, but in an operating lease, the liquidity of the asset is of paramount importance since the lessor needs to re-lease the asset at the end of the present lease's term. As industry practitioners like Barrington (1998) note, "[F]rom the investors' perspective, the critical issue is to purchase aircraft that [...] are likely to have a broad leasing market when their lease term ends." He further adds, regarding sale-leaseback transactions: "Although many airlines with a high credit standing have entered into sale-leasebacks, it is the asset quality and future residual exposure that is of greater relevance to investors."

Hence, the liquidity of the asset should play a more relevant role in an operating lease than in a capital lease. We, thus, expect the share of aircraft under operating leases to be larger than the share of aircraft under capital leases for more-liquid aircraft[5]:

H2. The share of aircraft under operating leases is larger than the share of aircraft under capital leases for more-liquid aircraft types.

A few papers (Berglöf and von Thadden, 1994; Hart and Moore, 1994) have also analyzed the relation between asset liquidity and the duration of financing contracts. In the case of lease contracts, there is a mechanical relation between the operating-versus-capital lease classification and the duration of contracts. In particular, an operating lease has to be shorter than 75% of the life of the asset. Thus, the interesting question to investigate empirically is how asset liquidity affects the duration of operating leases and capital leases.

Theoretical models focus on the maturity of debt contracts and do not explicitly consider contracts structured as leases. Hence, some of the theoretical arguments might not apply to lease contracts. In particular, operating leases—in which the asset returns to the lessor at the expiration of the contract—might not fit the theoretical arguments developed for debt contracts. Instead, two considerations are particularly relevant for operating leases. First, the lessor has to redeploy the aircraft after the leasing period and should hence prefer a longer-term contract if redeployability/liquidity is low. Second, the lessee makes a number of non-contractible investments in pilots, mechanics, and crews and thus also prefers longer-term contracts for less liquid aircraft. In summary, both parties should prefer longer leases for less liquid assets:

H3. The durations of operating leases are shorter for more-liquid aircraft.

The structure of a capital lease differs from the structure of an operating lease and is similar to the structure of a debt contract. In capital leases and in debt contracts, at the expiration of the contract the creditor/lessor has no claim on the asset. This means that ex post holdup or opportunistic incentives on the part of the lessor are limited. Also, one balloon payment is often due at maturity. Thus, the maturity of capital leases should follow the theoretical predictions for debt contracts. Hart and Moore (1994) suggest that asset liquidity prolongs debt maturity, since more-liquid assets have higher collateral values. Berglöf and von Thadden (1994) investigate how the tradeoff between strategic default and inefficient liquidation affects the maturity of financing, and suggest that more-liquid assets should have longer-term financing.

H4. The durations of capital leases are longer for more-liquid aircraft.

The previous discussion highlights how more-popular aircraft are more liquid and less specific. These characteristics also affect the equilibrium pricing of operating lease contracts. In particular, more-liquid aircraft should command lower lease rates. With more liquid aircraft, it is easier for the lessor to find a new lessee willing to take the aircraft, which decreases the expected costs of redeployment. Similarly, a more liquid aircraft simultaneously increases both the lessor's and the lessee's outside options when bargaining over lease terms, and lease rates then converge to competitive levels.[6]

[5] One natural question is why lease rates do not fully adjust to make lessees exactly indifferent between operating leasing and capital leasing. There are at least two related arguments in response. First, the arguments developed in this section suggest that, in several instances, both the lessee and the lessor prefer an operating lease when the aircraft is liquid. Second, different aircraft types are substitutes. For example, consider a carrier for which the operating lease is optimal and that, everything else being equal, prefers a more illiquid aircraft. At the rates that make this carrier indifferent between an operating lease and a capital lease for the illiquid aircraft, the carrier might find it optimal to acquire a more-liquid substitute aircraft under an operating lease.

[6] The financial contracting literature also highlights how asset (il)liquidity affects lessors' and lessees' outside options in bargaining and thus the bargaining outcome. The literature predicts that we should observe more dispersion of bargaining outcomes for less-liquid assets since, for at least one party, the difference between the outcome of the bargaining and the outside option is larger when assets are less liquid. Unfortunately, as will become clear in Section 4.1, the data do not allow a test of these additional predictions (for the effect of asset liquidity on contract renegotiations, see Benmelech and Bergman, 2009). However, it is important to note that these additional predictions still imply that an

H5. The markups of operating lease rates over prices are lower for more-liquid aircraft.

Lease contracts are affected not only by the characteristics of the assets, but also by the characteristics of the contracting parties. Harris and Raviv (1991) review a large theoretical and empirical literature that investigates how firm characteristics affect the tradeoffs between internal and external financing, and it would be interesting to investigate how these characteristics affect lease contracts (see Eisfeldt and Rampini, 2009, for a recent investigation). For example, arguments that mirror the previous discussion suggest that the credit standing of a carrier should matter more in capital leases than in operating leases. However, as will become clear when the data are described in more detail, the ability to test these arguments is severely limited by the lack of many important carrier characteristics. It is possible to construct one variable of interest—the size of the carrier—that previous literature has used as a proxy for creditworthiness, but the data do not allow constructing several other financial indicators that affect firms' default risks. Thus, the analysis is suggestive at best, because it is not possible to fully control for unobservable carrier characteristics. Most of the empirical analysis, therefore, controls for unobservable characteristics using carrier fixed-effects.

4. Empirical analysis

This section first describes the data employed in this study. It then compares two aircraft with a similar history but different degrees of "popularity"—the McDonnell-Douglas 80 and the Airbus 300-600—to illustrate in a simple but stark way how lease contracts of the two types of aircraft vary systematically according to our hypotheses. Finally, it subjects the hypotheses of Section 3 to formal empirical testing. Several robustness checks and discussions of alternative hypotheses conclude the section.

4.1. Data

The empirical analysis in this paper combines two distinct datasets. The first is an extensive database that provides comprehensive information on the characteristics and history of each Western-built commercial aircraft. The second dataset reports the prices and the operating lease rates of several aircraft models.

The database on aircraft characteristics has two distinct files. The first file contains detailed cross-sectional data of aircraft active in April 2003. This dataset (henceforth, cross-sectional data) reports detailed characteristics of aircraft, such as the type (Boeing 737), the model (Boeing 737-200), the engine, and the age; information related to the period with the current operator, such as the operational role of the aircraft (passenger transportation, freighter, etc.), the date on which the current operator acquired the aircraft, and whether the aircraft is leased or owned by its current operator. If the aircraft is leased, the dataset reports whether the lease is an operating or capital lease. For a sample of leased aircraft, the dataset also reports the start and end dates of the current contract. Most tests of the hypotheses H1–H4 are based on these cross-sectional data.

The cross-sectional data are complemented by a second file that contains data on the time-series of operators of each aircraft. This second file (henceforth, time-series data) has less information than the cross-sectional file. It contains information on the "birth" of each aircraft (date of the first flight); the sequence of operators with the relevant dates of operation; the operational role with each operator; and, if the aircraft is not currently in use, the date of the "death" of the aircraft (date the aircraft was scrapped). This file reports whether the aircraft was owned or leased by each operator, but unfortunately does not report the lease type (operating or capital), the duration of the initial lease, or whether or not the lease was later extended. These time-series data are used mainly to construct measures of aircraft liquidity, as described in detail in the next section.

The dataset on aircraft values is an unbalanced panel. It reports the historic values of prices and operating lease rates of different vintages (younger than 25 years old) for the most popular models during the period 1967–2003. There is no information on capital lease rates. The dataset is compiled by a consulting company that specializes in aircraft appraisals. The prices, similar to "Blue Book" prices for cars, are based on reported transactions and on the company's experience in consulting, appraisal, and fleet evaluation. The prices assume that the transaction was made on the basis of a single unit bought for cash by a buyer from a non-bankrupt seller. The operating lease rates are annual amounts calculated independently of prices. They reflect medium-risk credit and an average operating lease term (which varies with each aircraft model). All values are in nominal U.S. dollars and are deflated using the GDP Implicit Price Deflator with 2000 as the base year.

4.1.1. Measuring aircraft liquidity

I use the time-series data to construct measures of aircraft liquidity that I later match to the cross-sectional data and to the aircraft values dataset. The literature on liquidity in financial markets generally uses bid-ask spreads or market depth as measures of liquidity. In markets for corporate assets, however, bid-ask spreads and market depth cannot be measured. Illiquidity arises from the non-synchronicity of buyers and sellers. When the market for an asset is thin, non-synchronicity becomes more likely (see Lippman and McCall, 1986, for a model that formalizes this intuition). In fact, market participants and industry experts consider an aircraft type to be more liquid if it has a larger number of potential users. According to Wachovia Securities (2005), "[T]he following are drivers of marketability of a commercial aircraft type: Number of current operators ...; Number of Aircraft in production run ...; In-production status/backlog

(*footnote continued*)
outside financier should receive, *on average*, a higher return for a less liquid asset since ex ante he will not be willing to finance it otherwise.

...; Existence of a cargo conversion program...; Number of young aircraft on ground ...."

I thus measure the liquidity of an aircraft with the stock of aircraft of the same type and call this variable AIRCRAFT PER TYPE.[7] A similar, more aggregated version of this measure of asset liquidity has been used by Benmelech (2009) for 19th-century American railroads, and by Benmelech and Bergman (2008, 2009) for airlines. From the time-series data, it is possible to reconstruct the value of AIRCRAFT PER TYPE for each type i and year t.[8] I then match the measure of liquidity AIRCRAFT PER TYPE to the year in which the operator acquired the aircraft.[9]

Gavazza (2008) shows that aircraft with a high value of AIRCRAFT PER TYPE have some typical properties of liquid assets: (1) higher turnover, (2) higher capacity utilization, (3) lower dispersion of utilization levels, (4) higher mean prices, and (5) lower dispersion of transaction prices. These properties further reinforce the idea that AIRCRAFT PER TYPE is a valid measure of aircraft liquidity.

4.1.2. Calculating markups

If all aircraft are perfectly liquid assets, the annual operating lease rate should be equal to the expected cost of buying the aircraft at time t and selling it at time $t+1$. Therefore, the lease rate l_{skit} is equal to $p_{skit}-\beta E_t p_{s+1k\ it+1}$, where p_{skit} is the price of an aircraft, s is a vintage, k is a model, i is a type, t is a year, β is the discount factor and E_t is the expectation taken at time t.

Unfortunately, the expected price $E_t p_{s+1\ k\ it+1}$ is not observed in the data. We thus proceed in two alternative ways: (1) We assume that $E_t p_{s+1\ k\ it+1}=p_{s+1\ k\ it}$; and (2) we assume that the price of an aircraft (a model-vintage pair) declines by $(1-\delta)$ percent every year, and obtain an estimate $\hat{\delta}$ of δ via a panel-data regression $p_{s+1\ k\ it+1}=\delta p_{skit}+\varepsilon_{s+1\ kt\ +1}$. In this way, $E_t p_{s+1\ k\ it+1}=\hat{\delta} p_{skit}$, where $\hat{\delta}$ is estimated to be equal to 0.9375, with a standard error of 0.00171 and an $R^2=0.98$.

