Asset Liquidity, Boundaries of the Firm and Financial Contracts: Evidence from Aircraft Leases

Alessandro Gavazza[*]

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Abstract

This paper uses data on aircraft leasing contracts to examine how contracting costs simultaneously shape firms' boundaries as well as firms' financial structure. In particular, I study how the liquidity of the market of different types of aircraft affects the lease/own decision, the optimal maturity of lease contracts, and the mark-ups of lease rates over prices.

A lease contract integrates in a single agreement the primary issues of a vertical and a financing contract, but the literatures on vertical and financial contracting make different predictions on how the liquidity of the assets should affect lease contracts. For example, more liquid aircraft are more redeployable and should then have longer financing contracts (as in Shleifer and Vishny (1992)), but are also less specific and should then have shorter vertical contracts (as in Williamson (1979)).

I find that asset liquidity affects the existing types of lease contracts differently: operating leases adhere to the predictions of the vertical contracting literature, while capital leases follow the financial contracting predictions. This suggests that the growth of operating leases over time is an additional aspect of the vertical disintegration of production.

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[*]Yale School of Management. 135 Prospect Street, New Haven, CT 06520. Email: alessandro.gavazza@yale.edu. Homepage: http://www.som.yale.edu/faculty/ag562/

Parties' inability to write fully contingent contracts has been shown to generate contracting costs that have far-reaching implications for a wide range of firms' decisions. In this paper, I empirically examine the role of contracting costs in simultaneously shaping firms' boundaries and financial structure. Using detailed data on commercial aircraft, I investigate how the liquidity of the market of different types of aircraft generate contracting costs that affect whether carriers lease the aircraft they operate, the optimal maturity of lease contracts and the mark-ups of lease rates over aircraft prices.

A large theoretical literature has analyzed how incomplete contracts and contracting costs determine firms' decisions. The general view is that incomplete contracts are a potential source of inefficiency that prevents parties from earning the full returns from their investment. As a result, parties write contracts *ex ante* that minimize inefficiencies arising *ex-post* once contracts are signed.

The literature generally has analyzed the consequences of incomplete contracts following two related but distinct strands. Starting with the seminal work of Coase (1937), the first strand has investigated how incomplete contracts determine the boundaries between firms. The main idea is that asset ownership confers control rights over the assets that affect the efficiency of trading relationships. Firms then choose to execute transactions through markets or within the firm to minimize future contracting costs.[1] Starting with the seminal work of Berle and Means (1932), the second strand of the literature has investigated how incomplete contracts determine firms' capital structure. Investors provide firms with funds to purchase assets. Efficient use of corporate assets implies that optimal decisions depend on a large number 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 assets in some states of the world. Capital structure and financial contracts exactly determine the decision-making process that mitigates future contracting costs.

The literature has thus analyzed the implications of incomplete contracts for firms' decisions in two sequential steps. In the first step, the theory of the firm investigates how contracting costs determine who operates and who owns which assets, *i.e.* how decision rights over assets are determined between firms. In the second step, financial contracting theory investigates how contracting costs determine how firms finance the assets that the theory of the firm determined it is efficient for firms to operate and/or own, *i.e.* how decision rights over firm's assets shift from the firm to its financiers.[2]

The fundamental characteristic of a leasing agreement is that, when a firm leases an

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[1]There are two leading theories of vertical integration, The "Transaction Cost Economics" view of Williamson (1975, 1979) and the "Property Rights Theory" of Grossman and Hart (1986) and Hart and Moore (1990). There are slight differences between the two theories, but both emphasize that vertical integration should be more likely when assets are more specifics, which is the relevant issue in this paper. See Hart (1988, 1995) for a review and a discussion of the theoretical differences between the two theories.

[2]The separation is clear, for example, in Oliver Hart's book (1995). Part I is titled *Understanding Firms*; Part II is titled *Understanding Financial Structure*. It is interesting to note the sequential nature in time between the theory of the firm and the financial contracting theory. Most influential contributions to the modern theory of the firm were developed in the 1970s and 1980s, while most influential contributions to the financial contracting theory were developed in the 1990s. See Section 1.

asset, these two steps that the literature analyzes sequentially are determined simultaneously. Leasing separates the rights to the cash flows over the life of the lease from the financing and the rights to the salvage value of the asset. Hence, in a lease contract the user of the asset is simultaneously choosing whether to own the asset or not and how to finance it, thus integrating in a single contract the primary issues of a vertical and a financial contract.

In this paper, I focus on one specific aspect that lies at the heart of a leasing contract and 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) and Shleifer and Vishny (1992), among others) affects whether an aircraft is leased or not, the optimal maturity of lease contracts and the mark-ups of lease rates over aircraft prices.

The theory of the firm and the financial contracting literature agree that more liquid assets make leasing attractive. The reason is that more liquid assets are less *specific* (as in Williamson (1975, 1979) and Klein, Crawford and Alchian (1978)) and are more redeployable (as in Shleifer and Vishny (1992)), decreasing the expected costs of external ownership and external financing. For the same reasons, the two literatures agree that the mark-ups of lease rates over prices should be lower for more liquid aircraft. More liquid aircraft are easier to reallocate across carriers, and thus in equilibrium lessors command lower returns.

However, the two literatures make opposite predictions on how asset liquidity affects the maturity of lease contracts. On the one side, the corporate finance literature analyzes extensively the trade-offs between internal (equity) and external (debt) finance, treating leasing as a form of external finance that is a simple substitute for debt (since Miller and Upton (1976)). Financial contracting theories suggest that more liquid aircraft should have longer maturity of external financing. Hart and Moore (1994) argue that more liquid assets make longer term financing more feasible, since more liquid assets serve as better collateral. Shleifer and Vishny (1992) argue that long term financing has the benefit of constraining the user of capital not to undertake negative NPV projects but makes liquidation more likely. More liquid assets decrease the cost of liquidation and, therefore, longer term financing should increase with the liquidity of the equipment. On the other side, the theory of the firm suggests that longer lease contracts should be used for less liquid assets. The idea is that less liquid assets are more *specific*. Contracting over more specific assets increases the likelihood of ex-post hold-up or opportunistic behavior and, to mitigate ex-post opportunistic behavior, ex-ante parties choose to specify long-term contracts (Williamson (1975, 1979)).

Incomplete contracting theories thus have ambiguous predictions on the effects of asset liquidity on lease contracts. The predictions are further confused by the existence of two basic types of lease contracts, the operating lease and the capital lease. The precise classification[3] changes slightly for legal, taxation and accounting purposes, but the main idea is that the more the lessee acquires control and residual claims on the asset, the more the lease is classified as a capital lease. Hence, the intrinsic dual nature of leasing as a vertical and a financing contract and the opposite predictions of the vertical and the financial contracting

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[3]See Section 2.1.

literature all imply that it is ultimately an empirical question how contracting costs generated by the liquidity of the assets affect lease contracts, and whether they affect differently operating and capital leases.

The commercial aircraft market is an ideal candidate for testing and distinguishing these different theories. First, more than half of commercial aircraft are currently leased.[4] Second, there is an active secondary market for aircraft. All airlines in the world use the same types of aircraft and the aircraft is the only form of capital equipment that can be redeployed to an operator anywhere in the world within a day. These characteristics mean that there is a single world market for aircraft and the market is, in principle, thicker than some other markets for capital equipment. Third, it is easy to obtain a valid proxy for the liquidity of a given aircraft. Training and labor costs of pilots, crews and mechanics imply that carriers tend to minimize the number of types of aircraft they operate. Thus, the stock of a specific type of aircraft or the number of actual users are 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 the liquidity of the market affects aircraft lease contracts. I first analyze operating leases, where *a priori* financing considerations seem weaker. Consistent with both the literature on the theory of the firm and the financial contracting literature, I find that more liquid aircraft are more likely to be under operating lease and command lease rates with lower mark-ups over prices. I further find that more liquid aircraft have shorter operating leases, in accordance with the theory of the firm and in contrast with theories of financial contracting.

I then compare operating and capital leases and I find that asset liquidity differentially affects operating and capital leases. In particular, more liquid aircraft have shorter operating leases but longer capital leases. These patterns emerge exploiting both cross-sectional variation between different aircraft types and time-series variation within aircraft type. For example, using time-series variation, I find that lease contracts for the Boeing 737 had an average maturity of 66 months for an operating lease and 93 months for a capital lease if the contracts were signed when there were approximately 1900 units. When there were approximately 3600 units, then the average maturity of an operating lease decreased to 58 months, while the average maturity of a capital lease increased to 111 months. I thus find that operating and capital leases are substantially different contracts that likely serve different purposes. On one side, the operating lease has the characteristics of a vertical contract between a seller (lessor) and a buyer (lessee), where the main activity contracted is the eventual redeployment of the aircraft. On the other side, the capital lease has the characteristics of a financing contracts.

