Vintage Capital and Creditor Protection*

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Abstract

We provide novel evidence linking the level of creditor protection provided by law to the degree of usage of technologically older, vintage capital in the airline industry. Using a panel of aircraft-level data around the world, we find that better creditor rights are associated with both aircraft of a younger vintage and newer technology as well as firms with larger aircraft fleets. Moreover, we find that more profitable airlines, airlines with lower leverage ratios, and airlines with less debt overhang are less sensitive to prevailing creditor rights in their country. We propose that by mitigating financial shortfalls, enhanced legal protection of creditors facilitates the ability of firms to make large capital investments, adapt advanced technologies and foster productivity.

Introduction

There is a large body of evidence that better legal rules covering protection of corporate shareholders and creditors are associated with more developed financial markets and higher economic growth (La Porta et al., (1997), (1998); King and Levine, (1993); Beck et. al., (2000); and Rajan and Zingales, (1998)). While the empirical regularities found in the data are quite robust, most of the research is based on cross-country outcomes and suffers from small samples and potential identification problems (see Djankov at al. (2007)). In particular, the results from cross-country regressions do not pin down the underlying mechanism through which creditor rights and shareholder protection affect real economic outcomes. This paper attempts to fill this gap. We study the relation between creditor protection and the use of vintage capital in the airline industry in a sample of most of the aircraft in the world (494,653 aircraft-year observations) covering 5,987 operators in 129 countries in the years 1978-2003. We find that airlines enjoying the benefits of higher creditor protection operate aircraft of a newer technology and younger vintage.

The importance of new capital goods for economic growth has been suggested by Solow (1960): "...many if not most innovations need to be embodied in new kinds of durable equipment before they can be made effective. Improvements in technology affect output only to the extent that they are carried into practice either by net capital formation or by the replacement of old-fashioned equipment by the latest models..." More recent theoretical models show that capital of older vintage hampers productivity and growth (Benhabib and Rustichini (1991)), slows technology diffusion (Chari and Hopenhayn (1991)), and increases income inequality across individuals and countries (Jovanovic (1998)). Empirical estimates suggest that around 60% of US per-capita growth is due to technical change that is embodied in new more efficient capital goods (Greenwood, Hercowitz, and Krusell (1997)).[1] Our paper provides novel evidence on the creditor rights channel in technological adaption and capital formation.

While we propose and provide evidence on one mechanism connecting financial constraints and creditor protection to aircraft vintage and fleet size, our results suggest a broader link between financial development, investor protection and economic activity. Our empirical methodology differs from previous research which has focused mostly on aggregate, macroeconomic outcomes of investor protection such as financial market development and economic growth (King and Levine (1993), La

[1] See Boucekkine, de la Croix, and Licandro (2008) for a survey of the vintage capital literature.

Porta et al. (1997, 1998), Rajan and Zingales (1998)). The wealth of the data and our focus on an important global industry allow careful consideration and identification of the specific mechanism through which investor protection affects and fosters technical progress and economic development.

Our paper adds to a growing body of literature that uses industry- and firm-level data to evaluate the effects of investor protection and financial development on resource allocation (Fisman and Love (2004), Wurgler (2000)), economic growth (Demirguc-Kunt and Maksimovic (1998), Guiso, Sapienza, and Zingales (2005)), and financial contracts and lending structures (Bergman and Nicolaievsky (2007), Braun (2003), Esty and Megginson (2003), Lerner and Schoar (2005), Liberty and Mian (2007), Onega and Smith (2000), and Qian and Strahan (2006)).

We start by developing a simple price-theory model of an airline choosing its scale and average asset age given an *internal* financing constraint and *external* creditor protection that is determined at the country level. The airline must decide on the quantity of aircraft to purchase and their average age. Older aircrafts are assumed to be less efficient – either because of depreciation in aircraft efficiency stemming from their normal use, or because of technological improvements in aircraft design over time. We hypothesize that increased availability of external finance due to enhanced creditor protection will have two important effects on firms. First, when financial constraints are more relaxed, firms will be able to invest in newer, more expensive technologies, and second, since financing considerations will place fewer constraints on firm scale, firms will tend to be larger. We derive three empirical predictions from our simple model. The first prediction is about aircraft age. We expect that, all else equal, airlines operating in countries with lower creditor rights will have older fleets. Second, we predict that, all else equal, airlines operating in countries with lower creditor rights will have smaller fleets. Third, we show that the effect of the level of creditor rights on airline fleet age and size will be smaller for airlines with greater internal funds. Our model is closely related to Eisfeldt and Rampini (2007b) who show that firms which are credit constrained purchase more used, rather than new, capital because, higher ex-post maintenance payments of used capital relaxes current ex-ante financial constraints.

To test these hypotheses, we utilize a dataset which provides information on most of the aircraft operated worldwide. First we confirm our hypothesis that older aircraft tend to be less efficient. Using data on yearly utilization rates for most of the aircraft in the world during the period 1996-2006 we find that older aircraft are utilized less in terms of hours flown per year.

Using detailed profiles of every single aircraft in the world during the period 1978-2003 we then study the relation between the level of creditor protection of the country in which the aircraft is operated and owned and two measures of aircraft vintage. The first measure of vintage is simply aircraft age, defined as the time elapsed since the date of the aircraft delivery. For each aircraft we also define a second vintage measure, called 'technological age', which is calculated as the time elapsed since the model type of that aircraft was first introduced. The level of country creditor protection is measured using the creditor rights score as developed by La Porta et al. (1997, 1998), and in particular the more recent score that covers 129 countries in the years 1978-2003 (Djankov et al. (2007)). Consistent with our first hypotheses, our analysis shows that aircraft operated in countries with higher creditor protection are of a younger vintage and newer technology. Furthermore, we also find that operators' size are larger in countries with better creditor protection. These results continue to hold even after controlling for a variety of country and airline fixed-effects.

While omitted variables at the country level are the major concern in cross-country analysis, the panel dimension of our data allows us to control for country fixed-effects and hence to identify off of changes in creditor rights within a country. To further alleviate concerns about an omitted variables problem, we conduct a number of tests. First, we split our sample into aircraft operated by commercial and private airlines, and those operated by the military. We expect the negative relation between aircraft age and fleet size and creditor protection to hold only for non-military operators, since private and commercial operators are those required to raise funds from outside investors in cases of cash flow shortages. Moreover, only commercial and private operators would fall under the bankruptcy provisions of the local corporate and bankruptcy laws which are the essence of the creditor rights score. In contrast, sovereign debtors are incentivized to repay creditors mainly for reputational concerns and continued access to capital markets (Bulow and Rogoff (1989a,b)). Our results confirm this conjecture: we find that the creditor rights score is correlated with the age and fleet size of commercial and private operators but is uncorrelated with the age and size of military fleets.

As a further test, we split our sample into planes that are leased and those which are not leased. Following Eisfeldt and Rampini (2007a), we conjecture that leasing allows firms to alleviate some of the financial frictions associated with debt financing since asset repossession may be easier for a lessor than for a creditor. This implies first that airlines in countries with poor creditor rights will be more likely to lease rather than own aircraft, and second, that the negative relation between creditor rights and aircraft vintage described above should be concentrated amongst non-leased aircraft. We find support for both of these hypotheses in the data. Moving from a creditor rights score of 4 to a creditor rights score of zero increases the likelihood that an aircraft will be leased by 11.6 percentage points, representing an increase of 27.2 percent relative to the unconditional mean. Consistent with lease financing reducing financial frictions, while we find no relation between creditor rights and aircraft vintage amongst leased planes, we find a strong statistically significant negative relation amongst non-leased planes. By examining the relation between creditor right and both leased and non-leased aircraft separately, we alleviate the concern that what is driving our results is unobserved variation, and in particular unobserved variation in investment opportunities, that is correlated with creditor rights. Indeed, there is little reason to suspect that increased investment opportunities should differentially impact the vintage of leased as compared to non-leased aircraft. In contrast, the financing channel provides a clear prediction regarding the differential impact of creditor rights on the two methods of aircraft financing.

To test our third prediction that the effect of creditor rights will be smaller for airlines with greater internal funds, we focus on airlines with publicly available financial data. In a sample of the 67 world's largest airlines representing 29 countries and 49,496 aircraft-year observations, we find that more profitable airlines, airlines with lower leverage ratios, and airlines with less debt overhang (measured by long-term debt) are less sensitive to creditor rights, as our model predicts. While both leverage and long-term debt are clearly endogenous, our identification strategy relies on the interaction effects between country and firm characteristics. Furthermore, similar to our test regarding leased and non-leased aircraft, testing this third prediction also alleviates the concern that a correlation between creditor rights and unobserved investment opportunities is driving our results, since there is little reason to suspect that increases in creditor rights are more strongly correlated with improved investment opportunities in financially constrained firms as compared to financially unconstrained firms. In contrast, the financing channel provides a clear prediction regarding the differential impact of creditor rights on aircraft vintage.