We can then calculate the markup of the lease rate over the price as follows:

$$m_{skit}\equiv l_{skit}/(p_{skit}-\beta E_t p_{s+1\ k\ it+1}), \tag{1}$$

where $E_t p_{s+1\ k\ it+1}$ is given by one of the two formulas just described. The discount factor β is calculated as the inverse of the real interest rate—i.e., $1/(1+r_t)=(1+\pi_t)/(1+i_t)$, where i_t is Moody's Seasoned BAA Annual Corporate Bond Yield and π_t is the rate of inflation in year t. The variable m_{skit} thus measures the percent deviation of the lease rate from the benchmark of a perfectly liquid asset market.

I choose the yield of BAA corporate bonds because the average spread of the BAA corporate bond yield over the Treasury bond yield during our sample period is close to the average spread of the yield of aircraft-backed Securities, Equipment Trust Certificates (ETC) and Enhanced Equipment Trust Certificates (EETC) over the Treasury bond yield. More precisely, the spread of the BAA bond yield over the average between the 10-year Treasury bond yield and the 20-year Treasury Bond yield in our sample is equal to 198 basis points, while the spread of ETC and EETC over the corresponding treasury yields is 194 in the sample of Benmelech and Bergman (2009). All results where unchanged when using Moody's Seasoned AAA Corporate Bond Yield instead. I have also constructed markups using the realized values of prices—i.e., $E_t p_{s+1\ k\ it+1}=p_{s+1\ k\ it+1}$. The point estimates of the results were similar, but the standard errors were much higher because, due to time-series volatility of aircraft prices, the markups calculated in this latter way exhibit a much wider range of values. Sometimes, markups are negative (when prices increase) or very large (when prices decline substantially). Moreover, Jensen's inequality shows that

$$\frac{1}{(p_{skit}-\beta E_t p_{s+1\ k\ it+1})}\neq E\frac{1}{(p_{skit}-\beta p_{s+1\ k\ it+1})},$$

suggesting that using the realized values of prices and the ex post markups might not be the correct way to incorporate the information available to the parties at the time the lease terms are set.

4.1.3. Descriptive statistics

Table 1 provides summary statistics of the main variables used in the empirical analysis. Panel A provides summary statistics for the cross-sectional data of the aircraft characteristics dataset. I restrict the analysis to aircraft that are used for passenger transportation, so freighters and corporate aircraft are excluded from the sample. This is done to reduce "undesired" heterogeneity among operators in the sample. The sample consists of 14,301 aircraft, of which 52% are leased: 33.5% of all aircraft are under an operating lease and 18.6% under a capital lease. The average age of the aircraft in the sample is 10.57 years, with considerable variation (standard deviation of 8.59).

There are a total of 35 different aircraft types. There is considerable variation in AIRCRAFT PER TYPE, our measure of aircraft liquidity. Some aircraft types are very popular and have been produced in large numbers. Others have been less successful or are old types that are currently being retired. For example, the dataset reports that carriers are currently operating approximately 4000 Boeing 737s and as few as one Boeing 720. The empirical analysis uses the

[7] In a previous version of the paper, I also measured the liquidity of an aircraft type with the total number of carriers operating that given type. Clearly, the correlation of the total number of carriers operating a given type with AIRCRAFT PER TYPE is very high (0.94), and the results of all the empirical tests were almost identical to those presented here.

[8] It is important to note that I construct the measure of liquidity at the aircraft-type level. As specified above, a type is, for example, Boeing 737, Boeing 747, MD-80, etc. Within each type, there might be different models. For example, for the type Boeing 737, there are models B737-200, B737-300, etc. Within each type, the technical specifications of different models are very similar and, thus, consistent with industry norms, comparisons between types exactly capture differences in liquidity.

[9] Ideally, the measure of liquidity corresponds to the year in which the decision to own or lease was made or, if leasing is chosen, to the year in which the current lease contract started. However, for many observations, the data do not report such precise information. For example, for many leased aircraft, the start date of the current contract is missing. Nevertheless, in most cases, the date on which the operator acquired the aircraft coincides with the relevant date of the measures of liquidity. Hence, any discrepancy between the relevant date and the date used here is minimal.

Table 1
Summary statistics.

This table provides summary statistics of the variables used in the empirical analysis. Panel A presents summary statistics for all aircraft in the sample. The full sample is used in the test of hypothesis H1. The sample is restricted to leased aircraft only in the test of hypothesis H2. Aircraft per type corresponds to the total stock of aircraft of the same type in the year in which the carrier acquired the aircraft. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. Carrier fleet size is the total number of aircraft operated by a carrier. Panel B presents summary statistics of all leased aircraft for which lease maturity is available. These data are used to test hypotheses H3 and H4. Duration is measured in months. Panel C presents summary statistics for all aircraft for which prices and lease rates are available. These data are used to test hypothesis H5. Prices and lease rates in Panel C have been deflated, and values correspond to millions of year 2000 U.S. dollars. Markup is the ratio of the operating lease rate l_{skit} to the implicit rental rate $p_{skit}-\beta E_t p_{s+1\ k\ it+1}$, where p_{skit} is the price of an aircraft, s is a vintage, k is a model, i is a type, t is a year, β is the discount factor, and E_t is the expectation taken at time t. Since $E_t p_{s+1\ k\ it+1}$ is unobserved, we assume either that $E_t p_{s+1\ k\ it+1}=p_{s+1kit}$ or that $E_t p_{s+1\ k\ it+1}=\delta p_{skit}$ and estimate δ through a panel-data regression $p_{s+1\ k\ it+1}=\delta p_{skit}+\varepsilon_{s+1\ k\ t+1}$.

Panel A: All Aircraft (14,301 Observations)	Mean	St. dev.
Leased	52.1%	
Operating lease	33.5%	
Capital lease	18.6%	
Age of Aircraft	10.57	8.59
Types of Aircraft	35	
Aircraft per type	1202	1247
Carriers	713	
Carrier fleet size	191	231
Panel B: Leased Aircraft		
Duration of operating lease contract (2,086 Obs.)	100.34 months	50.87
Duration of capital lease contract (1,814 Obs.)	223.21 months	57.22
Panel C: Aircraft values (3,927 Observations)		
Price ($ millions)	31.88	26.97
Annual Lease Rates ($ millions)	3.57	2.52
Markup $l_{skit}/(p_{skit}-\beta p_{s+1kit})$	1.17	0.45
Markup $l_{skit}/(p_{skit}-\beta\delta p_{skit})$	1.16	0.48

logged variable Log(Aircraft per type), which takes into account the skewness of the liquidity measure. The use of the logarithm also makes the liquidity measure a concave function of the underlying variable, which is probably appropriate to capture the diminishing marginal liquidity effect of an increase in Aircraft per type.

There are 713 carriers in the sample, and there is considerable variation in the size of their fleets. Carrier fleet size is simply the total number of aircraft each carrier operates. There are carriers as big as American Airlines, with 826 aircraft, and as small as the 170 carriers that each operate just one aircraft. The empirical analysis uses the variable Log(carrier fleet size) to take into account skewness and diminishing marginal effects.

Panel B considers leased aircraft for which the duration of the lease is reported in the data. Unfortunately, the duration is missing for a number of leased aircraft. There is considerable variation in durations between the two types of leases (the average duration is 100 months for operating leases and 223 months for capital leases) and within each type of lease (the standard deviation of duration is 50 months for operating leases and 57 months for capital leases). Many observations are clustered at "focal" durations, such as 60 or 72 months. Interestingly, there are very few operating leases whose duration is close to 75% of the economic life of assets, which is the accounting cutoff to be considered an operating lease and, hence, off-balance sheet for the lessee, further reinforcing the idea that the operating versus capital classification is not a mere accounting difference.

Panel C reports summary statistics of the aircraft values dataset. The unit of observation is now a model-vintage pair, and there are a total of 3,927 model-vintage-year observations for which I could construct both versions of the operating lease markups.[10] The average price of an aircraft is $31.88 million (in 2000 U.S. dollars); the average annual lease rate is $3.57 million dollars; and the average markup is either 1.17 or 1.16, depending on how $E_t p_{s+1\ k\ it+1}$ is computed. Prices, lease rates, and markups exhibit considerable variation (overall standard deviation is around $27 million, $2.52 million, and either 0.45 or 0.48, respectively) across models, vintages, and years.

The strengths of the aircraft characteristics data lie in their coverage of the universe of commercial aircraft and in the richness of details for each individual aircraft. In the empirical analysis, this allows us to control for several features of the asset that are often unobserved in studies that rely on cross-sectional variation in the data. Information on carriers is more limited, and the empirical analysis uses carrier fixed-effects to control for unobserved carrier-specific factors that potentially drive the observed correlations between the liquidity of the aircraft and features of the contracts.

Similarly, the aircraft values data cover a large number of years and aircraft models, allowing controls for year-to-year aggregate shocks through year fixed-effects and for unobserved characteristics of the aircraft through aircraft-model fixed-effects. The limit of the aircraft values dataset is that the data are appraised values based on reported transactions and on fleet evaluations. Hence, they represent average values, and the empirical analysis can investigate only how aircraft liquidity affects these average values. Thus, the nature of the data precludes investigating other potentially interesting implications that the financial contracting literature has focused on, such as how lessors' and lessees' outside options in bargaining determine deviations from the average lease rates used here.

4.2. An illustrative comparison: Mc Donnell-Douglas 80 versus Airbus 300-600

Before proceeding to more-formal tests of the hypotheses of the effects of liquidity on the characteristics of

[10] We dropped the upper and lower one percent of lease rates as representing clear reporting mistakes with unusually small or high values.

Table 2
A comparison: McDonnell-Douglas 80 versus Airbus 300-600.

This table provides summary statistics of the variables used in the empirical analysis for two aircraft types: the McDonnell-Douglas 80 (MD80) and the Airbus 300-600 (A300-600). Aircraft per type corresponds to the total stock of aircraft of the same type in the year in which the carrier acquired the aircraft. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. Carrier size of fleet is the total number of aircraft operated by a carrier. Duration is measured in months. Markup is the ratio of the operating lease rate l_{skit} to the implicit rental rate $p_{skit} - \beta E_t p_{s+1\ k\ it+1}$, where p_{skit} is the price of an aircraft, s is a vintage, k is a model, i is a type, t is a year, β is the discount factor, and E_t is the expectation taken at time t. Since $E_t p_{s+1\ k\ it+1}$ is unobserved, we assume either that $E_t p_{s+1\ k\ it+1} = p_{s+1kit}$ or that $E_t p_{s+1\ k\ it+1} = \delta p_k it$ and estimate δ through a panel-data regression $p_{s+1\ k\ it+1} = \delta p_{skit} + \varepsilon_{s+1\ k\ t+1}$.

	MD 80	A300-600	Difference	t-Test
Panel A: All Aircraft				
Aircraft per type	833	138		
Aircraft—leased	59.3%	36.2%	0.231	0.000
Aircraft—Operating lease	33.6%	16.2%	0.174	0.000
Aircraft—Capital lease	25.6%	20.0%	0.056	0.049
Age of Aircraft	14.1	11.8		
Carriers	52	21		
Carrier size of fleet	382.61	217.7		
Panel B: Leased Aircraft				
Duration of operating lease contract (months)	98.6	120	−21.36	0.049
Duration of capital lease contract (months)	247.7	226.5	21.24	0.009
Panel C: Aircraft Values				
Markup $l_{skit}/(p_{skit} - \beta p_{s+1kit})$	1.20	1.36	−0.16	0.000
Markup $l_{skit}/(p_{skit} - \beta\delta p_{skit})$	1.14	1.31	−0.17	0.000

lease contracts, this subsection presents simple illustrative patterns comparing two well-known aircraft: the McDonnell-Douglas 80 (MD80) and the Airbus 300-600 (A300-600). The two aircraft have similar histories. Both were introduced in the 1980s and were based on successful older models, the DC-9 for the MD80 and the A300 for the A300-600. The MD80 is a short-haul narrow-body aircraft with around 150 seats, while the A300-600 is a medium-range wide-body aircraft with approximately 250 seats.