The mechanisms identified in these paper are not unique to the aircraft market, but they help understand 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. In fact, 80 percent of U.S. companies lease capital equipment. Of the \$668 billion spent by business on productive assets in 2003, \$208 billion, or 31 percent, was acquired by American businesses through

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[4]Approximately one third of the aircraft are under operating lease and one sixth under finance lease. See Section 4.1.

leasing.[5] However, I think it is fair to say that leasing has not received the attention in the literature adequate to its importance. Most of the literature on leasing has just 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.[6] In particular, following the insightful discussion of Smith and Wakeman (1985), a few authors have focused on some contracting aspects of leasing (see Krishnan and Moyer (1994), Sharpe and Nguyen (1995) and Eisfeldt and Rampini (2005)). My paper extends theses studies in several dimensions. First, I focus on one specific aspect - asset liquidity - which plays a prominent role in the theory. Second, my units of observation are exactly the assets - the aircraft - and the leases, not firm-level aggregate measures of leasing intensity. Third, I explicitly show how operating and capital leases have substantially different characteristics that make the operating lease a vertical contract and the capital lease a financing contract.

The paper also explains how the growth of the operating lease for capital equipment in recent years is one additional aspect of the vertical disintegration of production observed in most advanced economies. It further shows how distinct business activities, such as the decisions about financing and vertical integration, are becoming unified in the modern corporation. It thus provides a step towards a more comprehensive theory of the firm, as advocated by Bolton and Scharfstein (1998).

The remaining of the paper is organized as follows. Section 1 reviews the related literature. Section 2 presents institutional characteristics of lease contracts and of the market for aircraft. Section 3 lays out the theoretical hypotheses. The empirical analysis on operating leases is performed in Section 4. Section 5 compares operating and capital leases and Section 6 refutes alternative hypotheses. Section 7 concludes.

1   Related literature

The empirical analysis of contracts has been lagging behind the theoretical contributions, but in recent years has been growing rapidly, as documented by the survey by Chiappori and Salanié (2003). Most papers have tested the implications of asymmetric information between contracting parties, and empirical research on incomplete contracts has been more limited. Empirical tests of incomplete contracts have often focused either on the decision to vertically integrate (e.g. Baker and Hubbard, 2003 and 2004), or on financial contracts (e.g. Kaplan and Strömberg, 2003 and 2004). This paper shares with the existing empirical literature on incomplete contracts the methodology in the measurement of the liquidity of the assets, and applies it to lease contracts. Thus, the paper is mainly related to the literature on leasing, the literature on the boundaries of the firms and the literature on financial contracting.

As mentioned in the Introduction, most of the literature on leasing treats all leases (operating and capital) just as financing contracts and the lease vs. buy decision often

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[5]Source: Equipment Lease Foundation.

[6]Leasing has also been analyzed in the context of the durable goods literature. See Gavazza (2006) for a discussion of this literature.

becomes the lease vs. debt decision. Here, I explicitly consider one aspect - liquidity - that has been extensively analyzed in corporate finance and explicitly show how the data support the financial contracting predictions only for the capital lease. For the most popular lease contract - the operating lease - the data support instead the predictions of an alternative hypothesis - vertical contracting - that the previous literature on leasing has not explored thoroughly.[7]

The theoretical literature on the boundaries of the firm is very vast and I refer the reader to Hart (1988, 1995) for a review and for the theoretical differences between the transaction costs approach and the property rights approach to theory of the firm. In the empirical literature, the paper is closer to the seminal contributions of Monteverde and Teece (1984), Masten (1984), Joskow (1985), and in particular to the more recent contributions of Baker and Hubbard (2003, 2004) that examine how different measures of specificity or contractibility affect whether firms own assets or not.[8] Similarly, Joskow (1987), Masten and Crocker (1988), Pirrong (1993) and Hubbard (2001) show how firms write longer contracts as assets become more specific.

The theoretical literature on financial contracting is very large too and Hart (2001) is an excellent survey. On the empirical side, the paper is more closely related to the aforementioned papers on venture capital contracts by Kaplan and Strömberg (2003, 2004) and in particular to the recent contributions by Benmelech, Garmaise and Moskowitz (2006) and Benmelech (2005). Benmelech, Garmaise and Moskowitz (2006) 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 duration debt, and fewer creditors. Benmelech (2005) uses data from American railroads in the XIX century and finds that firms with more redeployable assets have longer debt maturity, but not higher leverage.

2   Institutional Characteristics

In this Section I first present the general characteristics of leasing contracts. Then I illustrate the features of the leasing contracts specific to commercial aircraft. I conclude the Section describing the markets for commercial aircraft, highlighting frictions and costs of redeployment.

2.1   Equipment Leasing

A lease is a contract between two parties by which the owner (lessor) grants the right to possess and use 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

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[7]Gavazza (2006) investigates the effects of the operating leasing on the allocation of aircraft. That paper shows 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.

[8]Similar issues are also in Holmes (1999) who focuses on the relationship between vertical integration and industry localization.

leases or arranges the lease of personal property and supplies all the financing. The vast majority of lessees are business concerns, accounting for more than 90 percent of all lease transactions.[9]

There are two basic types of lease, the capital lease and the operating lease. Generally speaking, if ownership of the leased asset transfers 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[10] changes slightly for legal, taxation and accounting purposes, but the main idea is that the more the lessee acquires control and residual claims on the asset, the more the lease is classified as a capital lease.

The classification has important implications for which party is treated as the owner of the asset in bankruptcy, or for tax and accounting purposes. Roughly speaking, in an operating lease the lessor is treated as the owner of the asset, which means for example that he can repossess the asset if the lessee enters Chapter 11 protection and rejects the lease. Moreover, in an operating lease the lessor treats the asset as capital expenditure and the rental payments as income, while the lessee records the rental payments as expenses. On the other side, in 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, while for tax purposes the lease is treated as a loan, so the lessee reports the asset as capital expenditure and the lease payments as interest.

2.1.1   Leasing Commercial Aircraft[11]

Aircraft is one the most important leased equipment type. It represents the second equipment type after computer equipment for *new* business volume, with 11% of the total of new business volume in 2004.[12] Since the duration of lease contracts for computers are substantially shorter than for aircraft, it is then likely that aircraft is the single largest equipment for total volume generated.

Most leases - operating and capital - are on a "net" basis with the lessee responsible for all operating expenses.[13] In addition, normal maintenance and repairs, airframe and engine overhauls, and compliance with return conditions of flight equipment on lease are paid for by the lessee. 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 United States Federal Aviation Administration or its foreign equivalent. Lessors

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[9]Public utilities and municipal governments each account for about 2 percent of all leasing. Data from the US Department of Commerce, US Industrial Outlook, various years.

[10]See Sharpe and Nguyen (1995) and Eisfeldt and Rampini (2005) and the references cited there.

[11]This section is based closely on Gavazza (2006).

[12]2004 State of Industry Report, Equipment Leasing and Finance Foundation.

[13]In recent years, new types of lease 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 cabin crew. A *dry* lease is the lease of the basic aircraft without insurance, crew, maintenance. Wet and damp leases are just a small fraction of all aircraft leases.

make periodic inspections of the condition of their leased aircraft.

The operating lease was founded by ILFC in the mid 1970 and became popular in the mid 1980 after the airline deregulation in US and Europe.[14] The largest lessors are not the aircraft manufacturers - Boeing and Airbus - even though both have recently established Trading/Leasing divisions. The largest lessor is GECAS, a unit of General Electric Company. GECAS today owns approximately 1200 aircraft, manages approximately 300 aircraft for others and has more than 230 airline customers. As a term of comparison, the largest carrier in the world, American Airlines, operates around 800 aircraft.

In its Annual Report, 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."*[15]

The capital lease has a longer history than the operating lease. A capital lease is often a leveraged transaction: part of the lease constitutes an equity investment (20% to 40%) and the remaining larger piece of the lease is leveraged, with bonds backed by the aircraft sold 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 1990, companies not directly related neither to aviation nor to financial services started to get involved into financial lease contracts.[16]

2.2   Liquidity of Commercial Aircraft

The commercial aircraft is a very unique type of capital. All airlines in the world use the same types of aircraft, and there are a relatively small number of types. Sometimes aircraft are purchased by governments and air cargo companies, but the major players are airlines and lessors. Also, the aircraft is 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 its own power. Thus, secondary markets for aircraft are a worldwide single market.

The market for used commercial aircraft might seem relatively liquid compared to the market for other more specialized equipment. However, the absolute number of transactions remains very small compared to financial markets and to other equipment markets. For example, in the twelve months between May 2002 and April 2003, of the total stock of 12,409 commercial aircraft used for passenger transportation older than 2 years, only 720 (5.8%) have been traded.[17]

Moreover, aircraft are differentiated products. Different types are designed to serve different markets and are imperfect substitutes for one another. Furthermore, each type of

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[14] See Habib and Johnsen (1999) and Gavazza (2005).

[15] Form 10-K, International Lease Finance Corporation - ILFC. Filed on March 11, 2004.

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

[17] As a term of comparison, Mas (2004) reports that more than 30,000 pieces of used construction equipment sold at auction in the United States only between January 1994 and September 2002.

aircraft also requires human-capital investment in specific skills for pilots, crew and mechanics that increases the degree of physical differentiation. For a given type, the number of annual transactions is very small. For example, only 21 units of the Boeing 747 traded between May 2002 and April 2003.