The rest of the paper is organized as follows. Section I presents a simple price-theory model. Section II provides a description of our data sources and summary statistics. Section III presents the empirical link between aircraft age and utilization and efficiency. Section IV describes the empirical analysis of the relation between creditor rights and aircraft age and fleet size. Section V concludes.

I. The Model

We begin by providing a simple model of a firm with an investment opportunity choosing the vintage of the technology it will operate and its scale given an external financing constraint. For simplicity, firms in our model will choose between two technologies – a new technology and an old one. Our main goal is to describe the cross sectional variation in the allocation of vintage capital across firms operating in countries with creditor protection, and hence financial constraints, of varying degree. The model is related to Eisfeldt and Rampini (2007b), but assumes that technologies of different vintage are characterized by different production functions.

Before describing the model, it is useful to note that while in an economy with no financial frictions a new technology should dominate the old technology it replaces (this is implicit in calling the technology new), in an economy with financial frictions firms may employ the old technology because the new technology is harder to finance. This is easiest seen with the following stylized example. Consider an old technology which costs 10 units, and yields 20 units of consumption, as compared to a new technology which costs 30 units and yields 50 units of consumption. Assume that firms in this economy can pledge only half their output to outside investors. A firm with no internal capital can therefore only finance the old technology, since its pledgeable income when trying to finance the new technology, 25, is less than the new technology's cost. Thus, while the new technology is clearly superior to the old – providing a net benefit of 20 rather than 10 units of consumption – it is harder to finance. In this economy, therefore, firms with no internal capital will only employ the old, easier to finance, technology.[2]

Thus, in analyzing firms' choice of technology adoption, the relative ease of financing of the two technologies will play a crucial role.

A. Technology allocation with exogenous prices

Consider a continuous set of firms deciding on their scale of operation and between the use of assets which embody either an old or a new technology. For consistency with the empirical section we refer to firms as airlines and their assets as aircraft, although the model obviously generalizes. For simplicity, we assume that airlines can use only one type of technology in their fleets.

[2] A reverse situation can easily hold as well. If the old technology costs 10 units and yields 19 units of consumption, and the new technology costs 30 and yields 60 units of consumption, firms with no internal capital will only be able to finance and utilize the new technology. In this situation, the new technology is both more profitable, *and* easier to finance than the old technology.

A fleet of q_{new} new aircraft is assumed to provide revenue $f(q_{new})$, where f is twice differentiable, concave, and $f(0) = 0$. Similarly, a fleet of q_{old} old aircraft is assumed to provide revenue $g(q_{old})$, where again, g is twice differentiable, concave, and $g(0) = 0$. As is common, concavity of the production function stems from decreasing returns to scale. In what follows it turns out useful to define the equivalence function between old and new aircraft. Specifically, let h be the function relating a fleet of new aircraft of size q_{new} to the size of the old aircraft fleet with equal revenue. Put differently, h satisfies $g(h(q_{new})) = f(q_{new})$, so that $h(q_{new})$ old aircraft provide equal revenue as q_{new} new aircraft. Since new aircraft are assumed to be more efficient than older aircraft – either because of depreciation in aircraft efficiency stemming from their normal use, or because of technological improvements in aircraft design over time – we have that $h(q_{new}) > q_{new}$ for all q_{new}.

Airlines are assumed to be price takers. New technology aircraft are supplied perfectly elastically at a price normalized to one, while the price of an old aircraft is assumed in this section to be exogenously given at p_{old}.

Initially, we assume that airlines have no internal funds and must purchase their fleets using funds raised in an external capital market. Each airline operates in a country with a level of protection provided to investors parameterized by μ, where μ measures the fraction of revenue that insiders within the airline can pledge to outside investors.[3] Thus, given any revenue R, the airline's pledgeable income – i.e. the maximal amount that it can guarantee as repayment to its investors – is $\mu * R$, with μ between zero and one. Capital markets are assumed to be perfectly competitive, and the discount factor is taken for simplicity to be 1.

To choose the size and technology of its fleet, each airline will compare the value of a new fleet to the value of an old one. The value of a fleet comprised of new aircraft in a country with investor protection μ is given by:

$$V_{new}(\mu) = Max[f(q_{new}) - q_{new}] \qquad (1)$$
$$s.t.\ q_{new} \leq \mu f(q_{new})$$

Similarly, the value of a fleet comprised of old aircraft in a country with investor protection μ is given by:

[3] $1 - \mu$ can be interpreted as the fraction of revenue insiders can costlessly expropriate from outside investors.

$$V_{old}(\mu, p_{old}) = Max[g(q_{old}) - p_{old}q_{old}] \tag{2}$$
$$s.t.\ p_{old}q_{old} \leq \mu g(q_{old})$$

As is standard in these problems, because capital markets are perfectly competitive, outside investors break even, so that the maximand of the maximization problems have airlines obtaining the full NPV of the project subject to the financing constraint. We further assume that $V_{new}(1) > V_{old}(1, p_{old})$ so that in an economy without financial constraints (or in one in which firms can pledge all of their output to investors), the new technology is superior to the old technology.[4]

To solve these maximization problems we define q^{uc}_{new} and q^{uc}_{old} as the respective solutions to the unconstrained problems, so that, for example, q^{uc}_{new} solves $Max_{(q)}(f(q) - q)$. The following lemma characterizes how the constrained solution to maximization problem (1) depends on the level of investor protection of the country in which the airline operates, μ. The analogous lemma regarding maximization problem (2) is straightforward and not repeated for brevity.

Lemma 1. Define q^c as the solution to the constrained new-fleet maximization problem (1). Then:
(i) If μ is large enough to satisfy $q^{uc} \leq \mu f(q^{uc})$, then $q^c = q^{uc}$.
(ii) Alternatively, if $q^{uc} > \mu f(q^{uc})$, then q^c satisfies $q = \mu f(q)$.
Proof. See Appendix.

Lemma 1 is quite intuitive: If the unconstrained solution satisfies the financing constraint, it will be the constrained solution as well. Otherwise, the airline will raise funds until it hits its financing constraint – i.e. it will raise external capital to the full extent possible implied by limited pledgeability of income. In this constrained region, it is easy to see that investment will be increasing in μ.

Figure 1 provides a graphical depiction of Lemma 1. For high μ, the financing constraint isn't binding in that the cost of investment q^{uc} is less than the pledgeable income $\mu f(q^{uc})$. The airline therefore chooses q^{uc}. As μ decreases below the μ^* satisfying $q^{uc} = \mu^* f(q^{uc})$, the constraint binds and the airline chooses the maximal fleet size fundable by outside investors – i.e. that solving $q = \mu f(q)$. Figure 2 depicts the resultant value and fleet-size functions for varying levels of investor

[4] This assumption is for expositional use only, and is no longer required once p_{old} is endogenized.

protection μ. As can be seen, for $\mu \leq \mu^*$ fleet size and the associated value function are increasing in μ, while for $\mu > \mu^*$, both fleet size and the value function are constant at their unconstrained level.

In choosing between the new and old technologies, an airline in a country with investor protection μ simply compares $V_{new}(\mu)$ to $V_{old}(\mu, p)$, where the solution to the maximization problems and their associated value functions are characterized as in Lemma 1. Proposition 1 describes this choice:

Proposition 1. *If h, the equivalency function between new and old technology, is convex in q_{new}, then for every p_{old} there exists a $\bar{\mu} \geq 0$ such that airlines with $\mu < \bar{\mu}$ choose the old technology, and airlines with $\mu > \bar{\mu}$ choose the new technology.*

Proof. *See Appendix.*

Proposition 1 states that if h is convex, the allocation of vintage capital is such that airlines operating in low investor protection countries will choose an old aircraft fleet, while those operating in high investor protection countries will choose a new aircraft fleet. Convexity of h is equivalent to stating that the rate of transformation between new aircraft and old is increasing in the size of the new aircraft fleet.[5] As one example, this condition is likely to hold because of diseconomies of scale in managing large sized fleets.

To gain intuition for Proposition 1, it is useful to combine maximization problems (1) and (2) into one, by realizing that, in effect, each airline can produce revenue $f(q_{new})$ at a cost of

$$c(q_{new}) = min[q_{new}, p_{old} * h(q_{new})]. \tag{3}$$

The maximization problem of an airline in a country with investor protection μ can be written therefore as

$$Max[f(q) - c(q)] \tag{4}$$
$$s.t.\ c(q) \leq \mu f(q)$$

[5]Thus, for example, if q new aircraft are revenue equivalent to $n_1 q$ old aircraft, more than $2n_1 q$ old aircraft are required to generate the revenue generated by $2q$ new aircraft.

Figure 3A depicts maximization problem 4 graphically. Defining q^*_{new} as the point where $q_{new} = p_{old} * h(q_{new})$, i.e. where the cost functions of the two technologies intersect, the figure shows that when h is convex, small fleet sizes (those with an equivalent q_{new} smaller than q^*_{new}) will be more easily financed by employing old aircraft. In contrast, large fleet sizes are more efficiently financed with the new technology. These two facts are crucial in determining the technology choice once the effect of the financing constraint is considered, as Figure 3B illustrates.