Although Table 2 shows simple averages, it is suggestive of the forces at work. The MD80 is, by our definition, more liquid than the A300-600: Aircraft per type is higher for the MD80 than for A300-600. Interestingly, the data show, as hypothesis H1 suggests, that the fraction of MD80s that are leased is substantially higher than the fraction of A300-600s: 59.3% versus 36.2%, respectively (the one-sided t-test has a p-value of 0.00). Moreover, the fraction of aircraft under each type of lease contract is higher for the MD80 than for the A300-600. But the difference between the fraction of MD80s and A300-600s under operating leases is substantially higher than the difference between the fraction of MD80s and A300-600s under capital leases: 0.174 versus 0.056 (the one-sided t-test of the difference, 0.119, has a p-value of 0.023). This difference-in-difference seems to suggest that liquidity has different effects on the two lease contracts, consistent with hypothesis H2.

Interesting differences emerge for the duration of lease contracts, too. The duration of operating leases is shorter for the MD80 than for the A300-600: 98.6 months versus 120 months (the one-sided t-test has a p-value of .049). Instead, the duration of capital leases is longer for the MD80 than for the A300-600: 247.7 months versus 226.5 months (the one-sided t-test has a p-value of 0.009). These differences highlight how greater liquidity has different effects on the two types of lease contracts, as suggested by hypotheses H3 and H4.

Similarly, remarkable differences emerge between the markups of lease rates over aircraft prices. As H5 predicts, the markups are smaller for the MD80 than for the A300-600: 1.20 versus 1.36 when $E_t p_{s+1\,kit+1} = p_{s+1}$ (the one-sided t-test has a p-value of 0.000), and 1.14 versus 1.31 when $E_t p_{s+1\ k\ it+1}$ is calculated as $\hat{\delta} p_{skit}$ (the one-sided t-test has a p-value of 0.000).

While this evidence is clearly not conclusive, these figures seem to uncover patterns consistent with the hypotheses. The next subsection develops other empirical strategies to test the hypotheses.

4.3. Testing the hypotheses

To test the hypotheses laid out in Section 3, I use the population of wide-body, narrow-body and regional commercial jets used for passenger transportation. I use the cross-section of all aircraft active as of April 2003 to test the effect of liquidity on whether aircraft are leased (hypothesis H1). I then restrict the sample to leased aircraft only to test the effect of liquidity on whether the lease contract is an operating or a capital lease (hypothesis H2). I further restrict the analysis to all leased aircraft for which the duration of the lease contract is available, investigating the effect of liquidity on lease maturity (hypotheses H3 and H4). I conclude the section by using the aircraft values dataset to analyze the effect of liquidity on lease rate markups (hypothesis H5).

4.3.1. Fraction of leased aircraft

This subsection investigates the relation between the ownership status of each individual aircraft and the liquidity of the aircraft, formally testing H1. The test is based on the following specification:

$$\text{Leased}_{lijt} = f(\alpha Y_{lijt} + \beta \text{Liquidity}_{it} + \mu_i + \gamma X_j). \quad (2)$$

The dependent variable Leased_{lijt} is equal to one if aircraft l of type i acquired by carrier j in year t is leased, and zero otherwise. Thus, the dependent variable is equal to one if the aircraft has either an operating or a capital lease. Y_{lijt} is a vector of variables specific to each aircraft l, such as Age of aircraft, Age squared, the (log of the) number of years since the aircraft type entered the market, and dummies for the engine manufacturer.[11] Liquidity_{it} is the measure of the liquidity of aircraft of type i in year t, Log(Aircraft per type_{it}), and μ_i is a vector of aircraft-type fixed effects. The inclusion of aircraft-type fixed-effects makes it possible to control for all type-specific characteristics that might affect whether or not an aircraft is leased, and it allows a cleaner identification of the effect of liquidity. X_j is a vector of variables specific to each carrier j; in particular, the simplest specifications controls for the size of the carrier using the log of the total number of aircraft the carrier operates, Log(carrier fleet size). Other specifications control for potentially unobserved carrier-specific factors using carrier fixed-effects.[12]

Letting f denote the cumulative distribution function of the normal distribution, Eq. (2) is a simple probit regression estimated by maximum likelihood. Column 1 in Panel A of Table 3 presents the estimates of the coefficients. The positive sign of the coefficient of the measure of liquidity indicates that more-liquid aircraft make leasing more likely, as predicted by H1. Moreover, the coefficients reported in Column 1 imply that the proxies for the liquidity of the aircraft are also economically significant. A 10% increase in Aircraft per type increases the probability that an aircraft is leased by 1.3 percentage points, which is approximately a 2.5% increase in the probability that the aircraft is leased.

The negative coefficient of Log(carrier fleet size) indicates that smaller carriers are more likely to lease, in accordance with the findings of Sharpe and Nguyen (1995) and Eisfeldt and Rampini (2009). As discussed in Section 3, however, the absence of several other useful controls that might be correlated with Log(carrier fleet size) does not allow us to clearly interpret its negative coefficient.

I have also estimated Eq. (2) employing a linear probability model and with slightly different specifications. Since approximately half of the aircraft in the sample are leased, the main drawback of the linear probability model—predicted probabilities outside the unit interval—is not a concern here: at most, 0.66% of the observations have a predicted probability below zero or above one in the specifications of Columns 3–5 in Table 3. The coefficients reported in Column 2 correspond to a linear probability model analogous to the probit model of Column 1. The specification reported in Column 3 uses dummy variables for the age of aircraft to capture in a flexible way potential nonlinearities beyond the quadratic of Column 1. The specification of Column 4 also adds carrier fixed-effects to capture carrier-specific unobserved non-random components that could bias the results.[13] In this way, I identify the effect of liquidity comparing within each carrier how the probability that each aircraft is leased covaries with liquidity, thus providing an even stronger test of hypothesis H1.

The signs of the coefficients reported in Columns 2–4 confirm the results found using the probit. The coefficients reported in Columns 2 and 3 also imply magnitudes very similar to the magnitudes of the probit. The inclusion of carrier fixed-effects in the specification of Column 4 reduces the magnitude of the effect of liquidity by about one-quarter. According to the coefficient of Log(aircraft per type) in Column 4, a 10% increase in liquidity increases the probability that the aircraft is leased by about 0.9 percentage points, corresponding to an increase in the probability that the aircraft is leased of approximately 2%. Overall, the specification reported in Column 4 suggests that unobserved carrier-specific effects do not affect the qualitative answers of our empirical tests, providing a significant robustness check to our previous results.

Column 5 presents the results of a specification that represents an additional, very powerful robustness check to the specifications of Columns 1–4. From the time-series dataset, I construct a panel dataset that records whether each individual aircraft (by serial number) was leased or not in each year in which the aircraft was active. I then regress this newly constructed dependent variable Leased on control variables—Age, Age Squared, the (log of the) number of years since the aircraft type entered the market—and on the measure of liquidity Log(aircraft per type), also including year fixed-effects, carrier fixed-effects, and, more important, individual aircraft (a serial number) fixed-effects. Using individual aircraft fixed-effects means that we are identifying the effect of liquidity on whether or not an aircraft is leased using information only on aircraft whose ownership status *changed* from owned to leased and vice versa during the sample period, beyond common year effects that are captured by year fixed-effects. In particular, the identification of the effect of liquidity in the specification in Column 5 excludes all liquid aircraft that are "born" leased and remain leased for their entire life, and all illiquid aircraft that are "born"

[11] General Electric is both an important producer of aircraft engines and one of the biggest operating lessors, and aircraft with GE engines are more likely to be leased. Hence, I add engine-maker fixed-effects to the regressions.

[12] As first observed by Neyman and Scott (1948), estimating fixed effects in a nonlinear model could generate the incidental parameter problem if the number of observations per fixed effect is small (see Lancaster, 2000 for a review article). However, in this case, there are 14,301 observations and only 35 aircraft-type fixed-effects, so the incidental parameter problem is not a concern for aircraft-type fixed-effects. In the case of carrier fixed-effects, in all specifications, I include a fixed effect only if the carrier operates more than 30 aircraft.

[13] Estimating Eq. (2) using a maximum likelihood probit model with the full set of carrier fixed-effects leads to the well-known problem of perfect classification in maximum likelihood estimation, since some carriers have either 0% or 100% of the fleet under lease. This is why I use the linear probability model instead.

Table 3
Asset liquidity and leasing versus owning.

This table investigates how asset liquidity affects whether aircraft are leased or owned. The dependent variable is equal to one if the aircraft is leased, and zero otherwise. Columns 1–4 present results of cross–sectional regressions, while Column 5 presents results of a panel-data fixed-effect regression. Column 1 presents the coefficient of a maximum likelihood probit. Columns 2–5 present the coefficients of linear regressions. Carrier fleet size is the total number of aircraft operated by a carrier. Aircraft per type corresponds to the total stock of aircraft of the same type in the year in which the carrier acquired the aircraft. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. The standard errors in parentheses are clustered at the type-year level.

Leased	(1)	(2)	(3)	(4)	(5)
Age	0.11082	0.03912			0.00522
	(0.01717)	(0.00577)			(0.00437)
Age Squared	−0.00323	−0.00110			−0.00014
	(0.00042)	(0.00014)			(0.00002)
Log(Carrier fleet size)	−0.15742	−0.05540	−0.05462		
	(0.02529)	(0.00839)	(0.00826)		
Log(Aircraft per type)	0.33418	0.11257	0.12080	0.09351	0.00910
	(0.06552)	(0.02125)	(0.02112)	(0.02016)	(0.00278)
Log(Years since introduction)	−0.16537	−0.04485	−0.02967	−0.01329	−0.12564
	(0.14691)	(0.05031)	(0.04564)	(0.04417)	(0.12021)
Age fixed-effects	No	No	Yes	Yes	No
Carrier fixed-effects	No	No	No	Yes	Yes
Engine maker fixed-effects	Yes	Yes	Yes	Yes	No
Aircraft type fixed-effects	Yes	Yes	Yes	Yes	NA
Year fixed-effects	No	No	No	No	Yes
Serial number fixed-effects	No	No	No	No	Yes
Log Likelihood	−8,796.48				
R^2		0.1430	0.1575	0.3190	0.7497
N	14,301	14,301	14,301	14,301	276,909

owned by their users and remain owned by their users for their entire life, thus providing a very strong check on the previous specifications.[14]

The results reported in Column 5 show that, qualitatively, all previous results are robust to this stronger test. The magnitude of the coefficient of the measure of liquidity Log(aircraft per type) is substantially reduced compared to the coefficient of the specification of Column 4, which is expected given that the identification of the coefficient uses information only from aircraft whose ownership status changed during their "life."

4.3.2. *Operating lease versus capital lease*

The previous analysis provided strong evidence that more-liquid aircraft are more likely to be leased, as hypothesis H1 suggests. According to hypothesis H2, as aircraft become more liquid, the share of aircraft under an operating lease should increase faster than the share of aircraft under a capital lease. To investigate the effect of liquidity on the proportion of operating leases versus capital leases, I restrict the sample to leased aircraft only and estimate regressions similar to Eq. (2), the main difference being that the dependent variable is equal to one if the aircraft is under an operating lease and zero if the aircraft is under a capital lease.