The market is organized around privately negotiated transactions.[18] Most major carriers have staff devoted to the acquisition and disposition of aircraft and sometimes independent brokers are used to match buyers and sellers. Aircraft are seldom sold at auctions. Pulvino (1998) reports that in one of the first auctions organized in 1994 to enhance the liquidity of the market, only 9 aircraft sold of the 35 offered for sale. Subsequent auctions even ended without a single sale. Hence, prices are very sensitive to parties' individual shocks and the bargaining power of sellers and buyers is an important determinant of transaction prices. For example, Pulvino (1998) finds that sellers in bad financial status sell aircraft at a 14 percent discount relative to the average market price.

Overall, all these characteristics seem to indicate that aircraft are less liquid assets than just cursory evidence might suggest. It is then likely that redeployment entails some costs and the next Section precisely explores how we expect parties to anticipate these future contracting costs when writing lease contracts.

3   The Hypotheses

In this Section, I describe how I expect lease contracts to be affected by the liquidity and the costs of redeploying the aircraft. In particular, I examine how different aircraft-specific and carrier-specific characteristics imply different costs of redeployment. Then I connect these characteristics to the terms of leasing contracts. The discussion mainly focuses on operating leases, as they are the most popular lease contracts. Institutional characteristics also suggests that vertical contracting issues might be stronger for operating leases.

Aircraft characteristics - A large theoretical literature investigates the role of assets' liquidation values in financial contracts, with a special focus on debt contracts. Williamson (1988) identifies an asset liquidation value with its redeployability - or value in its next best use - and Shleifer and Vishny (1992) argue that a larger number of potential users increases the liquidation value of an asset. The main idea of these incomplete contracts/transaction costs 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 costs of liquidation are lower the more redeployable 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 specific need to combine owner and user of the asset. In case of liquidation of the user, a specialized outside owner can repossess and redeploy the asset more effectively than could a debt-holder. However, Shleifer

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[18]This is one characteristic that Rauch (1999) and Nunn (2005) use 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.

and Vishny (1992) suggests that specialized owners (and hence lessors) tend to be lower-value users of capital and Pulvino (1999) finds evidence consistent with this idea exactly in the market for aircraft. The reason is that, while carriers might put the aircraft in use and generate revenue, a lessor needs to find a lessee 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 types that have few potential users, redeploying aircraft becomes costly.

Similarly, more liquid aircraft are less *specific* assets, in the language of Williamson (1975, 1979) and of the literature on the boundaries of the firm. According to incomplete contracting theories of the firm, contracting over specific assets might create ex-post hold-up or opportunistic incentives. To mitigate this ex-post opportunistic behavior, ex-ante carriers choose to own assets that are more *specific*.

As a result, the literature on the theory of the firm and the financial contracting literature agree that more liquid aircraft are more likely to be leased. An aircraft is more liquid if it has a larger number of potential users and, due to the differentiation of aircraft and the specificity of pilots, crew and mechanics, an aircraft has a larger number of potential users if either more units of the same type have been produced or more carriers are currently operating the same type. We thus expect:

H1: The share of aircraft under operating lease is larger for more liquid types, i.e. aircraft types that either have been produced in larger numbers or are operated by a larger number of carriers.

The literature has also analyzed the relationship between asset liquidity and the duration of contracts, but with contrasting predictions. On the one side, Hart and Moore (1994) argue that more liquid assets make longer term financing more feasible, since more liquid assets have higher liquidation values and thus serve as better collateral. In Shleifer and Vishny's (1992) model, long term financing has the benefit of constraining the user of capital not to undertake negative NPV projects but makes liquidation more likely. They predict that longer term financing increases with the liquidation value of the asset, since a higher liquidation value decreases the cost of liquidation.

On the other side, less liquid aircraft are more *specific* assets and contracting over specific assets might create ex-post hold-up or opportunistic incentives. When carriers lease assets, incomplete contracting theories of the firm suggest that ex-ante parties avoid opportunistic behavior specifying longer-term contracts for more *specific* assets.

What are the implications of these theoretical arguments for the duration of lease contracts? As described in Section 2.1, a lease contract merges the fundamental characteristics of both a financing and a vertical contract. However, the theories on financial and vertical contracting make exactly opposite predictions on how higher liquidity should affect the maturity of lease contracts. It then becomes an empirical question to establish which of these two contrasting theories applies to lease contracts. If lease contracts are closer to a financing contract, then more liquid aircraft should have longer lease contracts. If lease contracts are closer to a vertical contract, then more liquid aircraft should have shorter lease contracts. Thus, we can empirically test the financing contracting prediction against the

vertical contracting alternative:

H2a: The duration of operating lease contract is longer for more liquid aircraft.

H2b: The duration of operating lease contract is shorter for more liquid aircraft

The previous discussion highlights how more popular aircraft are more liquid and less specific. These characteristics clearly also affect the equilibrium pricing of lease contracts. In particular, more liquid aircraft should command lower lease rates. A more liquid aircraft implies that it is easier for the lessor to find a new lessee willing to take the aircraft, thus decreasing expected costs of redeployment. Similarly, a less specific aircraft increases both lessor's and lessee's outside options when bargaining over lease terms, and lease rates then converge to competitive levels. We thus expect:

H3: The mark-ups of operating lease rates over prices are lower for more liquid aircraft.

Carriers' characteristics - Lease contracts are affected not only by the characteristics of the assets, but also by the characteristics of the contracting parties and some carriers' characteristics affect the expected cost of redeploying aircraft. One such characteristic is likely a carrier's size of the fleet. The cost of redeploying assets is potentially very different for a big carrier than for a small carrier, and this difference has distinct implications for vertical or financial contracts. On one side, Gertner, Scharfstein and Stein (1994) show that, when firms are large and own multiple business units, assets can be redeployed within the firm. In the case of aircraft, the larger the network of routes a carrier operates, then the easier is to reallocate aircraft within the firm. Thus, larger carriers might have a lower need of redeploying assets through the market. Hence, if the operating lease is mainly a vertical contract for the redeployment of the aircraft, the advantages of contracting out the redeployment to lessors should be greater for smaller carriers. Thus, smaller carriers should lease more, and have shorter contracts.

On the other side, Harris and Raviv (1991) review a large theoretical and empirical literature that investigates the trade-offs between internal vs. external financing. The literature does not yield unambiguous results, but the common view is that external financing should increase with firm size, as 1) large firms should be less likely to default; 2) in case of default, bankruptcy costs should comprise a smaller fraction of the total residual value of the firm for larger firms.[19] Thus, the financial contracting literature suggests that external financing should increase with the size of the firm, as the expected costs of redeploying assets is lower. If leasing is mainly a financing contract, then larger carriers should lease more, and have longer lease contracts.

As a result, the two literatures make again contrasting predictions that we could parse out empirically testing how the size of the fleet affects whether a carrier leases aircraft or not.[20] However, as it will become clear when we describe our data in more detail, our tests

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[19]However, the issue is debated in the literature. For example, Shleifer and Vishny (1992) suggest that smaller firms are better candidates for debt finance.

[20]Note that both literatures agree that larger carriers should have longer lease contracts.

are severely limited by the lack of many important carrier characteristics. We can construct the main variable of interest - the size of the fleet - but the data do not allow to construct several financial indicators that affect the capital structure of firms. Thus, our analysis can only be suggestive at best, as we cannot fully control for unobservable carriers' characteristics that may be correlated with the size of the firm and bias our results.

4   Empirical Analysis

In this Section I first describe the data employed in this study. Then I compare two aircraft with a similar history but with different "popularity" - the McDonnell-Douglas 80 and the Airbus 300-600 - to illustrate in a simple but stark way how lease contracts on the two types of aircraft vary systematically according to our hypotheses. Finally, the hypotheses of Section 3 are subjected to formal empirical testing. The basic tests rely on cross-sectional evidence. I later check the robustness of the tests using two alternative strategies. The first uses an instrumental variables approach that controls for the potential endogeneity of our measures of liquidity. The second strategy exploits also the time-series dimension of the data to obtain within aircraft type variations in liquidity.

4.1   Data

The empirical analysis in this paper combines two distinct datasets. The first one is an extensive database that tracks the history of each western-built commercial aircraft. This database provides extensive information on the characteristics and on the history of each aircraft. The second dataset reports the prices and the operating lease rates of several aircraft models. I now describe each dataset in more detail.

Aircraft characteristics - The database has two distinct files. The first file has detailed data for the cross-section of aircraft active at one point in time (April 2003). This first file (henceforth, cross-section data) reports detailed aircraft characteristics - such as the type (Boeing 737), the model (Boeing 737-200), the engine, the age - and information related to the spell with the current operator - the operational role of the aircraft (passenger transportation, freighter,...), the date in 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 and also reports the start and end dates of the current contract.

I complement these cross-sectional data with a second file that contains data on the time-series of operators of each aircraft. This second file (henceforth, time-series data) contains information on the "birth" of each aircraft - i.e. the 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 aircraft - i.e. the date the aircraft was scrapped. This file reports whether the aircraft was owned or leased by each operator, but unfortunately does not report neither whether the lease is operating or capital, nor the duration of the initial lease and whether the lease was later extended or not.