Since by assumption, the new technology is preferred to the old technology in an unconstrained financing economy, the solution to maximization problem (4) without the financing constraint, q^{uc}, has $q^*_{new} < q^{uc}$. Therefore, as Figure 3B shows, when μ is high the financing constraint is not binding, and the unconstrained solution will be attainable by acquiring a fleet of new aircraft of size q^{uc}. As μ diminishes past the point where q^{uc} is financable (so that $c(q^{uc}) > \mu f(q^{uc})$; i.e. past μ^M in Figure 3B), the airline will remain with the new technology but finance the maximum fleet size possible given the financing constraint (i.e. choose a fleet of size q solving $q = \mu f(q)$). At some point, as μ diminishes further, the financing constraint associated with choosing the new technology will be sufficiently restrictive that the airline will choose to switch to the old, cheaper technology. Finally, when μ is sufficiently small ($\mu \leq \mu^L$ in the figure), the old technology provides the more efficient source of financing for any fleet that is financable (i.e. $p_{old} * h(q_{new}) < q_{new}$ for all q_{new} that are financable). Airlines operating in countries with these levels of μ therefore clearly choose to finance and acquire old aircraft fleets.

Figure 4 provides a graphical representation of the value functions of the new and old technology as a function of μ. As Proposition 1 states, low μ firms select the old technology, while high μ firms select the new technology.

B. Endogenous prices and fleet size

We now endogenize the price of old technology, p_{old}. To do so, we assume that there exists a measure α of preexisting old aircraft. Further, we assume that there is a measure β of firms, and that μ is distributed according to the distribution function G. An equilibrium p^*_{old} is then simply a price for old technology aircraft such that the market for old aircraft clears. The equilibrium is characterized by the following proposition:

Proposition 2. *If h, the equivalency function between new and old technology, is convex in q_{new}, then the equilibrium p^*_{old} is such that there exists a $\bar{\mu} > 0$ such that airlines with $\mu < \bar{\mu}$ choose the* *old technology, and airlines with $\mu > \bar{\mu}$ choose the new technology.*

Proof. *The proof is a direct consequence of Proposition 1. See Appendix.*

The intuition behind Proposition 2 is straightforward. All else equal, as the price of old technology, p_{old}, decreases, $V_{old}(\mu, p_{old})$ increases compared to $V_{new}(\mu)$. Old technology therefore becomes more attractive, and a larger fraction of airlines select it. (Figure 5 provides a graphical representation for three different values of p_{old}.) The price of old technology simply decreases to the point where the demand for old technology equals the supply. Further, from Proposition 1, we know that at the equilibrium price p^*_{old} it is the low μ firms which are the ones who choose the old technology while the high μ firms choose the new technology.

We next characterize the size of airlines' fleets as measured by their number of aircraft.

Proposition 3. *There exist μ^* and μ^{**} such that fleet sizes of airlines with $\mu \leq \mu^*$ are smaller than the fleet sizes of airlines with $\mu \geq \mu^{**}$*

Proof. *See Appendix.*

As is intuitive, Proposition 3 states that airlines operating in low μ countries are financially constrained, so that their fleet sizes are restricted. In contrast, those operating in relatively high μ countries will not be constrained, and indeed their fleet sizes will be equal to the unconstrained level. It should be noted that fleet sizes will not be monotonically increasing in μ, as at the μ where airlines switch from old to new technologies, their fleet size may discontinuously drop simply because the price of new aircraft is larger than that of old aircraft in equilibrium.

As a final step, we relax the assumption that airlines must fund all of their fleet acquisition employing external finance. We prove the following proposition:

Proposition 4. *For any level of internal capital A, there exists a $\mu(A)$, such that any airline with internal capital A operating in a country with investor protection $\mu > \mu(A)$ acquires the unconstrained new-technology fleet. Further, $\mu(A)$ is decreasing in A.*

Proof. *See Appendix.*

Proposition 4 states that all else equal, in equilibrium, firms with higher internal capital will be more likely to invest in the unconstrained size, new technology fleet, regardless of their country's level of investor protection. This is simply because they can rely more on internal funds to finance their acquisitions, and are hence less dependant on the external legal environment.

¿From Propositions 2 through 4 we generate the following three predictions which are tested in the empirical section:

Prediction 1: *All else equal, airlines operating in countries with lower investor protection will have older vintage fleets.*

Prediction 2: *All else equal, airlines operating in low investor protection countries will have smaller fleets than those operating in high investor protection countries.*

Prediction 3: *The effect of the level of investor protection on airline fleet vintage and size will be smaller for airlines with greater internal funds.*

II. Data and Summary Statistics

This section describes the data sources used in the empirical analysis and presents summary statistics for both aircraft age and fleet size.

A. Aircraft Level Data

Throughout our analysis we utilize data from the Ascend CASE database – a leading provider of individual aircraft and airline data which contains ownership and operating information about all commercial and corporate aircraft worldwide as well as many military and government aircraft. We construct a sample of all aircraft that are available in the database for the 129 countries that are included in Djankov at al. (2007). Our sample consists of all aircraft worldwide over the period January 1, 1978 to December 31, 2003 from Ascend CASE database.[6] The data are very detailed with regard to the individual aircraft and include information on aircraft characteristics such as model-type, serial number, year of construction, operating airline, and owner. In addition to data on aircraft's current operator and owner (the operator is different from the owner for leased aircrafts), Ascend CASE includes information on past owners and users of each aircraft. This enables us to uniquely identify, track and follow most of the aircrafts in the world during the time period studied in the paper.

For each aircraft in the sample, we construct two measures of aircraft vintage, which are then related to the creditor rights scores described below. The first measure is aircraft age, defined in

[6] Benmelech and Bergman (2007a, 2007b) provide an extensive description of the Ascend CASE database.

each year as the time elapsed from the year of the aircraft's initial delivery. The second measure of vintage, which we name 'technological age' is defined as the time elapsed from the year in which the aircraft's *model type* was first introduced. This second measure proxies for the age of the technology that is embodied in the aircraft. The Ascend CASE database defines two aircraft-type classification – *narrow* and *broad*. We thus define two variants of technological age corresponding to the two aircraft type classification. To fix ideas consider the following example: aircraft N368AA, built in 1991, and delivered on December, 5, 1991 to American Airlines is a Boeing 767-300ER. In this case, the broad classification is B767 which was first introduced in 1981. This particular variant of B767 (i.e. 300ER) was first introduced in 1986. Thus, as of the year 2008, the aircraft's age is 17 years, its technological age using the broad classification is 27 years, and its technological age using the narrow definition is 22 years.

Panel A of Table 1 displays summary statistics of aircraft age for 4 sub-periods (1978-1979, 1980-1989, 1990-1999, and 2000-2003), and for the entire sample. There are 494,653 aircraft-year observations in the entire sample, with an average (median) age of 13.0 (12.0) years, and a standard deviation of 9.2 years. The sample represents 219 aircraft types, 5,987 operators from 129 countries. As Panel A demonstrates the average aircraft age in the sample increased from 9.1 in the years 1978-1979 to 14.7 in the years 2000-2003, representing an overall aging of aircraft fleets around the world. Our sample covers 89 countries in the 1978-1979 sub-sample, 102 countries in the 1980-1989 sub-sample, and 129 countries onward, as information on creditor rights of post-socialists countries become available between 1989 and the mid 1990s.

In the last two columns of Panel A we split our sample into aircraft operated by commercial and private airlines (Commercial), and those operated by the military and government agencies (Military). The distinction between commercial and military aircraft plays an important role later in the analysis as we expect the negative relation between aircraft age and fleet size and creditor protection to hold only for non-military operators, since military operators would not fall under the bankruptcy provisions of local corporate and bankruptcy laws. There are 373,261 commercial aircraft and 121,392 that are classified as military aircraft in the sample. The commercial sample represents 161 aircraft types, 5,437 operators from 129 countries, while the military sample represents 200 aircraft types, 893 operators from 115 countries. Further, as can be seen in Panel A of the table, military aircraft are older than commercial aircraft; the average age of a commercial aircraft is 12.0 years compared to 16.0 years for military aircraft (p-value for an equal means t-test=0.000).

Panel B of Table 1 presents summary statistics for broad and narrow (in parentheses) technological age. The mean broad (narrow) technological age of the entire sample is 21.9 (18.2). As Panel B demonstrates the average broad technological age in the sample increased from 16.1 in the years 1978-1979 to 24.2 in the years 2000-2003. As in Panel A, we split our sample into commercial and military aircraft in the last two columns of Panel B. Military aircraft embody older technology than commercial aircraft; the average broad technological age of a commercial aircraft is 20.2 years compared to 27.0 years for military aircraft (p-value for an equal means t-test=0.000).