Table 4 reports the estimated coefficients. The specification of Column 1 is a probit regression that includes aircraft type fixed-effects. Column 1 shows that the estimated coefficient of Log(aircraft per type) is positive. This means that as aircraft become more liquid, the probability that an aircraft is leased with an operating lease rather than with a capital lease increases, as hypothesis H2 predicts. A 10% increase in Aircraft per type increases the probability that an aircraft is leased with an operating lease by 1.4 percentage points.

The specifications reported in Columns 2–5 employ linear probability models. The specification of Column 2 uses the same explanatory variables as the probit model of Column 1. The specification reported in Column 3 uses dummy variables for the age of aircraft. The specification of Column 4 also adds carrier fixed-effects to capture carrier-specific unobserved non-random components that could bias the results. In this way, the effect of liquidity is identified by comparing within each carrier how the probability that each aircraft is leased with an operating lease covaries with liquidity, thus providing an even stronger test of hypothesis H2. The specification of Column 5 further adds fixed-effects for the year of acquisition of the aircraft.

The signs of the coefficients reported in Columns 2–5 confirm the results found using the probit. The magnitude of the effect of liquidity is also very similar across all specifications. Moreover, the specifications reported in Columns 4 and 5 indicate that the test of hypothesis H2 is unaffected by carrier-specific effects, strengthening the findings.

4.3.3. *Maturity of operating and capital leases*

This subsection investigates the effect of aircraft liquidity on the duration of lease contracts, thus testing hypotheses H3 and H4. The analysis is based on the

[14] I drop engine maker (aircraft-type) fixed-effects because they are perfectly (almost perfectly) collinear with serial number fixed-effects.

Table 4
Asset liquidity and operating lease versus capital lease.

This table investigates how asset liquidity affects whether aircraft are leased with an operating lease or with a capital lease. The sample includes leased aircraft only. The dependent variable is equal to one if the aircraft is leased with an operating lease by the carrier that operates it, and zero if it is leased with a capital lease. Column 1 presents the coefficient of a maximum likelihood probit. Columns 2–5 present the coefficients of linear regressions. Carrier size of the fleet is the total number of aircraft operated by a carrier. Aircraft per type corresponds to the total stock of aircraft of the same type in the year in which the carrier acquired the aircraft. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. The standard errors in parentheses are clustered at the type-year level.

Leased	(1)	(2)	(3)	(4)	(5)
Age	−0.05942	−0.01372			
	(0.02407)	(0.00553)			
Age squared	0.00100	0.00003			
	(0.00087)	(0.00018)			
Log(Carrier size of fleet)	−0.39078	−0.10923	−0.10923		
	(0.03210)	(0.01063)	(0.01036)		
Log(Aircraft per type)	0.43809	0.13828	0.13597	0.11477	0.09806
	(0.10979)	(0.03142)	(0.03058)	(0.02457)	(0.02524)
Log(Years since introduction)	−0.67266	−0.67266	−0.17175	−0.04324	−0.03491
	(0.25846)	(0.06740)	(0.06372)	(0.04922)	(0.04776)
Age fixed-effects	No	No	Yes	Yes	No
Carrier fixed-effects	No	No	No	Yes	Yes
Engine maker fixed-effects	Yes	Yes	Yes	Yes	No
Aircraft type fixed-effects	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	No	No	No	No	Yes
Log Likelihood	−3,663.52				
R^2		0.2817	0.2920	0.4814	0.4858
N	7,462	7,462	7,462	7,462	7,462

following reduced-form equation:

$$\text{Duration}_{lijt} = \alpha Y_{lijt} + \beta \text{Liquidity}_{it} + \mu_i + \gamma_j + \eta_t + \varepsilon_{lijt}. \quad (3)$$

Duration_{lijt} is the duration (in months) of the lease contract of aircraft l of type i operated by carrier j signed in year t. As in Eq. (2), Y_{lijt} is a vector of variables specific to each individual aircraft; Liquidity_{it} is the measure of liquidity Log(Aircraft per type$_{it}$); μ_i is a vector of aircraft-type fixed-effects; γ_j is a vector of carrier fixed-effects to control for all possible unobserved carrier-specific factors; and η_t is a vector of fixed-effects for the year in which the lease started to capture unobserved common time effects.[15] The estimated equations also include lessor fixed-effects to control for lessor-specific unobserved factors.

As in Crocker and Masten (1988) and Joskow (1987), the sample is truncated. The data refer to a cross-section of leases at one point in time, April 2003. Thus, we observe a given lease if

$$\text{Duration}_{lijt} \geq T_{lijt} \equiv \text{April 2003} - \text{Lease Date}_{lij},$$

which is to say that the duration is longer than the truncation point T_{lijt}, the difference in months between April 2003 and the date the lease was signed. The truncated sample implies that ordinary least-squares estimates of Eq. (3) lead to biased and inconsistent coefficients. However, assuming that the unobservables ε_{lijt} are normally distributed, I can construct the likelihood of observing each contract given the nature of the truncation (see Maddala, 1983), and then estimate Eq. (3) using maximum likelihood.

I estimate Eq. (3) separately for operating and capital leases. Column 1 in Table 5 presents the maximum likelihood estimates of the coefficients of Eq. (3) for operating leases, and Column 2 reports the coefficients of the duration equation for capital leases.

The two columns show that the liquidity of the aircraft has significant predictive power. In Column 1, the negative coefficient of Log(aircraft per type) indicates that more-liquid aircraft have shorter operating leases, exactly as predicted by hypothesis H3. The magnitude of the coefficient shows that aircraft liquidity has economic significance, too. Doubling Aircraft per type shortens the duration until maturity of the operating lease by approximately 14 months.

Column 2 shows that the results for capital leases are remarkably different. Higher liquidity leads to longer capital leases, exactly as predicted by hypothesis H4. In particular, according to the specification of Column 2, doubling Aircraft per type lengthens the duration until maturity of the capital lease by around 13 months.

To illustrate the magnitudes of the coefficients and the implications for contract duration, Fig. 1 displays the fitted values for the Boeing 737 based on the estimated coefficients in Columns 1 and 2 of Table 5. The figure shows that an increase in liquidity has very different effects on operating and capital leases. For example, leases for the Boeing 737 had an average maturity of 100 months for operating leases and 205 months for capital leases if the contracts were signed in 1983, when the stock of Boeing 737s was equal to approximately 1,000 units. If the contracts were signed in 2003, when the stock of Boeing

[15] I group the oldest contracts in a single time dummy because there are too few observations per year to estimate all parameters consistently.

Table 5
Asset liquidity and the maturity of leases.

This table presents maximum likelihood estimates of the coefficients of Eq. (3) using data for operating leases and capital leases separately. The dependent variable is the duration of the lease contract (in months). The likelihood takes into account the truncation in the dependent variable. Aircraft per type corresponds to the total stock of aircraft of the same type in the year in which the carrier acquired the aircraft. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. The standard errors in parentheses are clustered at the type-year level.

Duration of lease contract	(1) Operating lease	(2) Capital lease
Age	−4.7416	−9.2320
	(0.62074)	(1.4464)
Age squared	0.12482	−0.02500
	(0.04004)	(0.12889)
Log(Aircraft per type)	−13.7005	12.9576
	(6.7345)	(6.8391)
Log(Years since introduction)	7.16913	0.32298
	(8.90684)	(11.7091)
Aircraft Type fixed-effects	Yes	Yes
Carrier fixed-effects	Yes	Yes
Lessor fixed-effects	Yes	Yes
Year fixed-effects	Yes	Yes
Log Likelihood	−8,349.9594	−7,227.00
N	2,086	1,814

737s was equal to approximately 4,000 units, then the average maturity of operating leases decreases to 80 months, while the average maturity of capital leases increases to 225 months.

4.3.4. Operating lease-rate markups

The analysis so far has shown that aircraft liquidity systematically affects several characteristics of lease contracts. This subsection shows that the markups of aircraft operating lease rates over prices vary with the liquidity of the aircraft, according to hypothesis H5. I combine the aircraft values and aircraft characteristics datasets and use panel data to estimate the following equation:

$$m_{skit} = \alpha Y_{skit} + \beta \text{Liquidity}_{it} + \zeta_{sk} + \eta_t + \varepsilon_{skit}, \tag{4}$$

where s is a vintage, k is a model, i is a type, t is a year, and m_{skit} is the markup as defined in Eq. (1).[16] Y_{skit} is a vector of variables such as Age, Age squared, and the (log of the) number of years since the aircraft type entered the market. Liquidity_{it} is the measure of the liquidity of aircraft of type i in year t Log(Aircraft per type$_{it}$); ζ_{sk} is a fixed effect for each aircraft model k-vintage s pair; η_t is a year fixed-effect; and ε_{skit} is the unobserved component. The inclusion of the model-vintage fixed-effects and the year fixed-effects implies that we identify the effect of liquidity by exploiting how Aircraft per type covaries with the markup using only the within-year and within-type deviations from its mean, thus providing a very powerful identification of the effect of liquidity on the markups of operating lease rates.[17]

The results are presented in Table 6. In the regressions presented in Column 1, the implicit rental rate is calculated under the assumption that the expected price of an aircraft of vintage $s+1$ model k type i in year $t+1$ is equal to the price of an aircraft of model k type i vintage $s+1$ in year t: $E_t p_{s+1\ k\ it+1} = p_{s+1kit}$. In the regressions presented in Column 2, the implicit rental rate is calculated under the assumption that the price of an aircraft of vintage $s+1$ model k type i in year $t+1$ is equal to δ percent of the price of the aircraft of vintage s model k type i in year t: $E_t p_{s+1\ k\ it+1} = \delta p_{skit}$, where $\delta = 0.9375$ is estimated via a panel-data regression.

As predicted by hypothesis H5, the negative signs of the coefficients of the measure of liquidity indicate that more-liquid aircraft have smaller operating lease-rate markups. Moreover, the magnitudes of the coefficients imply that an increase in liquidity has a considerable effect on markups. The estimates of Columns 1 and 2 imply that the average markup decreases by 1.4–2.0 percentage points when Aircraft per type increases by 10%. The magnitude also conforms reasonably well with the decrease in markups observed for the most popular aircraft. For example, the markups of a 10-year-old Boeing 737 decreases from 1.23 when Aircraft per type is around 2,500 units (in 1993) to 1.15 when Aircraft per type is around 3,100 units (in 1998).

Overall, the results of the empirical analysis match well with the predictions of Section 3, suggesting that liquidity shapes lease contracts in the way financial contracting theories suggest. Moreover, the empirical evidence provides strong support for the idea that capital and operating leases are different contracts and likely serve different purposes.

4.4. Robustness checks and alternative hypotheses

The results of the previous subsections provide strong evidence that aircraft liquidity systematically affects lease contracts according to the hypotheses laid out in Section 3. This subsection reports on robustness checks that control for the potential mismeasurement of the proxy for aircraft liquidity and that use a finer classification for the liquidity proxy. It also discusses potential sources of endogeneity of Aircraft per type, providing evidence against them and then confirming the results using instrumental variables that exogenously shift liquidity. Finally, it discusses the role of taxation, which previous literature has documented as affecting corporate leasing policies. The analysis confirms and strengthens the previous findings.