I restrict my analysis to aircraft that are used for passenger transportation, so aircraft employed as freighters or corporate aircraft are excluded from the sample. This is done to have an homogeneous group of operators in the sample.

Aircraft values - The dataset is an unbalanced panel. It reports the historic values of prices and lease rates of different vintages for the most popular models during the period 1967-2003. The dataset is compiled by a consulting company that specializes in aircraft appraisals. The prices are similar to "Blue Book" prices. They 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 lease rates are annual rates calculated independently of prices. They reflect medium risk credit and an average lease term (which varies with each aircraft model). All values are in nominal US dollars and I have deflated them using the GDP Implicit Price Deflator with 2000 as base year.

If all aircraft are perfectly liquid assets, the annual lease rate is equal to the expected cost of buying the aircraft at time t and selling it at time $t+1$, i.e. the lease rate is equal to $p_{i,j,t} - \beta E_t p_{i,j+1,t+1}$, where $p_{i,j,t}$ is the price of aircraft of model i vintage j in year t, β is the discount factor and E_t is the expectation taken at time t. Assuming $E_t p_{i,j+1,t+1} = p_{i,j+1,t}$, I can thus define the mark-up of the lease rate over price as follows:

$$m_{ijt} \equiv l_{ijt} / \left(p_{i,j,t} - \frac{1}{1+r_t} p_{i,j+1,t} \right) \qquad (1)$$

where l_{ijt} is the annual lease rate of aircraft ij in year t. The discount factor β is calculated as the inverse of the real interest rate, i.e. $\frac{1}{1+r_t} = \frac{1}{\frac{1+i_t}{1+\pi_t}}$, where i_t is Moody's Seasoned Baa Annual Corporate Bond Yield and π_t is the rate of inflation in year t.[21] m_{ijt} then measures the percent deviation of the lease rate from the benchmark of a perfectly liquid asset market.[22]

Table 1 provides summary statistics of the main variables used in the empirical analysis. Panel A provides summary statistics for the whole aircraft characteristics dataset. The sample consists of 14301 aircraft, of which 4797 (33.5%) are under an operating lease and 2665 (18.6%) are 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 our measures of aircraft liquidity, i.e. the number of aircraft per type - AIRCRAFT PER TYPE - or the number of operators per type - CARRIERS PER TYPE.[23] Some aircraft types are very popular, they have been produced in large numbers and have a large number of operators.

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[21] All results where unchanged when using Moody's Seasoned Aaa Corporate Bond Yield instead.

[22] As described, the construction of mark-ups assume $E_t p_{i,j+1,t+1} = p_{i,j+1,t}$. We have also constructed markups using instead the realized values instead of the expectation, i.e. $E_t p_{i,j+1,t+1} = p_{i,j+1,t+1}$. The results were very similar. The main difference is that, due to time-series volatility of aircraft prices, the mark-ups calculated in this latter way exhibit a much wider range of values. Sometimes mark-ups are negative (when prices increase) or vary large (when prices decline substantially).

[23] It is important to note that we constructed the measures of redeployability at the level of the aircraft

Table 1: Summary statistics

Panel A: All Aircraft	Mean	St. Dev.	Observations
Aircraft - Operating lease	4797		14301
Aircraft - Capital lease	2665		14301
Age of Aircraft	10.57	8.59	14301
Types of Aircraft	35		14301
Aircraft per type	408.6	673.19	14301
Carriers per type	38.37	50.77	14301
Carriers	713		14301
Carrier size of fleet	20.05	58.60	14301
Panel B: Leased Aircraft			
Duration of operating lease contract	100.34	50.87	2086
Duration of capital lease contract	223.21	57.22	1814
Panel C: Aircraft values			
Price	31.34	27.19	4097
Annual Lease Rates	3.18	2.33	4097
Mark-up	1.20	.51	4097

Others have been less successful or are old types currently being retired. For example, the dataset reports that carriers are currently operating as many as 3807 Boeing 737 and as few as 1 Boeing 720. Similarly, the data report there are as many as 287 operators for the Boeing 737 and as little as 1 for the Boeing 720. Obviously, the correlation between Aircraft per type and Carriers per type is very high (correlation coefficient is equal to .93).

Panel B considers aircraft characteristics only for leased aircraft. Unfortunately, the duration of the current lease contract is missing for a number of leased aircraft. We have durations for 2086 operating leases and 1814 capital leases. There is a 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 for operating leases and 57 for capital leases.

Panel C reports summary statistics of the aircraft values dataset. There are a total of 4093 model-vintage-year observations for which we could construct lease mark-ups.[24] The average price of an aircraft is 31.3 million (year 2000) dollars, the average annual lease rate is 3.18 million dollars and the average markup is 1.20. Prices, lease rates and mark-ups exhibit considerable variation (overall standard deviation is around 27 for prices, 2.33 for lease rates

type. As specified above, a type is for example Boeing 737, Boeing 747, MD-80 and so on. Within each type, there might be different models. For example, for the type Boeing 737, we have models B737-200, B737-300 and so on. Within each type, the technical specifications of different models are very similar and thus, consistent with industry norms, comparisons between types exactly captures differences in redeployability.

[24]I dropped the upper and lower 1% of lease rates as they were clear outliers with unusually small or high values.

Table 2: MD80 vs. A300-600

Panel A: All Aircraft	MD 80	A300-600
Aircraft	1103	185
Aircraft - Operating lease	33%	16%
Aircraft - Capital lease	25%	20%
Age of Aircraft	14.1	11.8
Carriers	52	21
Carrier size of fleet	61.2	90.9
Panel B: Leased Aircraft		
Duration of operating lease contract	98.6	120
Duration of capital lease contract	247.7	226.5
Panel C: Aircraft Values		
Mark-up	1.19	1.35

and .51 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 single aircraft. In the empirical analysis, this allows me to control for several features of the asset that are often unobserved in other studies that relied on cross-sectional data. Information on carriers is more limited, and in the empirical analysis I use carrier fixed effects to control for unobserved carrier-specific factors that potentially may drive the observed correlations between the liquidity of the aircraft and features of the contracts. Similarly, the panel dimension of the aircraft values dataset allows me to control for several time-invariant unobserved factors and obtain convincing evidence on the relationship between the liquidity of the aircraft and mark-ups of lease contracts.

4.2 An Illustrative Comparison: MD 80 vs. Airbus 300-600

Before proceeding to more formal tests of the hypotheses on the effects of liquidity on the characteristics of lease contracts, in this Subsection I presents simple illustrative patterns comparing two famous aircraft, the McDonnell-Douglas 80 (MD80) and the Airbus 300-600 (A300-600). The two aircraft have a similar history. Both have been introduced in the 80's and have been developed based on older successful models, the DC-9 for the MD80 and the A300 for the A300-600. The MD80 is a short-haul narrowbody aircraft with around 150 seats, while the B747 is a medium range widebody aircraft with approximately 250 seats.

Table 2 shows simple averages, but it is suggestive of the forces at work. The MD80 is more popular than the A300-600: the number of AIRCRAFT and CARRIERS is higher for the MD80 than for A300-600. In terms of our hypotheses, the MD80 is thus a more liquid aircraft than the A300-600. Interestingly, the data show that the fraction of MD80 under operating

lease is substantially higher than the fraction of A300-600 (33% vs. 16%, respectively[25]), as hypothesis *H1* suggests. The data also show that the fraction of aircraft under capital lease is instead closer between MD80 and A300-600, thus suggesting that liquidity has different effects on the two lease contracts.

Interesting differences emerge for the duration of lease contracts too. The duration of operating leases is shorter for MD80 than for A300-600 (98.6 vs. 120 months, respectively[26]), while the duration of capital leases is longer for MD80 than for A300-600 (247.7 vs. 226.5 months, respectively[27].) These differences highlight how greater liquidity has a different impact on the two lease contracts and seem to suggest that the financing hypothesis *H2a* applies to capital leases, while the vertical hypothesis *H2b* applies to operating leases.

Similarly, remarkable differences emerge when we compare the mark-ups of lease rates over aircraft prices. The mark-ups are smaller for MD80 than for A300-600 (1.19 vs 1.35, respectively[28]), exactly as *H3* predicts.

While this evidence is clearly not conclusive, these figures seem to uncover patterns consistent with our hypotheses. The next Subsection develops more sophisticated empirical strategies to test them.

4.3   Testing the Hypotheses

To test the hypotheses laid out in Section 3, I use the population of Widebody, Narrowbody and Regional commercial jets used for passenger transportation. I use the whole sample in the aircraft characteristics dataset to test the hypothesis concerning the fraction of aircraft on lease, i.e. *H1.* I then restrict the analysis to leased aircraft only to parse out the conflicting hypotheses concerning the duration of lease contracts, i.e. *H2a* versus *H2b.* I conclude the section combining the aircraft values dataset and the aircraft characteristics dataset to test the hypothesis concerning the lease rates mark-ups, i.e. *H3.*

4.3.1   Fraction of leased aircraft

In this subsection I investigate the relationship between the ownership status of each individual aircraft and the liquidity of the aircraft formally testing *H1.*

To test the hypothesis, I use the following specification:

$$\text{LEASED}_{lij} = f\left(\alpha Y_{lij} + \beta W_i + \gamma X_j\right). \tag{2}$$

The dependent variable LEASED_{lij} is equal to 1 if aircraft l of type i operated by carrier j is under operating lease and zero otherwise[29]. Y_{lij} is a set of variables specific to each aircraft

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[25] The one sided t test has a p-value of .000.