B. Country Level Data

The information in Ascend CASE also enables us to match data on each individual aircraft to country level macro and legal variables of the aircraft's country of operator and owner. We thus augment the data from Ascend CASE with country level macro data from the World Bank's World Development Indicators database. This macro data includes GDP, GDP growth, GDP per capita, GDP per capital growth as well as surface (country area in sq km.) and population data. We obtain data on legal origins and creditor rights from the new database assembled by Djankov et al. (2007) that covers 129 countries in the period 1978-2003. This new data is a major improvement upon the La Porta et al. (1997, 1998) data, as it covers many more countries, and tracks their variation in creditor rights score over time. It therefore enables a panel-data analysis using, for example country fixed effects, which identifies off of variation in creditor rights within a country over time.

For each country, the creditor rights index measures four powers of secured lenders in bankruptcy.[7] First, whether there are restrictions on bankruptcy filing; second, whether there is no 'automatic stay' or 'asset freeze' that prevents secured creditors from seizing their collateral. Third, whether secured creditors are paid first, and finally, whether a trustee different from the management runs the firm during reorganization. A value of one is assigned to each of the provisions when a country's law provides these powers to secured creditors. The creditor rights index is then calculated by aggregating the scores of the four provisions, so that the creditor rights index varies between a score of 0 (poor creditor rights) and a score of 4 (strong creditor rights). Djankov et. al. (2007) collect time series data on creditor rights for each of the 129 countries, by identifying all major reforms and assessing their impact on the creditor rights score.

[7]See Djankov et. al. (2007) for a comprehensive description of the index and its construction.

Panel C of Table 1 reports summary statistics of the creditor rights index, GDP per capita, and legal origin. The mean (median) creditor rights in the sample is 1.65 (1.0) and the standard deviation is 1.01. The sample includes 279,031 aircraft from countries with English legal origin, 108,415 from countries with French legal origin, 51,865 from Socialist legal origin, 47,580 from German legal origin, and 7,762 aircraft are from countries with a Nordic legal origin. Table 2 lists the top 20 countries with the most aircraft-year observations in the sample, and the bottom 20 countries with the least aircraft-year observations. With a total of 185,476 observations, the U.S. accounts for 37.50% of the sample, followed by the Russian Federation (38,519 aircraft), U.K. (20,077 aircraft), and Canada (18,500 aircraft). The countries with the least observations in the data are Bosnia and Herzegovina (44 aircraft), Albania (49 aircraft), Togo (62 aircraft), and Niger (66 aircraft).

C. Airline Level Data

Finally, we match aircraft information to airline financial data where available. Information on airline financial data is obtained from Compustat Global. We collect all firms in SIC codes 4500-4580 and manually match them to the aircraft level data from Ascend CASE. We also supplement the information with data from Compustat North America for U.S. airlines. After matching Ascend CASE to Compustat Global and Compustat North America and restricting the sample to the countries covered by Djankov et al. (2007), we are left with a subsample of 72 airlines from 29 countries, representing a panel of 94,272 aircraft-year observations.

III. Aircraft Vintage and Usage

An underlying assumption throughout our study is that assets of an older vintage are either less technologically advanced and hence less efficient, or that older vintage aircraft are less efficient due to physical depreciation. We therefore begin our empirical analysis with motivational evidence testing this assumption in the context of aircraft. Measuring individual aircraft efficiency requires information on inputs (number of seats, men hour, fuel costs, operating times, routes, etc.) and outputs (number of passengers, revenue, arrival times). We cannot measure aircraft efficiency directly as we do not have access to these data at such a fine resolution as an individual aircraft. Instead, we utilize data from the Ascend Case database on aircraft usage as an approximation of aircraft efficiency. Spanning the period 1996-2006, the data provides hourly utilization rates for

25,009 aircraft worldwide. For each aircraft in the sample, the data tallies the number of hours flown each year, as well as the aircraft type and year of build.

We hypothesize that if aircraft efficiency is indeed decreasing with aircraft vintage, airlines will tend to decrease the operating times of their older vintage aircraft. Thus, for example, if older vintage aircraft are less fuel-efficient, to the extent possible, airlines will shift their operations to the newer vintage aircraft in their fleet. Moreover, older aircraft require more maintenance and engines overhauls that would ground older aircraft for longer periods of time compared to newer ones.

Table 3 reports the results from estimating the relation between annual hourly usage and both aircraft age and aircraft technological age for all aircraft with non-zero usage.[8] For each aircraft-year pair, we calculate the age of an aircraft as the time that elapsed from its year of build and the aircraft's technological age as the time elapsed from the year in which the aircraft's model type was first introduced. All specifications include year fixed effects to account for temporal variation in average aircraft usage.

As can be seen from the table, the coefficient on aircraft age is consistently negative and is statistically significant at the 1% level whether we cluster the standard errors by aircraft-type or at the individual aircraft level. Thus, consistent with our underlying assumption that older vintage aircraft are less efficient, we find that aircraft usage declines with age. This result is robust to the addition of both aircraft type and aircraft fixed effects. The economic magnitude of this effect is significant: a one-standard-deviation increase in aircraft age of 8.62 years decreases aircraft yearly usage by approximately 450 hours, representing an 18 percent decline relative to the sample mean hourly usage of 2,466 hours. Similarly, aircraft technological age is negatively related to annual hourly usage, with a one standard deviation increase in technological age reducing annual usage by 312 hours.[9]

Figures 6 provides a graphical representation of this monotonic relation between age and usage.

[8]Since aircraft may drop out of the sample when they are retired from active service, we analyze the relation between usage and age only for aircraft that have been utilized during the year. Thus, we analyze the intensive, rather than extensive, margin, and as such our results can be viewed as a lower bound on the relation between age and utilization.

[9]When using technological age as a dependent variable, we do not employ aircraft-type fixed effects since this regression would not be well identified – for any given year, all aircraft of the same type have equal technological age. Adding aircraft-type fixed effects is thus equivalent to identifying off of a simple linear time trend. Further, we do not report technological age results with aircraft fixed effects, as clearly, the coefficient on technological age in this specification is identical to that on age in the specification with aircraft fixed effects (Columns 3 and 4).

To construct the figures we regress yearly aircraft usage on the set of indicator variables defined for each possible value of aircraft age, while including year and aircraft-type fixed effects as well. The figure graphs the coefficients on the age indicator-variables along with their 95 percent confidence interval calculated by clustering at the aircraft-type level.[10] The graph thus illustrates the evolution of aircraft usage with aircraft age. As can be seen from the figure, consistent with our assumption that aircraft efficiency improves over time, aircraft usage declines with aircraft age.

IV. Creditors Rights and Aircraft Vintage

A. Baseline Results

Our simple model shows that the effects of financial constraints should be exacerbated in countries with poor creditor rights, where the availability of debt capital may be limited and its cost much higher. We therefore predict that airlines that operate in countries with poorer investor protection operate older vintage aircraft with older technologies.

To test this prediction, we calculate the age and the technological age (using both the narrow and broad measures described above) of every aircraft in the 129 countries that are in our sample during the period 1978-2003. We then run the following specification:

$$Vintage_{iact} = Creditor\, rights_{ct} + \mathbf{X}_{ct} + \mathbf{y}_t + \mathbf{z}_{ac} + \epsilon_{iact}, \quad (5)$$

where the dependent variable, Vintage$_{iact}$, is either the age or the technological age of aircraft i operated by operator a in country c in year t. Creditor rights is the creditor rights score of country c in year t, as measured by Djankov, et al. (2007). $\mathbf{X}_c$ is a vector of country-specific control variables which includes the logarithm of country c's GDP per capita, the logarithm of its population and the logarithm of its area. In addition, in all specifications that do not include country fixed effects we include as control variables a set of indicator variables indicating the legal origin of the country – common law, French, German, Nordic, or Socialist.[11] Finally, all regressions include year fixed effects, $\mathbf{y}_t$, and depending on the specification may also include country and operator fixed effects represented by the vector of variables $\mathbf{z}$. Since aircraft operators maintain their affiliation with the country of operation throughout the sample, country and operator fixed effects are always

[10] The indicator variable for age equaling one is omitted, so that all coefficients are calculated in relation to the usage of aircraft of age one.

[11] Country fixed effects naturally preclude using legal origin controls as there is no time series variation in legal origin in our sample period. For brevity of exposition, tables do not exhibit the coefficients on the legal origin dummy variables.

applied separately in each specification. All regressions are estimated with heteroscedasticity robust standard errors which are clustered by country. In our data, standard errors that are clustered by country are tenfold larger than simple robust standard errors. Thus, when we do not cluster we get a t-statistic on creditor rights that is between 19.0 and 26.8. Since our variable of interest is creditor rights which is determined at the country level, we use the higher hurdle of clustering by country. The magnitudes of the differences between the standard errors when we cluster compared to simple robust standard errors are consistent with Kloek (1981) who show that clustered standard errors are proportional to the squared root of the clusters number which is $\sqrt{129} = 11.4$ in our sample.