4.4.1. Mismeasurement of liquidity

An important robustness check is to verify the results in light of potential mismeasurement of the proxy for

[16] Note that the panel variable is, therefore, a model-vintage pair. I have also reestimated Eq. (4) using model-age as a panel variable and the results are almost identical.

[17] The *Aircraft Values* dataset contains prices of several models k for each type i. Hence, I am using model-vintage pair fixed-effects ζ_{sk} since I am estimating Eq. (4) via a panel-data fixed-effects regression.

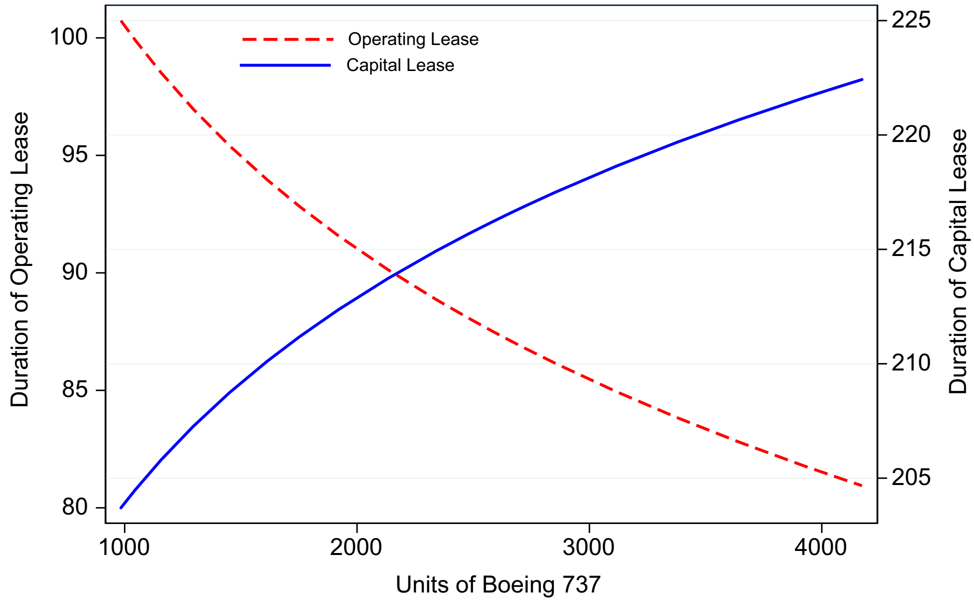

Fig. 1. Boeing 737s fitted lease maturities based on the coefficients of Table 5.

Table 6
Asset liquidity and markup of operating lease rates.

This table presents panel-data estimates of the coefficients of Eq. (4). The dependent variable is the markup of the operating lease rate l_{skit} over the implicit rental rate $p_{skit}-\beta E_t p_{s+1\ k\ it+1}$, where p_{skit} is the price of an aircraft, s is a vintage, k is a model, i is a type, t is a year, β is the discount factor, and E_t is the expectation taken at time t. In the regression presented in Column 1, the implicit rental rate is calculated under the assumption that the expected price of an aircraft of vintage $s+1$ of model k type i in year $t+1$ is equal to the price of an aircraft of vintage $s+1$ of model k type i in year t: $E_t p_{s+1\ k\ it+1} = p_{s+1kit}$. In the regression presented in Column 2, the implicit rental rate is calculated under the assumption that the price of an aircraft of vintage $s+1$ of model k type i in year $t+1$ is equal to δ percent of the price of the aircraft of vintage s of model k type i in year t: $E_t p_{s+1\ k\ it+1} = \delta p_{skit}$, where δ is estimated via an OLS regression. Aircraft per type corresponds to the total stock of aircraft of the same type in the year in which the carrier acquired the aircraft. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. All columns report coefficients obtained using panel-data regressions with fixed-effects for each model-vintage pair. The standard errors in parentheses are clustered at the type-year level.

Markup of Operating lease rate	(1) $\frac{l_{skit}}{p_{skit}-\beta p_{s+1kit}}$	(2) $\frac{l_{skit}}{p_{skit}-\beta\delta p_{skit}}$
Age	0.00407	−0.01909
	(0.00726)	(0.00642)
Age Squared	0.00143	0.00282
	(0.00022)	(0.00024)
Log(Aircraft per type)	−0.20623	−0.13738
	(0.05406)	(0.05645)
Log(Years since introduction)	−0.12602	−0.09057
	(0.10231)	(0.10554)
Year fixed-effects	Yes	Yes
Aircraft model-vintage fixed-effects	Yes	Yes
R^2	0.2966	0.5157
Groups	321	321
N	3,927	3,927

liquidity. The concern for potential mismeasurement arises because lessors are the owners of the aircraft, buying aircraft on the primary market and trading aircraft on the secondary market. As a result, the left-hand-side variable Leased affects the right-hand-side variable Aircraft per type. The idea is similar to a simultaneity bias, even though the reason here is more mechanical.

The potential problem is best explained with an example. Suppose that there are just two types of aircraft—A and B—and that, contrary to the hypothesis, liquidity has no effect on leasing decisions. Suppose also that in the absence of leasing, aircraft A and B have the same liquidity—that is, the same number of Aircraft per type. However, for reasons unrelated to liquidity, lessors buy disproportionately more of aircraft A than B. Then, since the measure of liquidity Aircraft per type includes both leased and non-leased aircraft, we would find a positive correlation between liquidity and the probability that the aircraft is leased, even though liquidity has nothing to do with the leasing decision. In other words, the measurement of right-hand-side liquidity could be affected by the left-hand-side Leased variable. Clearly, this concern applies to the tests of hypotheses H1 and H2 but not hypotheses H3 to H5.

This concern would be more acute with cross-sectional data aggregated at the type level instead of individual aircraft data and time-varying measures of liquidity. In particular, if the left-hand-side variable in Eq. (2) were the number of aircraft under lease, then mismeasurement would be a more serious concern. In this paper, mismeasurement of liquidity is probably lower since aircraft-type fixed-effects would capture it. Nonetheless, we can measure liquidity using the total number of aircraft of a given type that are *not* leased. If higher liquidity does not make leasing more likely, then the number of non-leased

Table 7
Robustness check: mismeasurement of liquidity—asset liquidity and leasing versus owning.

This table investigates how asset liquidity affects whether aircraft are leased or owned, excluding leased aircraft when calculating our measure of aircraft liquidity. The specifications used are identical to the specifications used in Table 3. The dependent variable is equal to one if the aircraft is leased, and zero otherwise. Columns 1–4 present results of cross–sectional regressions, while Column 5 presents results of a panel-data regression. Column 1 presents the coefficient of a maximum likelihood probit. Columns 2–5 present the coefficients of linear regressions. Carrier fleet size is the total number of aircraft operated by a carrier. Aircraft per type, non-leased corresponds to the total stock of non-leased aircraft of the same type in the year in which the carrier acquired the aircraft. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. The standard errors in parentheses are clustered at the type-year level.

Leased	(1)	(2)	(3)	(4)	(5)
Age	0.10920	0.03858			0.00505
	(0.01717)	(0.0057)			(0.00439)
Age Squared	−0.00319	−0.00109			−0.00015
	(0.00043)	(0.00013)			(0.00002)
Log(Carrier fleet size)	−0.16027	−0.05644	−0.05550		
	(0.02510)	(0.00830)	(0.00815)		
Log(Aircraft per type, non-leased)	0.38011	0.12791	0.13897	0.10629	0.00704
	(0.07625)	(0.02456)	(0.02447)	(0.02293)	(0.00302)
Log(Years since introduction)	−0.15984	−0.04320	−0.02706	−0.01053	−0.11323
	(0.14673)	(0.05029)	(0.04583)	(0.04423)	(0.12115)
Age fixed-effects	No	No	Yes	Yes	No
Carrier fixed-effects	No	No	No	Yes	Yes
Engine fixed-effects	Yes	Yes	Yes	Yes	No
Aircraft type fixed-effects	Yes	Yes	Yes	Yes	N/A
Year fixed-effects	No	No	No	No	Yes
Serial number fixed-effects	No	No	No	No	Yes
Log-Likelihood	−8,798.94				
R^2		0.1427	0.1573	0.3188	0.7497
N	14,301	14301	14,301	14,301	276,909

aircraft should have no effect on the leasing decision. If liquidity matters, for a given type, the number of non-leased aircraft should still affect the left-hand-side variable Leased. However, this new variable, called Aircraft per type, non-leased, will not suffer from the mismeasurement just described.

Table 7 reports the results of the regressions that investigate the share of leased versus owned aircraft. It corresponds to the specifications of Table 3. The results are similar to those reported in Table 3. For example, according to the specification of Column 4, increasing Aircraft per type, non-leased by 10% increases the probability that an aircraft is leased by around one percentage point.

Table 8 reports the results of the regressions that investigate whether an aircraft is operating-leased or capital-leased, using the same specifications as the regressions reported in Table 4. The table shows that the estimates are very similar to those reported in Table 4.

4.4.2. *A finer measure of liquidity*

An additional check is to verify the robustness of the results using a finer measure of liquidity. In previous regressions, the liquidity measure does not depend on vintage. However, if an aircraft type has been produced for a long time and its popularity is declining, the liquidity of the newest vintages would be low, even though the measure Aircraft per type would incorrectly indicate that they are liquid. Similarly, if an aircraft type has just been introduced, the liquidity of the newest vintages could be very high, even though the measure Aircraft per type would incorrectly indicate that they are illiquid.

To address this potential concern, I construct a measure of liquidity that also depends on the vintage of the aircraft. More precisely, for every year, I calculate from the time-series data the median age of the stock of aircraft of a given type and recompute the measure of liquidity counting the stock of aircraft of the same type whose age is either above or below the median age of that type. Hence, in addition to varying by type and by year, this new measure of liquidity, called Aircraft per type and vintage, varies also by age (albeit in a coarse way). I then match this new measure of liquidity Aircraft per type and vintage to each individual aircraft according to whether the age of the aircraft at the time the carrier acquired it was above or below the median age of all aircraft of the same type in the year of the acquisition. Since most aircraft are acquired new, most aircraft are matched to values of this new measure of liquidity that are below the median age of aircraft of the same type.

Tables 9–12 use this finer measure of liquidity to replicate the tests of hypotheses H1–H5 previously reported in Tables 3–6. Overall, the qualitative results are identical to the results reported in Tables 3–6. Moreover, in almost all cases, the coefficients of Aircraft per type and vintage imply that the quantitative effect of liquidity is slightly higher than reported in Tables 3–6, indicating that vintage effects play a role in determining aircraft liquidity and, thus, the characteristics of lease contracts.

4.4.3. *Exogeneity of liquidity: instrumental variables*

The evidence presented so far has shown that aircraft liquidity systematically affects lease contracts, as the

Table 8
Robustness check: mismeasurement of liquidity—asset liquidity and operating lease versus capital lease.

This table investigates how asset liquidity affects whether aircraft are leased with an operating lease or with a capital lease, excluding leased aircraft when calculating our measures of aircraft liquidity. The specifications used are identical to the specifications used in Table 4. The sample includes leased aircraft only. The dependent variable is equal to one if the aircraft is leased with an operating lease by the carrier that operates it, and zero if it is leased with a capital lease. Column 1 presents the coefficients of a maximum likelihood probit. Columns 2–5 present the coefficients of linear regressions. Carrier fleet size is the total number of aircraft operated by a carrier. Aircraft per type, non-leased corresponds to the total stock of non-leased aircraft of the same type in the year in which the carrier acquired the aircraft. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. The standard errors in parentheses are clustered at the type-year level.