[26] The one sided t test has a p-value of .049.

[27] The one sided t test has a p-value of .009.

[28] The one sided t test has a p-value of .000.

[29] Hence, the dependent variable is equal to 0 if an aircraft is owned or under capital lease. We have also studied a specification where the dependent variable is equal to 1 if an aircraft is under any form of lease (operating and capital) and 0 otherwise, and found similar results on the effects of liquidity. Section 5 studies the differences bewteen operating and capital leases.

LEASED	(1)	(2)	(3)	(4)	(5)	(6)
AGE	$-.0473$	$-.04745$	$-.01453$	$-.01460$	$-.00800$	$-.00809$
	(.0021)	(.00217)	(.00054)	(.00054)	(.00061)	(.00062)
CARRIER SIZE OF FLEET	$-.00184$	$-.00182$	$-.00050$	$-.00050$		
	(.00007)	(.00007)	(.000013)	(.000014)		
AIRCRAFT PER TYPE	.000063		.000021		.000033	
	$(9.2e-06)$		$(3.1e-06)$		$(3.9e-06)$	
CARRIERS PER TYPE		.00084		.000295		.00044
		(.00012)		(.000042)		(.00005)
CARRIER FIXED EFFECTS	No	No	No	No	YES	YES
LOG LIKELIHOOD	-7987.194	-7988.24				
R^2			.1376	.1376	.439	.439
N	14301	14301	14301	14301	14301	14301

Notes - Robust standard errors in parenthesis. The estimated equation also contains fixed effects for Widebody, Narrowbody and Regional aircraft (not reported). Columns (1) and (2) reports maximum likelihood estimates of a probit model, Columns (3)-(6) reports OLS estimates of a linear probability model.

l, such as AGE OF AIRCRAFT; W_i is a set of variables specific to each aircraft type i; in particular, we include our measures of liquidity, i.e. the total number of aircraft of type i (AIRCRAFT PER TYPE) or the total number of carriers operating aircraft type i (CARRIERS PER TYPE). We also include dummy variables for Narrowbody and Widebody aircraft, so we identify the effect of aircraft liquidity from variation within aircraft categories. X_j is a set of variables specific to each carrier j, in particular in our simplest specifications we control for the size of the carrier using the total number of aircraft the carrier operates (CARRIER SIZE OF FLEET). Later, we control for potentially unobserved carrier-specific factors using also carrier fixed effects.

Letting f to be the c.d.f. of the normal distribution, I can estimate equation (2) by maximum likelihood. Columns (1) and (2) in Table 3 presents the maximum likelihood estimates of the probit. In column (1) I measure the liquidity of the aircraft using AIRCRAFT PER TYPE, while in column (2) I use CARRIERS PER TYPE. Overall, the results show that more liquid aircraft make leasing more likely. The positive signs of the coefficients of the measures of liquidity are exactly as predicted by *H1*. More popular aircraft are more likely to be under operating lease.

Moreover, the negative sign on CARRIER SIZE OF FLEET indicates that smaller carriers are more likely to use aircraft under operating lease. As we suggested in Section 3, the advantages of contracting out the redeployment of the aircraft are larger for smaller carriers. Thus, the negative sign on CARRIER SIZE OF FLEET seems to indicate that the operating lease is closer to a vertical contract for the redeployment of the aircraft than to a financing contract. But as we already discussed in Section 3, unfortunately the absence of several other useful controls that might be correlated with CARRIER SIZE OF FLEET does not allow us to give a causal interpretation to its negative coefficient.

The coefficients reported in Table 3 imply that the proxies for the liquidity of the aircraft are also economically significant. For example, when we measure aircraft liquidity with AIRCRAFT PER TYPE, we find that, holding all other variables at their means, moving from the Boeing 717 with his 107 units to the A320 with his 1140 units increases the probability that aircraft is leased from .28 to .32. Moving then to the 3807 units of the Boeing 737 increase the probability that the aircraft is leased to .40. The increase in probability is very similar when we instead measure liquidity with CARRIERS PER TYPE.

I also re-estimate equation (2) employing a linear probability model. In columns (3) and (4) I report the estimates of the coefficients of the linear specification. The signs of the coefficients confirm the results found using the probits, and the magnitudes are only slightly different. For example, holding all other variables at their means, moving from the Boeing 717 with his 107 units to the A320 with his 1140 units increases the probability that the aircraft is leased from .34 to .365. Moving then to the 3807 units of the Boeing 737 increase the probability that the aircraft is leased to .423.

In columns (5) and (6), I also add carrier-fixed effects to the linear probability model in order to further control for carrier-specific unobserved non-random components that may bias the results.[30] In this way, we identify the effect of greater aircraft liquidity comparing within each carrier how the probability that each aircraft is leased covaries with AIRCRAFT PER TYPE or CARRIERS PER TYPE, thus providing an even stronger test of hypothesis *H1*. The estimates of the coefficients are very similar in columns (3) and (5), and columns (4) and (6). The signs of the coefficients do not change in the new estimation and, if anything, the magnitudes increase slightly. For example, holding as usual all other variables at their means, now the probability that a Boeing 717 is leased is .312. The probability then increases to .346 for the A320 and reaches .433 for the Boeing 737.

4.3.2 Duration of lease contracts

The previous Subsection showed that the fraction of leased aircraft differs systematically between types according to the liquidity of the aircraft as predicted by hypothesis *H1*. In this Subsection I show that similar patterns emerge when we consider the relationship between the duration of operating lease contracts and our proxies for aircraft liquidity. In particular, in this subsection we test the financing hypothesis *H2a* against the vertical alternative *H2b*. In light of the previous results, we now expect the data to favor the vertical contracting hypothesis, i.e. to favor *H2b* against *H2a*.

The analysis is based on the following reduced-form equation:

$$\log\left(\text{DURATION}_{lij}\right) = \alpha Y_{lij} + \beta W_i + \gamma X_j + \epsilon_{lij} \tag{3}$$

where DURATION_{lij} is the duration of the operating lease contract (in months) of each aircraft. Y_{lij} is a set of variables specific to each individual aircraft, such as AGE. W_i is a set

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[30]Estimating equation (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 carrier have either 0% or 100% of the fleet under operating lease. This is why we use the linear probability model instead.

of variables specific to each aircraft of type i. It includes the measures of aircraft liquidity AIRCRAFT PER TYPE - the total number of aircraft of type i - or CARRIERS PER TYPE - the total number of carriers operating aircraft of type i. As before, we also include dummy variables for Narrowbody and Widebody aircraft, so we identify again the effect of aircraft liquidity from variation within aircraft categories. X_j is a set of variables specific to each carrier j, in particular CARRIER SIZE OF FLEET, the size of the fleet of each carrier j. As in the previous regressions, we later employ also carrier fixed effects to control for potentially unobserved carrier-specific factors.

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

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

i.e. the duration is larger than the truncation point T_{lij} given by the difference between April 2003 and the date the lease was signed. The truncated sample means that estimating equation (3) using OLS yields inconsistent estimates. However, assuming that the unobservable ϵ_{ij} is normally distributed, I can construct the likelihood of observing each contract given the nature of the truncation, and then estimate equation (3) using maximum likelihood.

In Table 4, I present the maximum likelihood estimates of the coefficients of equation (3). I measure aircraft liquidity with AIRCRAFT PER TYPE in column (1) and with CARRIERS PER TYPE in column (2). Overall, the table shows that the proxies for aircraft liquidity have significant predictive power. The coefficients of AIRCRAFT PER TYPE and CARRIERS PER TYPE are significantly different from zero. The negative signs indicate that more liquid aircraft have shorter operating leases, thus favoring the vertical contracting hypothesis $H2b$ against the financial contracting hypothesis $H2a$.

The magnitudes show that the coefficients have economic significance too. For example, when we use AIRCRAFT PER TYPE to measure liquidity, we find that the average duration of a lease contract decreases from 88 to 77 months when moving from the Boeing 717 (107 units) to the Boeing 737 (3807 units). The effects are very similar if we use CARRIERS PER TYPE instead.

The positive sign of CARRIER SIZE OF FLEET indicates that operating lease contracts are longer the bigger is the fleet of the operator. This is consistent with both the vertical contracting literature and the financial contracting literature, as we discussed in Section 3. However, we want to reiterate that the absence of several other useful controls that might be correlated with CARRIER SIZE OF FLEET do not allow us to emphasize a causal relationship between the two variables. In any case, the coefficient of CARRIER SIZE OF FLEET implies that the average duration of a lease contract increases from 55 to 76 months when moving from a carrier with a fleet of 2 aircraft to a carrier with a fleet of 100 aircraft, and further increases to 91 months for a carrier with a fleet of 237 aircraft.