Table 4 provides results of regression (5) over the entire sample. As hypothesized, we find that enhanced creditor rights are consistently negatively associated with both aircraft age as well as aircraft technological age. As the first column of Table 4 demonstrates, with year fixed effects, increasing a country's creditor rights score from 0 to 4, reduces the age of aircraft by 1.8 years, or 13.9% of the mean aircraft age of 12.95 years. Adding either country or operator fixed effects (representing the 129 countries in the sample and 5,987 different operators) increases the magnitude of the negative impact of creditor rights on fleet aircraft age. With these fixed effects, a movement from a creditor rights score of 0 to a score of 4 reduces aircraft age by between 3.7 and 4.4 years, representing an approximately 30% reduction in the sample mean aircraft age.

Columns 4 to 6 of Table 4 show that enhanced creditor rights is also negatively related to aircraft technological age constructed using the broad aircraft classification scheme. This result holds when using year, country and operator fixed effects. The impact of creditor rights is economically large: moving the creditor rights score from 0 to 4 reduces average technological age of aircraft in an airline's fleet by between 1.6 and 3.7 years representing between 7.2 and 16.8 percent of the average technological age.[12] Finally, as columns 7-9 show, repeating the analysis using technological age defined at the narrow classification scheme yields similar results. In sum, consistent with our prediction, aircraft are younger and embody newer technology in countries with better creditor rights, controlling for GDP per capita, population, area and a battery of fixed-effects at the operator, country and year level.

While, as is usually the case, in cross-country analysis the main empirical challenge is endogene-

[12] As in columns 1 to 3, the magnitude of the effect is larger when either operator or country fixed effects are included.

ity, we utilize the panel nature of our data and the changes in creditor rights over time to overcome an omitted variables problem. By including country and operator fixed effects, we control for unobserved heterogeneity of operators and countries. In these specifications we identify off of changes in creditor rights over time within a country. Indeed, we find that in specifications which include country fixed effects, the negative association between creditor rights and age is the largest which is consistent with a large effect of changes in creditor rights within a country.

The negative relation between creditor rights and both aircraft age and aircraft technological age illustrates how improved investor protection and its associated reduction in financial frictions affects firm investment policy and ultimately real outcomes. The ability to raise external finance is an important determinant of firm's capacity to invest in newer technologies. Since technological improvement is a key driver of economic growth, this relation between creditor rights and technology adoption points to a channel through which investor protection affects real economic growth as found in prior work by Beck et al. (2000) and Rajan and Zingales (1998).

B. Commercial vs. Military Aircrafts

In Table 5, for every country, we divide our sample into aircraft operated by commercial airlines and private operators, and those operated by militaries, armed forces and government agencies. For example, as of December 31, 2003 there are ten U.S. federal agencies or military operators in our sample: Federal Aviation Administration, NASA, US Air Force, US Air National Guard, US Army, US Army National Guard, US Coast Guard, US Customs Service, US Marine Corps, and the US Navy. Likewise, as of December 31, 2003, there are four military operators and one government agency in the Islamic Republic of Iran: Iran National Cartographic Center, Iranian Air Force, Iranian Army, Iranian Navy, and the Iranian Revolutionary Guard.

We expect the negative relation between aircraft age and creditor protection to be concentrated in commercial and private aircraft operators, since these are the firms which would be required to raise funds from external investors in cases of financial shortfalls. In addition, commercial and private firms would fall under the bankruptcy provisions of the local corporate bankruptcy laws which are the essence of the creditor protection score. In contrast, government agencies, militaries and other armed forces obtain funding from their governments that are in turn subject to international law. However, when sovereign governments default on their debt creditors cannot seize the country's assets. Although lenders can potentially grab commercial or military and government-owned aircraft, this strategy is not very useful except as a strategy of harassment (Shleifer 2003). Instead, creditors litigate with their sovereign borrowers using international law. Sovereign borrowers are induced to settle with their creditors as they want to borrow again in the future (Bulow and Rogoff (1989a,b)). In summary, corporate and bankruptcy law do not apply to aircraft operated by militaries, armed forces and government agencies.

As an example of relations between a creditor and a soverign debtor, in June 2006, two Russian military jets - the Su-30MKK multirole fighter and the MiG-AT advanced trainer - were forced to leave the Le Bourget airshow following an attempt by French authorities to seize the two aircraft. The attempted seizure was based on a French court decision in a law suit against the Russian Federation by the Swiss hotel company Noga owned by Swiss Financier Nessim Gaon. The Russian delegation at Le Bourget was warned in advance by the airshow officials of a possible attempt to seize the two planes, which were promptly towed to a secure area at the airport to which civilians had no access. The planes were then given permission to leave and provided an air corridor to Russia by the French aviation authorities. As a response to the actions by the French authorities in Le Bourget, Russian and Ukrainian delegations canceled all planned flight programs, which included the much anticipated performance by the An-225 Mriya - the world's largest aircraft.

To formally test the hypothesis that the negative relation between aircraft age and creditor protection will be concentrated in commercial and private aircraft operators, Table 5 reports the results of running regression 5 separately for commercial aircraft and aircraft operated by militaries and other government agencies.[13] The dependent variable is aircraft age. Consistent with the results in Table 4, in all specifications, the age of commercial aircraft is statistically negatively related to creditor rights with a similar economic impact found in Table 4, while the age of military aircraft is unrelated to the creditor rights score in a statistically significant manner. Table 6 repeats the analysis, separating the sample into commercial aircraft and aircraft operated by militaries and other government agencies, but this time using aircraft technological age as the dependant variable. Again, we find that while aircraft technological age, defined using either the narrow or broad classification, is negatively related to creditor rights in the subsample of commercial aircraft, there is no statistically significant relation between the technological age of military aircraft and country creditor rights scores. Interestingly, while not statistically significant, we find that in the

[13]This specification is identical to running one regressions with all the explanatory variables interacted with a military dummy. We prefer to report the results separately for commercial and military aircraft as the exposition is clearer.

subsample of military aircraft, the coefficients on creditor right scores are actually positive.

C. Creditor Rights and Aircraft Leasing

In the analysis above, we do not distinguish between airlines that lease aircraft instead of purchasing them through debt financing.[14] Eisfeldt and Rampini (2007a) show that, in the U.S., since the repossession of leased assets is easier than foreclosure on collateral of secured debt, lease financing should have higher debt capacity than secured debt. Put differently, lease financing aids firms to circumvent some of the financial frictions associated with debt financing. To the extent that this result generalizes to other countries outside the U.S. – e.g. because the title to the asset remains with the lessor but is not in the possession of a secured creditor – we would expect airlines operating in countries with bad creditor rights to be more likely to use lease financing. Thus, airlines in countries with poor creditor rights may be forced to lease aircraft instead of purchasing them through debt financing, since asset repossession might be easier for lessors who maintain the title to their aircraft. Further, if leasing reduces financial frictions, then this argument would also suggest that the results found in Tables 4 - 6 showing that creditor rights is negatively related to aircraft vintage should be concentrated amongst non-leased aircraft.

As a test providing support for these conjectures, we first run a probit regression on the sample of all commercial aircraft, relating a country's creditor rights score to the likelihood of an individual aircraft being leased, as opposed to being owned by an airline. We find that

$$Pr(Aicraft\,leased = 1) = \Phi(-0.029 * Creditor\,Rights_{ct} + \mathbf{X}_{ct} + \mathbf{y}_t), \tag{6}$$

where $\Phi(\cdot)$ is the standard normal cumulative distribution function, Creditor rights is the creditor rights score of country c in year t as measured by Djankov et al. (2007), $\mathbf{X}_c$ is the vector of control variables used in regression 5, and $\mathbf{y}_t$ is a vector of year fixed effects. The point estimate of -0.029 (p-value=0.005) implies that airlines in countries with poor creditor rights are indeed more likely to lease their aircraft. This effect is economically significant: moving from a creditor rights score of 4 to a creditor rights score of 0 increases the likelihood that an aircraft will be leased by 11.6 percentage points, representing an increase of 27.2 percent relative to the unconditional mean. Thus, the data do indeed suggest that airlines operating in countries with low creditor protection are more likely to resort to lease financing.

[14] Lease financing of aircraft is fairly common, particularly in the United States (See e.g. Benmelech and Bergman 2007 and Gavazza 2007).

To test the second conjecture, that since lease financing reduces financial frictions the negative relation between creditor rights and aircraft vintage should be concentrated amongst non-leased aircraft, we repeat the analysis in regression 5 separately for both leased and non-leased aircraft.[15] Results are reported in Table 7.

Consistent with our conjecture, we find that the negative relation between aircraft vintage and country creditor rights is indeed concentrated amongst owned, rather than leased, aircraft. Amongst owned aircraft, increased creditor rights is associated with younger aircraft vintage – with a zero to 4 movement in creditor rights associated with a reduction of between 4 and 2.65 years in aircraft vintage. In contrast, in the leased aircraft subsample, in all of the specifications the coefficient on creditor rights is not statistically different from zero.