Leased	(1)	(2)	(3)	(4)	(5)
Age	−0.06096	−0.01418			
	(0.02383)	(0.00549)			
Age Squared	0.00103	0.00005			
	(0.00086)	(0.00018)			
Log(Carrier fleet size)	−0.39590	−0.11096	−0.11090		
	(0.03188)	(0.01059)	(0.01030)		
Log(Aircraft per type, non-leased)	0.49387	0.15512	0.15145	0.12851	0.11310
	(0.12945)	(0.01059)	(0.03542)	(0.02833)	(0.02900)
Log(Years since introduction)	−0.65941	−0.18031	−0.16229	−0.03669	−0.03239
	(0.25402)	(0.06618)	(0.06256)	(0.04853)	(0.04732)
Age fixed-effects	No	No	Yes	Yes	No
Carrier fixed-effects	No	No	No	Yes	Yes
Engine maker fixed-effects	Yes	Yes	Yes	Yes	No
Aircraft type fixed-effects	Yes	Yes	Yes	Yes	N/A
Year fixed-effects	No	No	No	No	Yes
Log Likelihood	−3,665.94				
R^2		0.2809	0.2910	0.4808	0.4858
N	7,462	7,462	7,462	7,462	7,462

Table 9
Robustness check: a finer measure of liquidity—asset liquidity and leasing versus owning.

This table investigates how asset liquidity affects whether aircraft are leased or owned using a finer measure of aircraft liquidity. The specifications used are identical to the specifications used in Table 3. The dependent variable is equal to one if the aircraft is leased, and zero otherwise. Columns 1–4 present results of cross–sectional regressions, while Column 5 presents results of a panel-data fixed-effect regression. Column 1 presents the coefficient of a maximum likelihood probit. Columns 2–5 present the coefficients of linear regressions. Carrier fleet size is the total number of aircraft operated by a carrier. Aircraft per type and vintage corresponds to the stock of aircraft of the same type and same vintage bin (above or below median age of all aircraft of the same type in a given year) in the year of acquisition by the current carrier. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. The standard errors in parentheses are clustered at the type-year level.

Leased	(1)	(2)	(3)	(4)	(5)
Age	0.10930	0.03881			0.00225
	(0.01738)	(0.00582)			(0.00116)
Age Squared	−0.00311	−0.00107			−0.00015
	(0.00044)	(0.00014)			(0.00002)
Log(Carrier fleet size)	−0.16055	−0.05663	−0.05556		
	(0.02502)	(0.00829)	(0.00815)		
Log(Aircraft per type and vintage)	0.33468	0.11469	0.12944	0.09651	0.01258
	(0.07704)	(0.02571)	(0.02521)	(0.02426)	(0.00366)
Log(Years since introduction)	−0.13525	−0.03733	−0.02857	−0.00905	−0.01248
	(0.15026)	(0.05212)	(0.04725)	(0.04626)	(0.00864)
Age fixed-effects	No	No	Yes	Yes	No
Carrier fixed-effects	No	No	No	Yes	Yes
Engine maker fixed-effects	Yes	Yes	Yes	Yes	No
Aircraft type fixed-effects	Yes	Yes	Yes	Yes	N/A
Year fixed-effects	No	No	No	No	Yes
Serial number fixed-effects	No	No	No	No	Yes
Log Likelihood	−8,792.05				
R^2		0.1430	0.1575	0.3190	0.7497
N	14,301	14,301	14,301	14,301	276,909

hypotheses suggest. Moreover, the richness of the data has allowed us to rule out a number of factors—such as unobserved characteristics of the carrier or time-invariant characteristics of the aircraft—that might have driven the observed correlations.

Nonetheless, the use of a quantity-based measure of liquidity such as Aircraft per type can create a few potential challenges to the identification of the effect of liquidity. For example, one potential concern about the measure of liquidity Aircraft per type is the direction of causality. A

Table 10
Robustness check: a finer measure of liquidity—asset liquidity and operating lease versus capital lease.

This table investigates how asset liquidity affects whether aircraft are leased with an operating lease or with a capital lease, using a finer measure of aircraft liquidity. The specifications used are identical to the specifications used in Table 4. The sample includes leased aircraft only. The dependent variable is equal to one if the aircraft is leased with an operating lease by the carrier that operates it, and zero if it is leased with a capital lease. Column 1 presents the coefficient of a maximum likelihood probit. Columns 2–5 present the coefficients of linear regressions. Carrier fleet size is the total number of aircraft operated by a carrier. Aircraft per type and vintage corresponds to the stock of aircraft of the same type and same vintage bin (above or below median age of all aircraft of the same type in a given year) in the year of acquisition by the current carrier. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. The standard errors in parentheses are clustered at the type-year level.

Leased	(1)	(2)	(3)	(4)	(5)
Age	−0.06112	−0.01372			
	(0.02403)	(0.00554)			
Age Squared	0.00117	0.00006			
	(0.00087)	(0.00019)			
Log(Carrier fleet size)	−0.39458	−0.11073	−0.11062		
	(0.03194)	(0.01057)	(0.01029)		
Log(Aircraft per type and vintage)	0.46116	0.14650	0.14637	0.11575	0.09499
	(0.12450)	(0.03616)	(0.03599)	(0.02914)	(0.02971)
Log(Years since introduction)	−0.66096	−0.18558	−0.17415	−0.03780	−0.02670
	(0.25502)	(0.06848)	(0.06500)	(0.05089)	(0.04938)
Age fixed-effects	No	No	Yes	Yes	No
Carrier fixed-effects	No	No	No	Yes	Yes
Engine maker fixed-effects	Yes	Yes	Yes	Yes	No
Aircraft type fixed-effects	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	No	No	No	No	Yes
Log Likelihood	−3,671.97				
R^2		0.2796	0.2903	0.4795	0.4843
N	7,462	7,462	7,462	7,462	7,462

Table 11
Robustness check: a finer measure of liquidity—asset liquidity and the maturity of leases.

This table presents maximum likelihood estimates of the coefficients of Eq. (3) with data for operating leases and capital leases separately, using a finer measure of aircraft liquidity. The specifications used are identical to the specifications used in Table 5. The dependent variable is the duration of the lease contract (in months). The likelihood takes into account the truncation in the dependent variable. Aircraft per type and vintage corresponds to the stock of aircraft of the same type and same vintage bin (above or below the median age of all aircraft of the same type in a given year) in the year of acquisition by the current carrier. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. The standard errors in parentheses are clustered at the type-year level.

Duration of lease contract	(1) Operating lease	(2) Capital Lease
Age	−8.0848	−14.0766
	(1.0420)	(1.7819)
Age squared	0.10729	−0.31184
	(0.04619)	(0.08783)
Log(Aircraft per type and vintage)	−10.2538	18.5620
	(5.8852)	(5.5239)
Log(Years since introduction)	−24.9013	−26.1556
	(7.7612)	(11.7091)
Aircraft Type fixed-effects	Yes	Yes
Carrier fixed-effects	Yes	Yes
Lessor fixed-effects	Yes	Yes
Year fixed-effects	Yes	Yes
Log Likelihood	−9,302.054	−8,298.946
N	2,086	1,814

reverse-causality argument suggests that instead of asset liquidity affecting leasing contracts according to the hypotheses, it is the behavior of leasing companies that affects the measure of liquidity Aircraft per type.

The role of General Electric (GE) illustrates this reverse-causality argument. GE is both an important lessor through GE Commercial Aviation Services (GECAS) and an important producer of aircraft engines, and GECAS tends to lease aircraft with GE engines.[18] As GECAS has grown over time, it has purchased mainly aircraft types that use GE engines. Potentially, GECAS's demand for aircraft types with GE engines could have a significant multiplier effect. That is, it could lead to a large increase in demand for aircraft types with GE engines from non-GECAS buyers. If this were true, then the observed correlation between leasing and the number of aircraft could actually be driven simply by the increasing market impact of GECAS. In other words, it would not be intrinsic asset liquidity that drives the leasing decision, but that the leasing activities of GECAS have driven production and, thus, Aircraft per type. However, this reverse-causality

[18] GE produces aircraft engines on its own (GEAE) and through CFMI, a 50/50 joint venture with SNECMA (a French company). CFMI is the exclusive provider of engines for Boeing's most popular aircraft, the 737. CFMI also produces engines for the Airbus A320 family and the A340-200/300. GEAE produces engines for the Boeing 777, 767, and 747 aircraft, and the Airbus A300, A310, and A330. In all of these cases, CFMI and GEAE compete with Pratt & Whitney (a division of UTC), Rolls Royce, and IAE (a Pratt & Whitney/Rolls Royce joint venture).

Table 12
Robustness check: a finer measure of liquidity—asset liquidity and markup of operating lease rates.

This table presents panel-data estimates of the coefficients of Eq. (4) using a finer measure of aircraft liquidity. The specifications used are identical to the specifications used in Table 6. The dependent variable is the markup of the operating lease rate l_{skit} over the implicit rental rate $p_{skit}-\beta E_t p_{s+1\ k\ it+1}$, where p_{skit} is the price of an aircraft, s is a vintage, k is a model, i is a type, t is a year, β is the discount factor, and E_t is the expectation taken at time t. In the regression presented in Column 1, the implicit rental rate is calculated under the assumption that the expected price of an aircraft of vintage $s+1$ of model k type i in year $t+1$ is equal to the price of an aircraft of vintage $s+1$ of model k type i in year t: $E_t p_{s+1\ k\ it+1} = p_{s+1kit}$. In the regression presented in Column 2, the implicit rental rate is calculated under the assumption that the price of an aircraft of vintage s+1 of model k type i in year $t+1$ is equal to δ percent of the price of the aircraft of vintage s of model k type i in year t: $E_t p_{s+1\ k\ it+1} = \delta p_{skit}$, where δ is estimated via an OLS regression. Aircraft per type and vintage corresponds to the stock of aircraft of the same type and same vintage bin (above or below the median age of all aircraft of the same type in year t) in the year t. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. All columns report coefficients obtained using panel-data regressions with fixed-effects for each model-vintage pair. The standard errors in parentheses are clustered at the type-year level.

Markup of Operating lease rate	(1) $\frac{l_{skit}}{p_{skit}-\beta p_{s+1kit}}$	(2) $\frac{l_{skit}}{p_{skit}-\beta\delta p_{skit}}$
Age	0.00739	−0.01698
	(0.00713)	(0.00621)
Age squared	0.00146	0.00282
	(0.00022)	(0.00024)
Log(Aircraft per type and vintage)	−0.20506	−0.15616
	(0.05120)	(0.05260)
Log(Years since introduction)	−0.21446	−0.12621
	(0.08312)	(0.08447)
Year fixed-effects	Yes	Yes
Aircraft model-vintage fixed-effects	Yes	Yes
R^2	0.2747	0.4974
Groups	321	321
N	3,927	3,927

argument is at odds with several empirical facts. First, this argument would be consistent with some of the results, such as the test of hypothesis H1 on the lease versus owned margin, but clearly cannot explain other results, such as the tests of hypotheses H2, H3 and H4 on the differential effect of liquidity on operating and capital leases, and the test of hypothesis H5 on the markups of lease rates. Second, all the regressions included aircraft type and engine maker fixed-effects, and these fixed-effects would capture most of the empirical content of this argument. Third, and perhaps most important, the empirical results still hold when aircraft with GE (and CFMI, a GE joint venture) engines are dropped from the analysis.