We repeated the analysis also including carrier fixed effects to further control for carrier-specific unobserved factors. Columns (3) and (4) reports the results of these specifications. The estimates with or without carriers fixed effects are very similar. The signs of the coefficients are unchanged and the magnitudes are just slightly smaller when carrier fixed effects

Table 4: Duration of lease contract

LOG(DURATION OF CONTRACT)	(1)	(2)	(3)	(4)
AGE AT SIGNING	−.0419	−.0418	−.0395	−.0395
	(.0021)	(.0021)	(.0022)	(.0022)
CARRIER SIZE OF FLEET	.00076	.00074		
	(.00006)	(.00005)		
AIRCRAFT PER TYPE	−.00003		−.00002	
	(.00001)		(.000011)	
CARRIERS PER TYPE		−.00049		−.00036
		(.00014)		(.00015)
CARRIER FIXED EFFECTS	No	No	YES	YES
LOG LIKELIHOOD	−480.09	−477.47	264.75	266.05
N	2086	2086	2086	2086

Notes - Robust standard errors in parenthesis. The estimated equation also contains fixed effects for Widebody, Narrowbody and Regional aircraft (not reported).

are included. For example, the average duration of an operating lease contract decreases from 72 to 66 months when moving from the Boeing 717 (107 units) to the Boeing 737 (3807 units).

4.3.3 Lease rates mark-ups

The analysis so far has shown that several characteristics of lease contracts are systematically affected by how liquid is the aircraft. In this subsection I show that also the mark-ups of aircraft lease rates over prices vary according to the liquidity of the aircraft according to hypothesis *H3*.

In order to study how mark-ups vary with the liquidity of the aircraft, we combine the aircraft values and aircraft characteristics dataset. More specifically, we reconstruct from our time-series data the total stock of aircraft of a given type in each year t. Then, for each aircraft for which we could construct the mark-ups $m_{i,j,t}$ as defined in equation (1), we match the measures of liquidity of that specific type (AIRCRAFT PER TYPE or CARRIERS PER TYPE) in year t to the mark-ups $m_{i,j,t}$. Thus, differently from the previous regressions, now the aircraft liquidity measures vary also over time within aircraft type.

We then use panel-data to estimate the following equation:

$$m_{ijt} = \alpha + \beta Y_{ijt} + \gamma W_{It} + \delta_i + \eta_t + \epsilon_{ijt} \tag{4}$$

where i represents a model within type I, j a vintage, t a year and $m_{i,j,t}$ is the markup as defined in equation (1).[31] Y_{ijt} is a set of variables specific to each individual aircraft, such

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[31]Note that the panel variable is thus a model-vintage pair. We have also re-estimated equation 4 using model-age as a panel variable. The results are almost identical.

Table 5: Mark-up of lease rates

MARK-UP OF LEASE RATES	(1)	(2)	(3)	(4)
AGE	.0015	.00169	.0231	.0226
	(.00146)	(.00147)	(.005)	(.0055)
AIRCRAFT PER TYPE	−.00020		−.00020	
	(.00003)		(.00003)	
CARRIERS PER TYPE		−.00362		−.00361
		(.00046)		(.00046)
R^2	.573	.569	.231	.219
GROUPS	319	319	319	319
N	4097	4097	4097	4097

Notes - Robust standard errors in parenthesis. The equation estimated in Columns (1) and (2) also contains aircraft model and year fixed effects (not reported); The equation estimated in Columns (3) and (4) also contains year fixed effects (not reported).

as AGE. W_{It} is a set of variables specific to each aircraft of type I in year t. It includes the measures of liquidity AIRCRAFT PER TYPE - the total number of aircraft of type I in year t - or CARRIERS PER TYPE - the total number of carriers operating aircraft of type I in year t. δ_i is an aircraft-model fixed effect, η_t is an year fixed effect and ϵ_{ijt} is an observed component. The inclusion of model and year fixed effects implies that we identify the effect of liquidity exploiting how AIRCRAFT PER TYPE or CARRIERS PER TYPE covary with the mark-ups using only the within-year and within-type deviations from their respective means, thus providing a very powerful identification of the effect of liquidity on mark-ups.

The results are presented in Table 5. Columns (1) and (2) present the results when equation (4) is estimated using random effects, while columns (3) and (4) present the results when equation (4) is estimated using fixed effects.[32] Exactly as predicted by hypothesis *H3*, the negative signs of AIRCRAFT PER TYPE or CARRIERS PER TYPE indicate that more liquid aircraft have smaller mark-ups. Moreover, the magnitudes of the coefficients imply that an increase in liquidity has a considerable effect on mark-ups. The fixed-effects estimates of column (3) imply that the average mark-up decreases by .2 when the AIRCRAFT PER TYPE increases by one standard deviation (1000 aircraft), thus capturing approximately half of a standard deviation in mark-ups. The magnitude also conforms well with the decrease in mark-ups we observe for the most famous aircraft. For example, the mark-ups of a 10 year-old Boeing 737 decreased from 1.23 when AIRCRAFT PER TYPE was around 2500 units (year 1993), to 1.15 when AIRCRAFT PER TYPE was around 3100 (year 1998).

It is also important to highlight the coefficient of the variable AGE. The coefficient is positive. In the consistent specifications - the fixed effect specifications of columns (3) and (4) - it is also significantly different from zero. Quite likely, aircraft are more difficult to redeploy

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[32]Obviously perfect collinearity prevents the estimation also of model dummies δ_i in the fixed effect estimation.

as they become older and the positive coefficient of AGE seems then again consistent with the idea that more liquid aircraft command lower mark-ups.[33]

4.4   Robustness Checks and Additional Evidence

The results of the previous subsection provides already quite strong evidence that the liquidity of the aircraft systematically affects lease contracts. In addition, the evidence on the duration of the contracts indicates that the operating lease is closer to a vertical contract between a supplier (lessor) and a buyer (lessee) than to a financing contract.

In this Subsection we present additional evidence through several robustness checks to the previous analysis. In particular, while the entire analysis already controlled through carrier fixed effects for unobserved characteristics of the *operator* of the aircraft that could have driven the observed correlations, there might still be the concern that unobserved characteristics of the *aircraft* that are correlated with liquidity are driving our results. The panel-data analysis on lease mark-ups already controlled for this concern through aircraft fixed effects, thus providing a very strong test to hypothesis *H3*. In this subsection we show that also the tests of hypotheses *H1* and the "horse-race" between *H2a* and *H2b* survive this type of concerns using two different empirical strategies. The first controls for the potential endogeneity of our measures of aircraft liquidity using an instrumental variable approach. The second re-estimates equations (2) and (3) exploiting the time-series variation in our measures of liquidity of aircraft types, thus enabling us to control for unobserved characteristics of the aircraft using aircraft type fixed effects. The analysis confirms and strengthens our previous findings.

4.4.1   Instrumental variables

The first robustness check we perform is to control for the potential endogeneity of our measures of liquidity of the aircraft. The concern for potential endogeneity arises because lessors are the owners and thus the buyers of the aircraft. As a result, AIRCRAFT PER TYPE might suffer from simultaneity bias. For example, AIRCRAFT PER TYPE may be high because lessors demand a large number of a specific type of aircraft. As a result of lessors' purchases, we would mechanically find that an aircraft is more likely to be leased when AIRCRAFT PER TYPE is large. Similarly, lessors may systematically prefer to acquire aircraft that have shorter lease contracts and lessors' purchasing activity may disproportionately increase the number of AIRCRAFT PER TYPE. In these cases, we could not give a causal interpretation to the aircraft-specific measures of liquidity and our empirical analysis would lead to incorrect tests of hypotheses *H1* and *H2*.

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[33]The theoretical literature has also analyzed how the liquidity of the assets directly affects the price of the assets, predicting that more liquid asset should command higher prices. We have investigated empirically the issue in the case of aircraft. More precisely, we have estimated an equation similar to equation (4), but the dependent variable was (log of) $p_{i,j,t}$, the price of aircraft of model i, vintage j in year t. As predicted by the literature, we find that more liquid aircraft command higher prices. We do not report the results here, since the focus of the paper is on how asset liquidity affects lease contracts, but results are available from the author.

Table 6: Leased Aircraft: Instrumental Variables

Share of Leased Aircraft	(1)	(2)
Age	$-.0145$	$-.008085$
	$(.00054)$	$(.00062)$
Carrier size of fleet	$-.00050$	
	$(.00001)$	
Aircraft per type	$.000021$	$.000033$
	$(3.20e-06)$	$(4.03e-06)$
Carrier Fixed effects	No	Yes
R^2	0.1373	0.4388
N	14301	14301

Notes - Robust standard errors in parenthesis. The estimated equation also contains fixed effects for Widebody, Narrowbody and Regional aircraft (not reported).

To address the concern for potential endogeneity, I employ an instrumental variable approach. One obvious candidate as an instrument for Aircraft per type is the total number of aircraft of a given type that is not leased. This is clearly correlated to the total number of aircraft but does not suffer from the simultaneity bias just described. I also employ other instruments that arguably exogenously shift the total number of aircraft of a given type. I employ as instruments the total number of engines, the weight and the number of seats of the aircraft. A larger number of engines, a higher weight and a greater number of seats indicate that the aircraft is bigger and has a longer flying range. These two variables are correlated with Aircraft per type as the number of people traveling from point A to point B is generally a *negative* function of the distance between A and B. Hence, the size and the range of the aircraft are negatively correlated with Aircraft per type.