Another benefit to examining the effect of creditor right on leased and non-leased aircraft separately is that it alleviates the concern that variation in investment opportunities correlated with variation in creditor rights is driving our results. While this concern is partly addressed by our battery of operator and country fixed effects specifications, to the extent that time series variation in creditor rights is correlated with investment opportunities – for example because bankruptcy reform may be enacted simultaneously with other economic reforms (see e.g. Acharya and Subramanian, 2007) – we cannot completely rule out variation in investment opportunities, rather than variation in financial frictions, driving decisions regarding the vintage of employed capital. However, the fact that the negative relation between creditor rights on aircraft vintage is concentrated amongst non-leased aircraft alleviates this concern (especially when we also control for operator fixed-effects in these regressions), since there is little reason to suspect that increased investment opportunities should differentially impact the vintage of leased as compared to non-leased aircraft. In contrast, the financing channel discussed above provides a clear prediction regarding the differential impact of creditor rights on the two methods of aircraft financing.

D. Government Ownership and Aircraft Vintage

As an additional test of the financing channel, we further hypothesize that commercial airlines with government ownership can utilize the government as a source of capital to ease financing constraints. Thus, commercial airlines wholly or partially owned by the government probably have

[15] As before, this specification is isomorphic to running one regressions with all the explanatory variables interacted with a leasing dummy. We have confirmed that results hold in both specifications.

a 'soft' budget constraint and as a result should have fleets of younger vintage. Furthermore, governments may be willing to invest more in new aircraft in their 'flag carriers' as they represent the country internationally. If our creditor rights measure is correlated with government ownership then our analysis may be capturing government ownership and not legal protection for creditors. We construct a dummy variable taking on the value of 1 for airlines with some government ownership as of January 2003 (for which we have the data) and zero otherwise. We then run a cross sectional regression for all commercial aircraft in 2003, regressing aircraft vintage on country creditor rights scores, the government ownership dummy variable, and our standard set of controls from regression 5. As in Table 7, the sample is divided into leased and non-leased aircraft. The results are presented in Table 8. First, as can be seen, as hypothesized, and consistent with a financing channel for vintage capital, government ownership is negatively related to aircraft vintage, suggesting that governments do indeed relieve some of the financial constraints of the airlines which they own. Moreover, even after controlling for government ownership, creditor rights is negatively related to both aircraft age and technological age of non-leased aircraft. The coefficients of creditor rights in the different specifications (between -0.799 and -1.390) are higher than those found in the panel data regressions. Interestingly, we also find that the effect of government ownership on aircraft vintage is symmetric between leased and non-leased aircraft, as evidenced by the equal magnitude of the coefficients on the government dummy variable across the specifications. Thus, again our results are not likely to be driven by omitted investment opportunities.

E. Creditor Rights, Financial Constraints and Aircraft Vintage

We now turn to analyze the effect of creditor rights on aircraft age conditional on the financial condition of the operator. According to prediction 3 of our model and consistent with Eisfeldt and Rampini (2007b) we expect the effect of creditor rights on aircraft age to be larger for more financially constrained airlines. Since airlines with greater internal funds are less likely to rely on external financing, they should be less affected by the legal system or local financial development.

Similar to the previous section, testing prediction 3 alleviates the concern that creditor rights are positively correlated with unobserved investment opportunities, and that it this correlation is what drives the negative relation between creditor rights and aircraft vintage. This is because there is little reason to suspect that increases in creditor rights are more strongly correlated with improved investment opportunities in financially constrained firms as compared to financially unconstrained firms.

To test prediction 3, we obtain information on airline financial data from Compustat Global. Because theoretically and empirically the effect of creditor rights should be and indeed is concentrated on non-leased aircraft, we focus our analysis on the non-leased subsample of aircraft. We are able to match 67 airlines from 29 countries to the countries covered by Djankov et al. (2007), representing a panel of 49,496 non-military aircraft. We then employ in our regression specification interaction terms between the country's creditor rights index and airline-level measures of financial distress. Our approach is similar to Rajan and Zingales (1998) who identify the effects of financial development on growth using interaction terms between financial development (at the country level) and financial dependence (at the industry level). Our analysis focuses on two measures of financial constraints: leverage and long-term debt, both used by Eisfeldt and Rampimi (2007b) which were found empirically to be determinants of used capital investment. We obtain similar results using other measures such as profitability. We estimate the following regression:

$$\begin{aligned} Vintage_{iact} &= Creditor\,rights_{ct} + FinConst_{act} + Creditor\,rights_{ct} \times FinConst_{act} \\ &+ \mathbf{X}_c + \mathbf{y}_t + \mathbf{z}_{ac} + \epsilon_{iact} \end{aligned} \tag{7}$$

As in regression 5, $Vintage_{iact}$ is either the age or the technological age of aircraft i operated by operator a in country c in year t. Creditor rights is the creditor rights score of country c in year t, as measured by Djankov et al. (2007), $FinConst_{act}$ is a measure of the airline financial constraints (either leverage defined as total debt divided by the book value of assets, or long-term debt defined as long-term debt divided by the book value of assets), $Creditor\,rights_{ct} \times FinConst_{act}$ is an interaction term between creditor rights and airline financial constraints, $\mathbf{X}_c$ is a vector of country-specific control variables which includes the logarithm of country c's GDP per capita, the logarithm of its population and the logarithm of its area. In addition, as in regression 5, in specifications that do not include country or operator fixed effects, we include as control variables a set of indicator variables indicating the legal origin of the country (not reported for brevity). Finally, all regressions include year fixed effects, $\mathbf{y}_t$, and depending on the specification may also include country or operator fixed effects represented by the vector of variables $\mathbf{z}$. All regression are estimated with heteroscedasticity robust standard errors clustered by country. Results using aircraft age as the dependent variable are presented in Table 9, while results using aircraft technological age as the dependent variable are provided in Table 10.

As can be seen in Table 9, consistent with prediction 3, the interaction term between creditor rights and leverage (columns 1-3), and the interaction term between creditor rights and long-term debt (columns 4-6) are negative, indicating that the effect of creditor rights on aircraft age is indeed concentrated in financially constrained airlines. While both leverage and long-term debt are clearly endogenous, our identification strategy in Table 9 relies on the interaction between country and firm characteristics. By focusing on interaction effects we reduce the number of potential alternative explanations for our findings. Moreover, in order to control for unobserved operator heterogeneity we include operator fixed effects in several of our specifications and find both statistically and economically significant results. Focusing on the third column of Table 9, we find that reducing a countrys level of investor protection from a creditor-rights score of 4 to a creditor rights score of 0, increases the average age of aircraft operated by airlines in the 25th percentile of leverage by 0.41 years. In contrast, for airlines in the 75th leverage percentile, i.e. those that are arguably more financially constrained, we find that reducing creditor rights from a score of 4 to a score of 0 increases average age by more than four times as much – 1.83 years , representing a 14 percent increase compared to the sample wide average of aircraft age.

For robustness, we repeat the analysis in columns seven and eight of Table 9 using a probit regression specification with a dependent indicator variable that takes on the value of one when an aircrafts age is greater than 30 years and zero otherwise (marginal effects are reported). All independent variables are identical to those used in the OLS specification in regression 7, and the specification is run using year fixed effects. As can be seen, we find that the interaction terms between creditor rights and our two measures of financial constraints, leverage and long-term debt, are once again negative. Thus, consistent with prediction 3 of the model, there are more old planes in countries with low creditor protection, especially amongst firms with high leverage or long-term debt ratios. The economic significance is also large: calculated at the 25th percentile of firm leverage, increasing a countrys level of creditor rights from a score of 0 to a score of 4 reduces the likelihood that firms operating in this country will operate old aircraft, as proxied by having an age greater than 30, by an insignificant 0.4 percentage points. In contrast, when calculated at the 75th percentile of leverage, the same movement in creditor rights reduces the likelihood that a firm will operate old aircraft by 4 percentage points, representing a decrease of 86.9 percent relative to the unconditional mean.

In Table 10 we repeat the analysis, this time using the two measures of aircraft technological age (broad and narrow) rather than aircraft age. We report the results with year and country fixed-effects. We obtain similar qualitative results but statistically weaker results when we include operator fixed-effects. As can be seen from the table, while the results are somewhat weaker than in Table 9, we find again that the interaction coefficients between our measures of financial constraints – leverage and long-term debt – and the creditor rights score are negative, indicating that consistent with prediction 3, the negative effect of creditor rights on aircraft technological age is concentrated in firms with poor financial conditions. As in Table 9, for robustness we repeat the analysis using a probit specification with a dependent variable which equals one when an aircraft's technological age is greater than 30 (columns 7 and 8). Again, we find that the interaction coefficients between creditor rights and both leverage and long-term debt are negative, consistent with prediction 3. Thus, planes in countries with low creditor rights are more likely to be technologically old, and further, this effect is concentrated amongst airlines with high leverage or long-term debt. For example, while at the 25th percentile of firm long-term debt, increasing a country's creditor rights score from zero to 4 reduces the likelihood that firms operating in this country will use technologically old aircraft by 0.34 percentage points, the same movement calculated at the 75th percentile of long-term debt reduces this likelihood by 3.7 percentage points, representing a decrease of 80 percent relative to the unconditional mean.