Another potential concern about the empirical analysis is that an omitted variable simultaneously drives *all* features of leasing contracts and the measure of liquidity Aircraft per type. In other words, the liquidity of an aircraft type could be driven by unobserved factors that are correlated with the leasing decision. If this were the case, the correlation between Aircraft per type and features of leasing contracts would be spurious.

The argument developed by Morrell (2001) illustrates this potential concern. Morell argues that one advantage of leasing is that lessors receive price discounts from the manufacturers on their orders and are able to pass part of these savings to lessees. If discounts are related to the quantities of aircraft purchased, then lessors might buy more popular/liquid aircraft simply because they get bigger discounts. However, this argument is again at odds with several empirical facts. First, this explanation is consistent with some of our results, such as the test of hypothesis H1 on the lease versus owned margin or the test of hypothesis H5 on the markups of lease rates, but probably cannot explain the tests of hypotheses H2, H3 and H4 on the differential effect of liquidity on operating and capital leases. Second, the data show that, in particular, small lessors, which own few aircraft (thus no large purchases) and mainly purchase used aircraft (thus no manufacturer's discount), are the ones that choose the most-liquid aircraft. Third, this argument does not explain the *disadvantages* of leasing in some cases; in particular, it fails to explain why not all aircraft are leased. There are only two big producers of narrow-body and wide-body aircraft (Boeing and Airbus), in addition to the producers of regional aircraft (Embraer and Bombardier). The specialized press suggests that lessors might get discounts from manufacturers for bulk purchases, but then the composition of these aircraft matters much less. If anything, evidence on manufacturers' learning curves (Benkard, 2000) suggests that manufacturers should give steeper discounts on less liquid aircraft, as the marginal effect on the manufacturer's costs from one further unit produced is bigger for less liquid aircraft. Indeed, Gavazza (2008) shows that aircraft prices increase as aircraft become more liquid. Thus, it is unlikely that unobserved factors like discounts explain *all* our empirical results.

More generally, the inclusion of carrier fixed-effects in all the regressions precludes the possibility that unobserved carrier-specific factors generate the empirical results; the inclusion of aircraft type fixed-effects precludes the possibility that unobserved aircraft-type-specific factors generate the empirical results; and the inclusion of year fixed-effects precludes the possibility that unobserved time-specific factors generate the empirical results. Hence, it is not so easy to imagine an omitted factor that is uncorrelated with carrier heterogeneity, aircraft-type heterogeneity, and year heterogeneity but that is simultaneously strongly enough correlated with characteristics of leasing contracts and aircraft liquidity to drive all the empirical results. In addition, it is important to note that the direction of the potential bias caused by endogeneity concerns is not unambiguous. For example, if manufacturers give steeper discounts to lessors on less liquid aircraft, then this argument would work against our finding that more-liquid aircraft are more likely to be leased.

Furthermore, as described in the Appendix, the business of aircraft leasing developed in the mid-1980s, well after the introduction of popular aircraft like the B727 (introduced in 1964), the B737 (introduced in 1968), or the B747 (introduced in 1970). The data reveal that aircraft that were the most liquid in the mid-1980s (in particular the B727, the B737, and the B747) were the first to be leased, suggesting that endogeneity arguments (reverse causality or omitted variables) are inconsistent with the origin and evolution of the aircraft leasing business.

In any case, it is important to address all potential endogeneity concerns using an instrumental variable approach to directly check the robustness of the results of the tests of hypotheses H1 and H5.[19] Industry practitioners strongly consider Aircraft per type to be a very precise measure of liquidity (Littlejohns and McGairl, 1998). However, the concern is that Aircraft per type might not be regarded solely as a proxy for liquidity. Checking the robustness of the empirical results using instruments that (arguably) exogenously shift Aircraft per type helps alleviate these concerns.

The discussion in Section 2.2 implies that our measure of liquidity should be highly correlated with recent aircraft production and recent aircraft retirements. Hence, good instruments include present and lagged shifters that move manufacturers' costs and aircraft operating costs. To be valid instruments, the variables must be exogenous in the sense that they are not choice variables of the leasing companies and the carriers. Moreover, they must change over time and across aircraft types. Hence, I use as instruments the interactions between a cost shifter—the world aluminum price—and the maximum takeoff weight of the aircraft type or the average number of seats in the aircraft type. The idea behind these instruments is that shocks to the price of aluminum have a different effect on the supply/production of larger aircraft than on the supply/production of smaller aircraft. Similarly, I also include as instruments the interactions between the world price of oil and (1) the number of engines of the aircraft; (2) the maximum takeoff weight of the aircraft; and (3) and the number of years since the aircraft type has been phased out of production. The idea behind these instruments is that when the price of oil rises, aircraft that have more engines, are heavier, and have been out of production longer are more likely to be either retired or see weak demand.[20,21] Benkard (2000) uses similar instruments.

The first-stage regressions (not reported) verify that the instruments are correlated with the measure of liquidity Aircraft per type. As expected, all the instruments have a negative sign, which confirms that when oil prices and aluminum prices are high, aircraft types that have more engines, are heavier, are larger, etc., have a smaller (and maybe negative) net flow into the stock Aircraft per type. Moreover, the *F*-tests on the exogenous instruments have values above 15 in all specifications, which means that the weak-instruments problem is not a concern in the data.

Table 13 replicates the tests of hypothesis H1 reported in Table 3 using the above instruments for liquidity.[22] The table shows that all results are robust to this alternative identification. As is often the case in specifications using instrumental variables, the standard errors increase compared to the simpler specifications without instruments. However, all the coefficients remain statistically significant at least at the 10% level. According to the probit estimates of Column 1 or the linear probability estimates of Columns 2 and 3, a 10% increase in Aircraft per type increases the probability that an aircraft is leased by about 1.2–1.5 percentage points, which is very close to the estimates of 1.1–1.2 reported in Table 3. The hypothesis that the coefficients are identical cannot be rejected (the *p*-values for the specifications of columns 2 and 3 are equal to 0.7130 and 0.8927, respectively). The specification of Column 4 also includes carrier fixed-effects, and in this case, the magnitude of the coefficient of the proxy for liquidity decreases. The coefficient of Log(Aircraft per type) in Column 4 indicates that a 10% increase in liquidity increases the probability that the aircraft is leased by about 0.88 percentage points, which is again very similar to the result reported in Table 3. Moreover, the results reported in Column 5 confirm that the qualitative results survive the much stronger identification of the panel-data specification with individual aircraft fixed-effects *and* instruments used in Column 5.

Table 14 replicates the tests of hypothesis H5 reported in Table 6, instrumenting for Aircraft per type.The signs of the coefficients reported in Table 14 confirm that more-liquid aircraft command lower markups, and the results are robust to different ways of calculating the markups. The magnitude of the coefficients of Log(Aircraft per type) increases relative to Table 6, indicating that markups increase by approximately five percentage points when Aircraft per type increases by 10%.

In summary, reverse causality and simultaneity do not appear to drive the empirical results. The results still hold with instruments that exogenously shift the measure of liquidity. Overall, the robustness checks reported in Tables 7–14 reinforce the idea that asset liquidity is an important determinant of which assets are owned or leased, and of the provisions in lease contracts.

4.4.4. *The role of taxation*

Several papers suggest that leasing provides taxation advantages to the contracting parties and investigate how

[19] In a previous version of the paper, I also checked the robustness of our results using a second proxy for liquidity. Shleifer and Vishny (1992) suggest that a high volume of transactions in an industry is evidence of high liquidity, and the across-industries study of Schlingemann et al. (2002) measures the liquidity of an industry's assets using assets' turnover rate—the ratio of the value of the industry's corporate transactions to the value of the industry's total assets. Hence, I used as a measure of liquidity the turnover rate of each aircraft type—i.e., the fraction of used type i aircraft traded in year t. All results (available upon request) are robust to this alternative measure.

[20] See Goolsbee (1998) for an empirical analysis of the effect of the price of oil on the retirement of Boeing 727s.

[21] The price of oil and price of aluminum have been deflated using the GDP Implicit Price Deflator with 2000 as the base year.

[22] There is a minor difference in the number of observations in the specification of column (5) since for very old aircraft we were unable to match the instruments to the observations.

Table 13
Robustness check: instrumental variables—asset liquidity and leasing versus owning.

This table replicates Table 3, instrumenting for the measure of liquidity. The dependent variable is equal to one if the aircraft is leased, and zero otherwise. Columns 1–4 present results of cross–sectional regressions, while Column 5 presents results of a panel-data regression. Column 1 presents the coefficient of a maximum likelihood probit. Columns 2–4 present the coefficients of OLS regressions. Carrier fleet size is the total number of aircraft operated by a carrier. Aircraft per type corresponds to the total stock of aircraft of the same type in the year in which the carrier acquired the aircraft, instrumented using the instruments described in Section 4.4.3. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. The standard errors in parentheses are clustered at the type-year level.

Leased	(1)	(2)	(3)	(4)	(5)
Age	0.11594	0.04137			0.01011
	(0.02123)	(0.00721)			(0.01234)
Age squared	−0.00355	−0.00124			−0.00012
	(0.00089)	(0.00029)			(0.00001)
Log(Carrier fleet size)	−0.29155	−0.05164	−0.05401		
	(0.31822)	(0.01037)	(0.00926)		
Log(Aircraft per type)	0.43776	0.15670	0.12787	0.08709	0.01479
	(0.24018)	(0.07975)	(0.05245)	(0.05012)	(0.00356)
Log(years since introduction)	−0.29155	−0.09836	−0.03816	−0.00560	−0.30027
	(0.31822)	(0.10654)	(0.07235)	(0.07147)	(0.37310)
Age fixed-effects	No	No	Yes	Yes	No
Carrier fixed-effects	No	No	No	Yes	Yes
Engine maker fixed-effects	Yes	Yes	Yes	Yes	No
Aircraft type fixed-effects	Yes	Yes	Yes	Yes	N/A
Year fixed-effects	No	No	No	No	Yes
Serial number fixed-effects	No	No	No	No	Yes
Log Likelihood	−15,114.76				
R^2		0.1418	0.1575	0.3190	0.2146
N	14,301	14,301	14,301	14,301	234,296

Table 14
Robustness check: instrumental variables—asset liquidity and markup of operating lease rates.

This table replicates Table 6, instrumenting for the measure of liquidity. It presents panel-data estimates of the coefficients of Eq. (4). The dependent variable is the markup of the operating lease rate l_{skit} over the implicit rental rate $p_{skit} - \beta E_t p_{s+1\ k\ it+1}$, where p_{skit} is the price of an aircraft, s is a vintage, k is a model, i is a type, t is a year, β is the discount factor, and E_t is the expectation taken at time t. In the regression presented in Column 1, the implicit rental rate is calculated under the assumption that the expected price of an aircraft of vintage $s+1$ of model k type i in year $t+1$ is equal to the price of an aircraft of vintage $s+1$ of model k type i in year t: $E_t p_{s+1\ k\ it+1} = p_{s+1kit}$. In the regression presented in Column 2, the implicit rental rate is calculated under the assumption that the price of an aircraft of vintage $s+1$ of model k type i in year $t+1$ is equal to δ percent of the price of the aircraft of vintage s of model k type i in year t: $E_t p_{s+1\ k\ it+1} = \delta p_{skit}$, where δ is estimated via an OLS regression. Aircraft per type corresponds to the total stock of aircraft of the same type in the year in which the carrier acquired the aircraft, instrumented using the instruments described in Section 4.4.3. Years since introduction is the number of years since an aircraft of the same type was first delivered, measured at the time in which the carrier acquired the aircraft. All columns report coefficients obtained using panel-data regressions with fixed-effects for each model-vintage pair. The standard errors in parentheses are clustered at the type-year level.