For sake of brevity, I report in Table 6 only the IV estimates of the linear probability models when instrumenting Aircraft per type.[34] I report results for two specifications. In column (1) I control for carrier characteristics using Carrier size of fleet, while in column (2) I employ carrier fixed-effects.

The results are almost identical to those reported in Table 3. We therefore conclude that simultaneity bias does not seem to be a concern in the test of hypothesis *H1.*

A similar approach can be used to control for the potential endogeneity in the lease duration equation.[35] In Table 7, I report the estimates of the truncated duration equation (3) using the instruments just described. Again, the results are almost identical to those reported

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[34]Note that the variable Aircraft per type only varies between different types. Thus, the first stage regression is run with only 35 observations, the number of different types in our sample.

[35]Instrumenting in a non-linear equation as equation (4) is slightly more involved than in a standard linear equation. I use the two-step control function approach as in Blundell and Powell (2003). The procedure involves inserting also the residuals from the first step as a regressor in the second step. Standard errors need to be corrected to account for the first stage.

Table 7: Duration of lease contract: Instrumental Variables

LOG(DURATION OF CONTRACT)	(1)	(2)
AGE AT SIGNING	−.0418	−.0396
	(.0021)	(.0022)
CARRIER SIZE OF FLEET	.00076	
	(.00006)	
AIRCRAFT PER TYPE	−.000027	−.000027
	(.000011)	(.000015)
CARRIER FIXED EFFECTS	No	YES
LOG-LIKELIHOOD	−480.04	265.25
N	2086	2086

Notes - Robust standard errors in parenthesis. The estimated equation also contains fixed effects for Widebody, Narrowbody and Regional aircraft (not reported).

in Table 4. Thus, simultaneity bias does not seem to affect the tests of our hypotheses.

4.4.2 Time-series variation

The empirical tests of hypothesis *H1* and the "horse-race" between hypotheses *H2a* and *H2b* was entirely based on our cross-sectional data and hence on variation in our measures of liquidity between different aircraft types. While we controlled thoroughly for unobserved characteristics of the *operator* of the aircraft that could have biased the coefficients, there might still be the concern that unobserved characteristics of the *aircraft* are correlated with liquidity. However, the richness of the data allows us to address this potential concern exploiting also the time-series variation in our measures of liquidity, in a way similar to what we did in the analysis of lease rates mark-ups.

The negative coefficients of the AGE variable in Tables 3 and 6 is already suggesting that the fraction of leased aircraft increases with the liquidity of the aircraft. The expansion of the airline industry in the last 30 years means that only a small number of aircraft types was phased out and for most types we observed an increase in our measures of liquidity AIRCRAFT PER TYPE and CARRIERS PER TYPE. The negative coefficient on AGE is therefore consistent with the idea that leasing becomes more likely as the stock of aircraft of a given type increases over time.

To further strengthen our analysis, we use the total stock of aircraft of a given type in each year constructed from our time-series data and employed already to estimate equation (4). Then, for each aircraft we match the time-varying measure of liquidity AIRCRAFT PER TYPE either to the year the current operator of the aircraft started operating the specific aircraft in the case of the operating lease equation (2), or to the year the current lease contract started in the case of the lease duration equation (3). Thus, now the measure of aircraft liquidity varies also within aircraft type.[36]

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[36] We have also conducted our analysis using CARRIERS PER TYPE as the measure of liquidity. The results

Table 8: Leased Aircraft: Time-series variation

Share of Leased Aircraft	(1)	(2)
Age	−.000019	.0058
	(.0005)	(.001)
Aircraft per type	.0000581	.000107
	$(4.23e-06)$	$(9.60e-06)$
Fixed effects	Carrier	Aircraft type, Carrier
R^2	0.4357	0.4481
N	14232	14232

Notes - Robust standard errors in parenthesis. The estimated equation also contains fixed effects for Widebody, Narrowbody and Regional aircraft (not reported).

In Table 8 I present the results estimating equation (2) using a linear probability model. In column (1) I present the results of a specification with only carrier type fixed effects, while in column (2) I add also aircraft type fixed effects to the specification, so we identify the effect of greater liquidity simply through time-series variation within each carrier and within each aircraft type.

The positive coefficients indicate that our results survive through these additional checks. In particular, we still find that more liquid aircraft make leasing more likely. Moreover, the magnitude of the coefficient of Aircraft per type is now even larger than in Table 3. For example, the coefficients of column (2) imply that the probability that a new Boeing 737 was under operating lease increased from .26 in the year 1990 when Aircraft per type was around 1900 to .44 in the year 2000 when Aircraft per type was around 3600.

We also re-estimate equation (3) using the time-series variation in our measure of liquidity. Table 9 reports the estimates from the maximum likelihood procedure that corrects for our truncated sample. Column (1) adds aircraft type fixed effects to the regressors used in the specification of column (3) of Table 4. Column (2) includes also a flexible polynomial in time to capture unobserved variables which may also have changed over time. Hence, we identify the effect of liquidity on the duration of contracts from time-series variation in Aircraft per type within each carrier and within each type, after controlling for a common time-trend.

The signs of the coefficients do not change in these additional specifications, and the magnitudes are even larger than previously found. For example, the coefficients of column (2) now indicate that the duration of an operating lease contract on a new Boeing 737 decreased from around 66 months if the lease started in the year 1990 when Aircraft per type was around 1900 to 58 months if the lease was instead signed in the year 2000 when Aircraft per type was around 3600. Moreover, not only the magnitudes of the coefficients are bigger, but also now our measure of liquidity has a larger standard deviation, so that a change of one standard deviation in Aircraft per type explains a higher fraction

are almost identical and therefore omitted.

Table 9: Duration of lease contracts: Time-series variation

Log(Duration of Contract)	(1)	(2)
Age at Signing	−.0400	−.0367
	(.0021)	(.0021)
Aircraft per type	−.00013	−.000075
	(.00003)	(.00004)
Fixed effects	Aircraft type, Carrier	Aircraft type, Carrier
Time Trend	No	Yes
Log Likelihood	319.92	375.85
N	2074	2074

Notes - Robust standard errors in parenthesis. The equation estimated in Column (1) also contains fixed effects for Widebody, Narrowbody and Regional aircraft (not reported). The equation estimated in Column (2) also contains aircraft type fixed effects.

of the variation of Duration.

Overall, the additional robustness checks performed in this subsection corroborate the idea that the liquidity of the aircraft affects operating lease contracts in the ways our hypotheses indicated. Moreover, the additional checks on the duration of lease contracts confirm the hypothesis that the operating lease is more similar to a vertical contract than to a financing contract.

5   Comparisons with capital lease

In this Section we investigate the differences between the capital and the operating lease. The previous analysis brought strong evidence in favor of the idea that operating leases are vertical contracts between the supplier (the lessor) and the buyer (the lessee) of one specific service (the redeployment). In light of the discussion of Section 3, we might expect operating and capital lease to have different economic purposes and the capital lease to be closer to a financing contract. Thus, liquidity of the aircraft could affect differently operating and capital leases, as highlighted by our hypotheses *H2a* vs. *H2b*.

To investigate whether capital and operating leases are indeed different contracts with different characteristics and different purposes, we first estimate a multinomial version of equation (2). The dependent variable now takes on three possible values: the aircraft can be under an operating lease, a capital lease or owned by the carrier (in which case is generally financed through internal finance (cash or equity) or debt).

Table 10 reports the maximum likelihood estimates. The excluded category is owned aircraft, so all coefficients are relative to owned aircraft. It is interesting to note how the estimated coefficients imply different patterns for the operating and capital lease. First, the coefficients of Aircraft per type in the operating lease equation and in the capital lease

Table 10: Multinomial Probit: Capital vs. Operating Leases.

	OPERATING LEASE	CAPITAL LEASE
AGE	−.0608	.0028
	(.0030)	(.0027)
CARRIER SIZE OF FLEET	−.0021	.0008
	(.0001)	(.00007)
AIRCRAFT PER TYPE	.00009	.00004
	(.00001)	(.000015)
N	14301	
LOG-LIKELIHOOD	−13410.183	

Notes - Robust standard errors in parenthesis. The estimated equations also contains fixed effects for Widebody, Narrowbody and Regional aircraft (not reported).

equation are statistically different from each other.[37] Higher aircraft liquidity as proxied by AIRCRAFT PER TYPE induces more operating lease and more capital lease, but the effect of an increase in liquidity is different for the two lease contracts.