F. Creditor Rights and Fleet Size

We now analyze the relation between creditor rights and fleet size. According to Prediction 2 of the model, firms operating in countries with better creditor rights should operate larger fleets on average. This is because operator scale will not be constrained by the availability and cost of external finance. This prediction is broadly consistent with the empirical findings in Kumar, Rajan, and Zingales (2002) who find that the average firm size is larger in countries with better institutional development.

In order to test this prediction we need a measure of fleet size. Measuring fleet size, however, is somewhat complicated by the fact that airline fleets include multiple aircraft types of different size and use. Thus, a measure of fleet size must weigh aircraft of different variety in an appropriate manner. For example, a passenger capacity measure such as the number of seats will not capture the size of cargo aircraft. Rather than committing to one particular weight system, we test Prediction 2 using a number of weighing schemes. To do so, for each aircraft type in our sample, we gather information on that aircraft type's maximal seat capacity, its maximal takeoff weight, and the aircraft type's wingspan. This data is gathered from Singfield (2005) as well as from a variety of Internet sources. Based on this information, for each operator and year in our sample, we then construct four measures of fleet size. The first is simply an equal-weighted sum of all aircraft operated. The remaining three measures of fleet size weigh each aircraft in the fleet using one of three weights described above. Thus, these measures are: (1) the sum of the seat capacities of all aircraft in the fleet, (2) the sum of the maximal takeoff weight of all aircraft in the fleet, and (3) the sum of the wingspans of all aircraft in the fleet.

Having constructed these four fleet-size measures, we then run the following regression specification for all operator fleets in our sample period of 1978-2003:

$$log(Size_{act}) = Creditor\, rights_{ct} + \mathbf{X}_{ct} + \mathbf{y}_t + \mathbf{z}_a, \tag{8}$$

The dependant variable, log(Size$_{act}$), is the logarithm of each of our four fleet-size measures for operator a in country c in year t. As usual, Creditor rights is the creditor rights score of country c in year t, and $\mathbf{X}_c$ is a vector of country-specific control variables which includes the logarithm of country cs GDP per capita, the logarithm of its population and the logarithm of its area. All regressions include year fixed effects, $\mathbf{y}_t$, and operator fixed effects represented by the vector of variables $\mathbf{z}_a$. The regressions are estimated with heteroscedasticity robust standard errors clustered by country. Finally, as in the case of aircraft age, regression 8 is estimated separately for commercial operators and military operators.

The results are provided in Table 11. As our results demonstrate, using all four fleet-size proxies, the coefficient on the creditor rights index is consistently positive and statistically significant in the commercial operators regressions after controlling for GDP per capita, population, area, as well as year and operator fixed effects. In contrast to commercial operators, and consistent with our previous results, there is no robust relation between creditor rights and fleet size of military operators. None of the creditor rights coefficients are statistically different from zero in any of the military operators regressions, and the point estimates in these regressions are always lower than their commercial regressions counterparts (they are actually negative in 2 out of 4 regressions). Thus, consistent with prediction 2 of the model, airlines in countries with higher creditor rights do indeed operate larger fleets. Given that we run a semi-log specification with respect to creditor rights, the coefficient of creditor rights is equal to the percentage change in fleet size associated with a unit change in creditor rights ($dlog(Size)_{act}/dCR_{ct}$). This effect is economically significant. For example, moving from the lowest creditor rights score of zero, to the highest score of four, increases the number of aircraft in a commercial airline's fleet by 26.8 percent. Moving from the lowest to the highest score of creditor rights increases total fleet seat capacity by 80 percent. The effect for the remaining two fleet size measures – total fleet maximal takeoff weight and total fleet wingspan – is 71.2 and 64.4 percent, respectively. As an aside, the fact that the effect of increased creditor protection on fleet size is smaller for the non-weighted number-of-aircraft fleet measure than when weighing fleet size by aircraft seat capacity, maximal takeoff weight, and wingspan, suggests that the increase in the number of aircraft due to enhanced investor protection concentrates amongst larger, and hence more expensive, planes.

Finally, we study the relation between fleet size and creditor rights conditional on the financial constraints that an airline is facing using our sample of 72 airlines. For each of the airlines in the data we calculate our 4 measures of fleet size and run the following regression specification:

$$\begin{aligned} log(Size_{act}) &= Creditor\,rights_{ct} + FinConst_{act} + Creditor\,rights_{ct} \times FinConst_{act} \\ &+ \mathbf{X}_c + \mathbf{y}_t + \mathbf{z}_a + \epsilon_{iact} \end{aligned} \tag{9}$$

The dependant variable, log(Size$_{act}$), is the logarithm of each of our four fleet-size measures for operator a in country c in year t. Creditor rights is the creditor rights score of country c in year t, $FinConst_{act}$ is a measure of the airline financial constraints (either leverage defined as total debt divided by the book value of assets, or long-term debt defined as long-term debt divided by the book value of assets), $Creditor\,rights_{ct} \times FinConst_{act}$ is an interaction term between creditor rights and airline financial constraints, $\mathbf{X}_c$ is a vector of country-specific control variables which includes the logarithm of country c's GDP per capita, the logarithm of its population and the logarithm of its area. In addition, all regressions include year fixed effects, $\mathbf{y}_t$, and operator fixed effects represented by the vector of variables $\mathbf{z}_a$. All regression are estimated with robust standard errors that are clustered by country. Results are provided in Table 12. We find no evidence that creditor rights affect airlines size in a statistically significant manner or that financially constrained airlines benefit more from creditor rights. We believe that the lack of results in Table 12 stem from the fact that by studying airlines with publicly available financial data, we are focusing on the largest airlines in each of the 29 countries we cover, and thus a selection bias with respect to size works against our finding any relation between creditor rights, financial constraints and airline size. Alternatively, this result could be driven by the positive relation between leverage and fleet size which arises when airlines use debt to purchase additional aircraft.

V. Conclusion

Most of the evidence that legal protection of investors is associated with more developed financial markets and faster economic growth is based on cross-country outcomes and suffers from small sample and other econometric issues. In particular, results from cross-country regressions do not identify the channel through which legal protection affects real economic outcomes. Our paper adds to the growing body of micro-level evidence that suggests that financial development facilitates growth

We provide novel evidence linking creditor rights and vintage capital using a panel of aircraft-level data around the world. Consistent with theories that emphasize the protection of property rights as essential for economic development, we find that better creditor rights are associated with aircraft of a younger vintage and firms with larger aircraft fleets. Moreover, we find that more profitable airlines, airlines with lower leverage ratios, and airlines with less debt overhang are less sensitive to creditor rights as they may use internal funds, rather than external capital, to finance investment.

The evidence in our paper shows that legal protection of creditor rights affects both capital vintage, technological diffusion and firm scale. Better creditor protection helps airlines to mitigate financial short-falls and enhance investment in newer, more efficient and more technologically advanced aircraft. While we study the relation between vintage aircraft and creditor rights, our results propose a broader link, not confined only to the airline industry, between investor protection, real corporate investment and economic growth; legal protection of creditors facilitates the ability of firms to make large capital investments, adapt advanced technologies and fosters productivity.

Appendix

Proof of Lemma 1. Denote q^c the solution to the constrained problem. Part (i) of the lemma is trivial, since if the unconstrained solution to the maximization problem satisfies the constraint, it is clearly the constrained solution as well. To prove part (ii), define the Lagrangian of the maximization problem as $L = f(q) - q + \lambda[\mu f(q) - q]$. Without loss of generality, assume that $f'(0)$ is large enough so that $q = 0$ is not an optimal solution. The first order condition with respect to q, which is clearly necessary and sufficient, is $f'(q) - 1 + \lambda[\mu f'(q) - 1] = 0$. Further, $\lambda \geq 0$ and $\mu f(q) \geq q$ with complementary slackness. Now, if $\lambda = 0$, the constraint does not bind, the optimal solution satisfies $f'(q^c) = 1$, so that the unconstrained solution, q^{uc}, is the constrained solution as well. Alternatively, if $\lambda > 0$, the constraint binds, so that $\mu f(q^c) = q^c$. Further, we have that $f'(q^c) = 1 + \lambda[\mu f'(q^c) - 1]$. Define now $F(q) = \mu f(q) - q$. We have that F is concave, $F(0) = 0$ and $F(q^c) = 0$. It is easy to see that this implies that $F'(q^c) < 0$, or equivalently, $\mu f'(q^c) < 1$. Thus, because $\lambda > 0$, $f'(q^c) < 1$. Since f is concave, and since $f'(q^{uc}) = 1$, we have that $q^c < q^{uc}$. Since q^c is not equal to q^{uc}, we must have that $q^{uc} > \mu f(q^{uc})$, as part (ii) of the lemma states. For Proposition 1 we also note that the value function for the constrained maximization problem $V(\mu)$ is clearly increasing in μ when the constraint binds, since by the Envelope Theorem, $DV/D\mu = \partial L/\partial\mu = \lambda f(q^c) > 0$.