Markup of operating lease rate	(1) $\frac{l_{skit}}{p_{skit} - \beta p_{s+1kit}}$	(2) $\frac{l_{skit}}{p_{skit} - \beta\delta p_{skit}}$
Age	0.00113	−0.02230
	(0.00618)	(0.00505)
Age Squared	0.00108	0.00237
	(0.00013)	(0.00013)
Log(Aircraft per type)	−0.50626	−0.49311
	(0.05506)	(0.05921)
Log(Years since introduction)	0.27840	0.39189
	(0.09403)	(0.09430)
Year fixed-effects	Yes	Yes
Aircraft model-vintage fixed-effects	Yes	Yes
R^2	0.6115	0.7189
Groups	316	316
N	3,797	3,797

taxes affect corporate leasing policies (Miller and Upton, 1976; Myers, Dill, and Bautista, 1976; Graham, Lemmon, and Schallheim, 1998). The idea is that leases allow for the transfer of tax shields from firms that cannot fully utilize the associated tax deduction (lessees) to firms that can (lessors).

However, it is unlikely that taxes explain the observed correlations between aircraft liquidity and features of lease contracts. First, Babcock and Bewsher (1998) note that in an operating lease, "any tax benefits are normally incidental." Second, it is not clear why there is a substantial mix of leased and non-leased assets. If leasing were so favorable from a taxation perspective, we should probably expect all aircraft to be leased. Third, there is considerable variation in the fraction of aircraft leased among different aircraft types, and taxation advantages (if any) will not depend on aircraft type. Fourth, any tax benefit would be specific to a lessor or lessee, and would not vary within a carrier or within a lessor. Hence, in the empirical analysis, these advantages would have been picked up by carrier and lessor fixed-effects and would not explain the observed variation across different aircraft types within a given carrier. In summary, it is unlikely that taxes invalidate the tests of the hypotheses.

5. Related literature

Most of the finance literature on leasing investigates firms' incentives to lease and suggests that the lease-versus-buy decision often becomes the lease-versus-debt decision. Most of the literature on leasing has focused on the tax advantages, following Miller and Upton (1976) and Myers, Dill, and Bautista (1976). This paper contributes to a small but growing literature that shows that the economics of leasing go well beyond tax-minimization strategies. In particular, following the insightful discussion of Smith and Wakeman (1985), a few authors have focused on certain contracting aspects of leasing (see Krishnan and Moyer, 1994; Sharpe and Nguyen, 1995; Eisfeldt and Rampini, 2009). Leasing has also been analyzed in the context of the durable-goods literature. Gavazza (2009) discusses this literature and also investigates the effects of the operating leasing on the allocation of aircraft, showing that aircraft lessors reduce transaction costs and enhance the efficiency of allocations. As a result, leased aircraft trade more frequently and produce more output (fly more hours) than owned aircraft.

The theoretical literature on financial contracting is large, and Hart (2001) provides an excellent survey of it. Closely related is the work of Habib and Johnsen (1999), who investigate the role of different forms of external financing in efficiently redeploying assets, with a special focus on aircraft financing. On the empirical side, my paper is more closely related to Kaplan and Strömberg (2003, 2004) and, in particular, to Benmelech, Garmaise, and Moskowitz (2005) and Benmelech (2009). Kaplan and Strömberg (2003, 2004) study the allocation of control rights in venture capital financing contracts. Benmelech, Garmaise, and Moskowitz (2005) use data from commercial-loan contracts and proxy liquidity using zoning regulations. They find that greater liquidity is associated with larger loans, lower interest rates, longer maturity and longer duration debt, and fewer creditors. Benmelech (2009) uses data from American railroads in the 19th century and finds that firms with more-redeployable assets have longer debt maturity but not higher leverage. Also related are recent papers by Benmelech and Bergman (2008, 2009), that investigate the role of asset liquidity in the renegotiation and pricing of financial contracts.

More broadly, the current paper is also related to the empirical literature that investigates how asset specificity affects contracting between parties. In particular, this paper shares some features with the important contributions of Monteverde and Teece (1982), Masten (1984), Joskow (1985), and, in particular, the more recent contributions of Baker and Hubbard (2003, 2004). All of these papers examine how different measures of specificity or contractibility affect whether or not firms own assets. Similarly, Joskow (1987), Crocker and Masten (1988), Pirrong (1993), and Hubbard (2001) show how firms write longer contracts as assets become more specific.

6. Conclusion

Starting with the seminal work of Berle and Means (1932), an important literature investigates how incomplete contracts determine firms' capital structures. Investors provide firms with funds to purchase assets. Efficient use of corporate assets implies that optimal decisions depend on an array of contingencies. When it is impossible to specify contingent contracts, parties can still choose a decision-making process in advance that shifts decision rights over the asset in certain states of the world. Capital structure and financial contracts exactly determine the decision-making process that mitigates future contracting costs.

This paper focuses on one specific aspect that lies at the heart of a leasing contract and that has received a lot of attention in the financial contracting literature: the salvage/liquidation value of the asset. I empirically analyze how the liquidity of the asset (as in Williamson, 1988; Shleifer and Vishny, 1992)—in this case, aircraft—affects whether or not carriers lease the aircraft they operate, the optimal maturity of lease contracts and the markups of lease rates over aircraft prices. The evidence suggests that more-liquid aircraft (1) are more likely to be leased, particularly through operating leases; (2) have shorter operating leases; (3) have longer capital leases; and (4) command lower markups of operating lease rates.

Much of the literature on leasing merely treats all leases as financing contracts, and the lease-versus-buy decision often becomes the lease-versus-debt decision. This paper illustrates the different roles of operating and capital lease contracts. Leasing has grown substantially in recent years and is now extensively used in the market for corporate assets. However, the reasons for this growth have not been investigated by the literature. The evidence reported in this paper illustrates how leasing becomes more popular as the market for an asset becomes more liquid.

Appendix A. Leasing commercial aircraft [23]

Aircraft, one of the most important types of leased equipment, generated 11% of the total of new leases in

[23] This section is based closely on Gavazza (2009).

2004, second only to computer equipment.[24] Since the duration of lease contracts for computers is substantially shorter than for aircraft, it is likely that aircraft are the single largest equipment category for total volume generated.

Most aircraft leases—operating and capital—are on a "net" basis, with the lessee responsible for all operating expenses. In addition, the lessee pays for normal maintenance and repairs, airframe and engine overhauls, and compliance with return conditions for flight equipment on lease. Under the provisions of some leases, the lessor contributes to the cost of certain airframe and engine overhauls. Lessors require their lessees to comply with the standards of either the U.S. Federal Aviation Administration or its national foreign equivalents. Lessors also make periodic inspections of the condition of their leased aircraft.

In recent years, new types of leases have appeared in which lessors offer some services together with the aircraft. In a *wet* lease, the lessor provides the aircraft, one or more complete crews (including engineers), including their salaries and usually allowances, all maintenance for the aircraft, and insurance, which usually includes hull and third-party liability. A *damp* lease is similar to a wet lease but usually without the cabin crew. A *dry* lease is the lease of the basic aircraft without insurance, crew, or maintenance. Wet and damp leases are a small fraction of all aircraft leases.

First used in the mid-1970s by International Lease Finance Corporation (ILFC), an aircraft lessor, the operating lease became popular in the mid-1980s after airline deregulation in the United States and Europe (see Habib and Johnsen, 1999; Gavazza, 2009) The largest lessors are not the aircraft manufacturers—Boeing and Airbus—even though both have recently established trading and leasing divisions. The largest lessor is GECAS, a unit of General Electric Company. GECAS today owns approximately 1,200 aircraft, manages approximately 300 aircraft for others, and has more than 230 airline customers. As a means of comparison, the largest carrier in the world, American Airlines, operates around 800 aircraft.

Barrington (1998) notes that "the business of owning aircraft on real operating leases is similar to the business of trading in commodities." For example, in its 2003 10-K, ILFC describes its business as follows:

> International Lease Finance Corporation is primarily engaged in the acquisition of new commercial jet aircraft and the leasing of those aircraft to airlines throughout the world. In addition to its leasing activity, the Company regularly sells aircraft from its leased aircraft fleet to third party lessors and airlines.

Initially, operating lessors were mainly buying surplus second-hand aircraft from carriers and leasing them to other carriers, particularly those with poor access to debt and equity markets. In the mid-1980s, lessors started to acquire new aircraft directly from manufacturers and also entered into sale-leaseback transactions with carriers.[25] As a result, today almost all airlines use operating leases as a component of their capital structure. Almost all operating lessors' purchases of new aircraft have a designated lessee at the time of the order. In fact, the first speculative order was placed by GECAS only in the late 1990s, and the number and size of speculative orders have remained small in recent years.

The capital lease has a longer history than the operating lease. A capital lease is often a leveraged transaction: the lessor holds an equity investment (20–40%), and the larger remaining piece of the lease is leveraged. The lessor funds the leverage by selling bonds backed by the aircraft in the public market. Generally, banks and financial institutions are the lessors, which means that they hold the equity portion of the capital lease contract. In the late 1990s, companies directly related neither to aviation nor to financial services started to get involved with capital lease contracts.[26]

Lessors tend to specialize in one type of lease only. For example, at the end of 2004, ILFC maintained more than 600 aircraft on operating lease and only nine on capital lease. By contrast, State Street Bank maintained more than 50 aircraft on capital lease and none on operating lease. This specialization suggests that there are no economies of scope between the operating and capital leases. General Electric is the most notable exception, since it has an important role in both the operating and the capital leases markets. However, it is interesting to note that while GECAS offers operating leases and other fleet solutions, a separate subdivision—PKAir Finance—offers capital leases and other financing solutions. Moreover, it is interesting to note that the two main players in the operating lease market—ILFC and GECAS—jointly have more than 50% of the market. In contrast, the structure of the capital lease market is much less concentrated, with no single lessor having more than a 10% market share. This additional difference suggests that "technological" considerations such as economies of scale are also different in the operating and capital lease markets. Furthermore, operating lessors frequently provide other fleet-management solutions and intermediation services—such as asset management and aircraft trading—in addition to operating leases; and capital lessors also arrange other financing options—such as debt financing, equipment trust certificates, and securitization deals—in addition to capital leases. Together, the mere existence of two contracts, the stark contrast in the market structures of operating and capital leases, and the clear differences in the additional products offered by capital and operating lessors reinforce the idea that the two lease contracts have rather distinct roles and raise distinct economic issues.

[24] 2004 State of Industry Report, Equipment Leasing and Finance Foundation.

[25] In a typical sale-leaseback transaction, the carrier initially owns the aircraft, then sells it and simultaneously leases it back from a lessor.

[26] See, for example, "Aircraft Leasing Gives Companies Diversity, Risk," *Wall Street Journal*, 23 April 2003.

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