Second, it is remarkable to note that the coefficient of CARRIER SIZE OF FLEET is negative in the operating lease equation (as already found in Table 3) and positive in the capital lease equation. The difference indicates that as the size of the fleet grows, carriers switch from operating leasing to ownership first, and then from ownership to capital leasing. This pattern seems to indicate that as the size of fleet grows, carriers switch from external ownership (and external finance) to internal ownership and internal finance, and then to internal ownership and external finance. This is consistent with the contrasting predictions we reviewed in Section 3 and seems to indicate again that the two lease contracts have fundamentally different characteristics. However, the absence of controls that might be correlated with CARRIER SIZE OF FLEET suggests caution in interpreting the observed patterns, even though now this new evidence also requires that the unobserved factors have exactly opposite correlations with CARRIER SIZE OF FLEET in the operating lease and in the capital lease equations.

We also investigates how liquidity affects the duration of capital lease contracts. In Table 11 we present the coefficients of the maximum likelihood estimation of equation (3) using data for capital lease contracts only. For sake of brevity, we report only the results when we consider both cross-sectional and time-series variation in our liquidity proxies, which corresponds to the estimates of Subsection 4.4.2. The results for the capital lease are reported in column (1) and, for ease of comparison, we also report in column (2) the results for the operating lease as already reported in column (2) of Table 9.

The results are remarkable. Higher liquidity, as measured by AIRCRAFT PER TYPE, leads to shorter operating lease but longer capital leases. To appreciate the magnitudes of

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[37]The test of equality of the coefficients has a p-value of 0.0005.

Table 11: Duration of lease contracts: Capital vs. Operating Leases.

Log(Duration of Contract)	Capital Lease	Operating Lease
Age at Signing	−.0500	−.0367
	(.0018)	(.0021)
Aircraft per type	.00010	−.000075
	(.00002)	(.00004)
Fixed effects	Aircraft type, Carrier	Aircraft type, Carrier
Time Trend	Yes	Yes
Log Likelihood	1346.18	375.85
N	1814	2074

Notes - Robust standard errors in parenthesis.

the coefficients and the implications for contract duration, I plot in Figure 1 the fitted values for the Boeing 737 based on the estimated coefficients. The Figure shows that the increase in the stock of aircraft of a given type has very different effects on operating and capital leases. For example, contracts for the Boeing 737 had an average maturity of 66 months for an operating lease and 93 months for a capital lease if the contracts were signed when the stock of Boeing 737 was equal to approximately 1900 units. If the contracts were signed when the stock of Boeing 737 was equal to 3600 units, then the average maturity of an operating lease decreased to 58 months while the average maturity of a capital lease increased to 111 months.

Overall, these results match well the predictions of Section 3, providing strong support for the idea that capital and operating leases are very different contracts that serve different purposes. The previous Sections show that operating leases have characteristics very similar to vertical contracts, while the new evidence of this Section provides strong support for the idea that capital leases are financing contracts, with similar characteristics to debt contracts.

6   Alternative hypothesis

The evidence presented so far has shown that the liquidity of the aircraft affects systematically lease contracts as our hypotheses suggested. 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.

In principle, however, our measures of redeployability could still be correlated with time-varying aircraft characteristics. The characteristic that is most likely to be correlated with our measures of liquidity is the volatility of the aircraft price. A large literature has analyzed theoretically and empirically the link between asset liquidity and the volatility of prices, and then the implications for risk-averse investors.
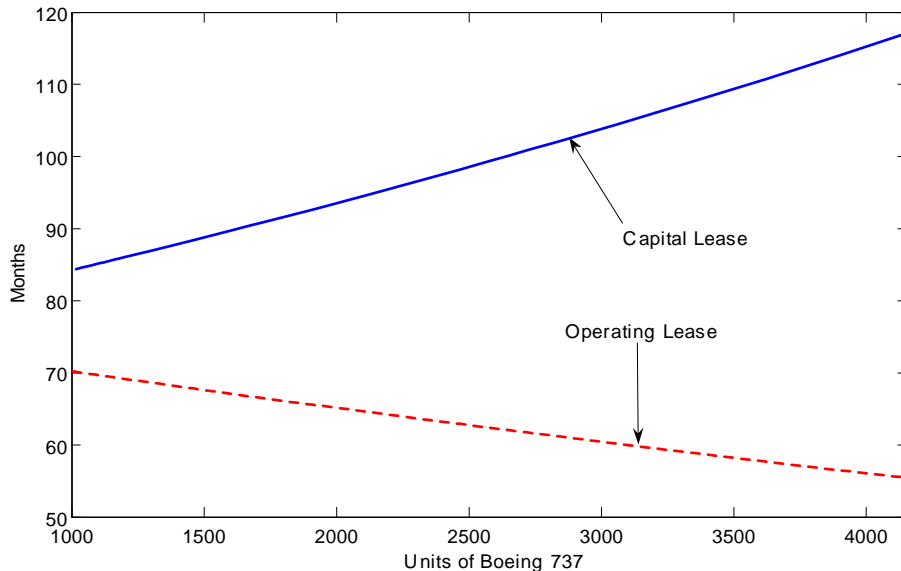
Figure 1: FITTED DURATIONS BASED ON THE COEFFICIENTS REPORTED IN TABLE 11.

In the context of aircraft, however, it is not exactly clear how the assumption of risk-neutrality that is always made for firms should affect the choices of assets with different volatilities. Moreover, the presence of outside financiers such as lessors should also bound the fluctuations of aircraft prices. Pulvino (1999) documents how leasing companies arbitrage prices over time, buying used aircraft during industry downturns and selling them during industry expansions. Hence, the link between lower liquidity and more volatile prices might be spurious in the case of aircraft.

To explore the issue more formally, we investigated empirically the relationship between volatility of prices and liquidity. The dependent variable is the absolute value of the percentage change of the price of an aircraft of a given model-age pair from the previous year. For example, one observation reports the absolute value of the percentage change of a one year old Boeing 737-800 from 1990 to 1991. More precisely, the dependent variable is:

$$\left| \frac{p_{i,j,t} - p_{i,j-1,t-1}}{p_{i,j-1,t-1}} \right|$$

where, as before, i is model, j is vintage (year of "birth") and t is year. Our key independent variables are the measures of liquidity AIRCRAFT PER TYPE or CARRIERS PER TYPE previously defined.

One potential concern with the above regressions is that our dependent variable is the realized volatility of price, while the relevant theoretical variable should be the expected volatility. However, for each model-vintage our panel covers a span of years long enough such that it is unlikely that our dependent variable just captures a small number of realizations that might substantially differ from the theoretical expectation.

In Table 12, we present the results of a number of regressions. The Table shows that the coefficients on AIRCRAFT PER TYPE or CARRIERS PER TYPE are never significantly

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Table 12: Volatility of prices

$\left\lvert\frac{p_{ijt}-p_{i,j-1,t-1}}{p_{i,j-1,t-1}}\right\rvert$	(1)	(2)	(3)	(4)
AGE	.0025	.00699	.0025	.0070
	(.0003)	(.00046)	(.0003)	(.0004)
AIRCRAFT PER TYPE	$3.81e-07$	$-5.72e-07$		
	$(3.05e-06)$	$(3.28e-06)$		
CARRIERS PER TYPE			$-.000011$	$-.000028$
			(.000054)	(.000058)
FIXED EFFECTS	Aircraft model, Year	Year	Aircraft model, Year	Year
R^2	.526	.474	.527	.472
Groups	318	318	318	318
N	4062	4062	4062	4062

Notes - Robust standard errors in parenthesis.

different from zero. The trading activity and intertemporal arbitrage of intermediaries has the effect of smoothing the fluctuations of prices. As a result, we do not observe larger swings for less liquid aircraft.

We thus conclude that our liquidity measures are not just capturing the effect of the volatility of prices. This is an additional robustness check to our previous analysis and further reinforces the tests of our hypotheses.

7   Conclusion

In this paper I examined empirically how incomplete contracts and contracting costs simultaneously shape firms' boundaries and financial structure analyzing commercial aircraft' lease contracts. In particular, I investigated how the liquidity of the different aircraft types generate contracting costs that affect whether carriers lease the aircraft they operate, the optimal maturity of lease contracts and the mark-ups of lease rates over aircraft prices.

Most of the literature on leasing treats all different leases just as financing contracts and the lease vs. buy decision often becomes the lease vs. debt decision. This paper shows how lease contracts integrate the salient aspects of both a vertical contract and a financing contract. However, the literature on the boundaries of the firm and the literature on financial contracting sometimes make contrasting predictions on how contracting costs should affect the structure of lease contracts. In particular, I focus on one aspect - the liquidity of aircraft - that has been extensively analyzed in the financial contracting literature. I use the methodology adopted in previous empirical studies on the boundaries of the firm and on financial contracts to measure the liquidity of aircraft, and I apply it to lease contracts to distinguish the contrasting predictions.

The empirical analysis supports the idea that the most popular lease contract - the

operating lease - is a vertical contract between a seller (lessor) and a buyer (lessee) where the service contracted out is the eventual redeployment of the aircraft. The data support the financial contracting predictions instead for the capital lease.

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. This paper illustrates how leasing becomes more popular as the market for an asset becomes more liquid. It thus suggests that leasing is an additional aspect of the vertical disintegration of production observed in most advanced economies. It further shows how contractual innovations like leasing contracts are simultaneously affecting distinct corporate decisions - such as the decisions about financing and vertical integration - in the modern firm.

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