Proof of Proposition 1. Define $z(q_{new}) = p_{old} * h(q_{new})$ to be the price of obtaining revenue $f(q_{new})$ using a fleet of old technology aircraft. For simplicity in what follows we drop the subscript and denote q_{new} by q. If $z'(0) \geq 1$, from the convexity of z we have that $z(q) > q$ for all $q > 0$. Under this situation, the proposition trivially holds for $\bar{\mu} = 0$, as the new technology dominates the old technology. Similarly, if $z'(0) < 1$ and $z(q) < q$ for all $q > 0$ the proposition trivially holds with $\bar{\mu} = 1$ as the old technology dominates the new technology.Assume then that $z'(0) < 1$ and that there exists a $q > 0$ with $z(q) = q$. By the convexity of z, this q is unique, and we denote it by $q*$. Clearly $z(q) < q$ for $q < q*$ and $z(q) > q$ for $q > q*$.

Since f is concave and $f(0) = 0$, we have that for any μ, the set of all q satisfying $q \leq \mu f(q)$ equals $[0, \bar{q}]$ for some $\bar{q}$. Similarly, since z is convex and $z(0) = 0$, for any μ the set of all q satisfying $z(q) \leq \mu f(q)$ equals $[0, \bar{q}]$ for some $\bar{q}$. Now, for any μ we define the 'financable set' to be all q with $c(q) \leq \mu f(q)$, where $c(q) = min(z(q), q)$. We thus have that for any μ, the financable set equals $[0, q]$ for some q.

Define $\mu*$ to satisfy $\mu f(q) = q*$. By definition of $q*$, the financable set at $\mu*$ is $[0, q*]$. Since in this region $z(q) < q$ for all q which are financable, a firm operating in a country with creditor protection $\mu*$ chooses the old technology fleet. Similarly, for any $\mu < \mu*$, the financable set equals $[0, q']$ for some $q' < q*$, so that again, $z(q) < q$ for all financable q. Thus, again, any firm operating in a country with creditor protection $\mu < \mu*$ chooses the old technology.

Define q^{uc} to be the solution to the unconstrained problem $Max_q[f(q) - c(q)]$. Since by assumption the new technology is preferred to the old when $\mu = 1$, we have that $c(q^{uc}) = q^{uc}$ so that $q^{uc} > q*$. Define $\mu**$ to satisfy $\mu f(q) = q^{uc}$. Clearly, for any $\mu \geq \mu**$, q^{uc} is financable, so that a firm operating in a country with creditor protection $\mu > \mu**$ chooses the unconstrained solution and hence the new technology.

Now, for all $\mu* < \mu < \mu**$ we have that the financable set equals $[0, \bar{q}(\mu)]$ for some $q* < \bar{q}(\mu) < q^{uc}$. Define $V(\mu)$ to be the solution to the maximization problem of a firm operating in a country with creditor protection $\mu* < \mu < \mu**$. That is, $V = Max_q[f(q) - c(q)]$ s.t. $q \leq \bar{q}(\mu)$. Further, define V_1 as the solution to the maximization problem $Max_q[f(q) - c(q)]$ s.t. $q \leq q*$, and $V_2(\mu)$ as the solution to the maximization problem $Max_q[f(q) - c(q)]$ s.t. $q* \leq q < \bar{q}(\mu)$. Clearly, $V = max[V_1, V_2(\mu)]$. Further, a firm in country μ will choose the new technology if and only if $V_2(\mu) > V_1$. By Lemma 1, $V_2(\mu)$ is increasing in μ. Also, since the new technology is preferred to the old with no constraints, we have that $V_2(\mu**) > V_1$. Thus, since V_1 is independent of μ, there exists a $\mu* \leq \bar{\mu} < \mu**$, such that for all $\mu* \leq \mu \leq \bar{\mu}$, $V_1 \geq V_2(\mu)$ and for all $\bar{\mu} \leq \mu \leq \mu**$, $V_2(\mu) \geq V_1$. Therefore, firms operating in countries with $\mu* \leq \mu \leq \bar{\mu}$ will choose the old technology, while firms operating in countries with $\bar{\mu} < \mu \leq \mu**$ will choose the new technology. This, combined with the fact that firms in countries with $\mu \leq \mu*$ choose the old technology, while firms in countries with $\mu \geq \mu**$ choose the new technology proves the proposition.

Proof of Proposition 2. The proof is a direct consequence of Proposition 1.

Proof of Proposition 3. The proposition is a direct consequence of the fact that as μ tends to zero, the fleet size that is financable under the constrained maximization problem tends to zero as well.

Proof of Proposition 4. Denote q^{uc} as the unconstrained first best new technology fleet size. For all $A \geq q^{uc}$, we clearly have that $\mu(A) = 0$. For $A < \mu(A)$, q^{uc} is financable if $q^{uc} \leq \mu f(q^{uc}) + A$. Thus, $\mu(A)$ is implicitly defined by the equation $q^{uc} = \mu(A) f(q^{uc}) + A$. Further, since $q(uc) < f(q^{uc})$, $\mu(A) \leq 1$. By the implicit function theorem we have that $\mu'(A) = -1/f(q) < 0$.

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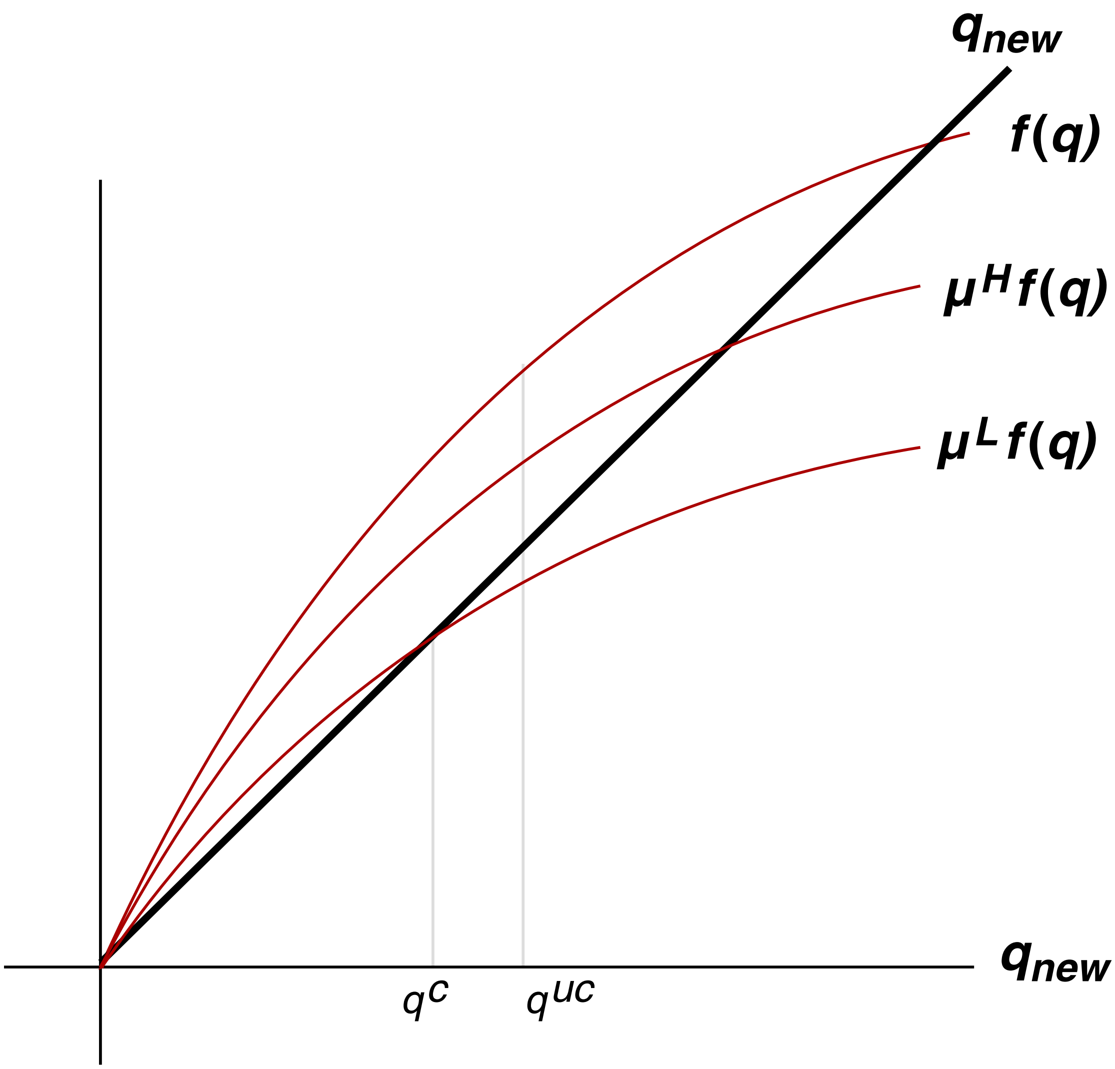

FIGURE 1: Basic new-technology maximization problem with financial constraint.

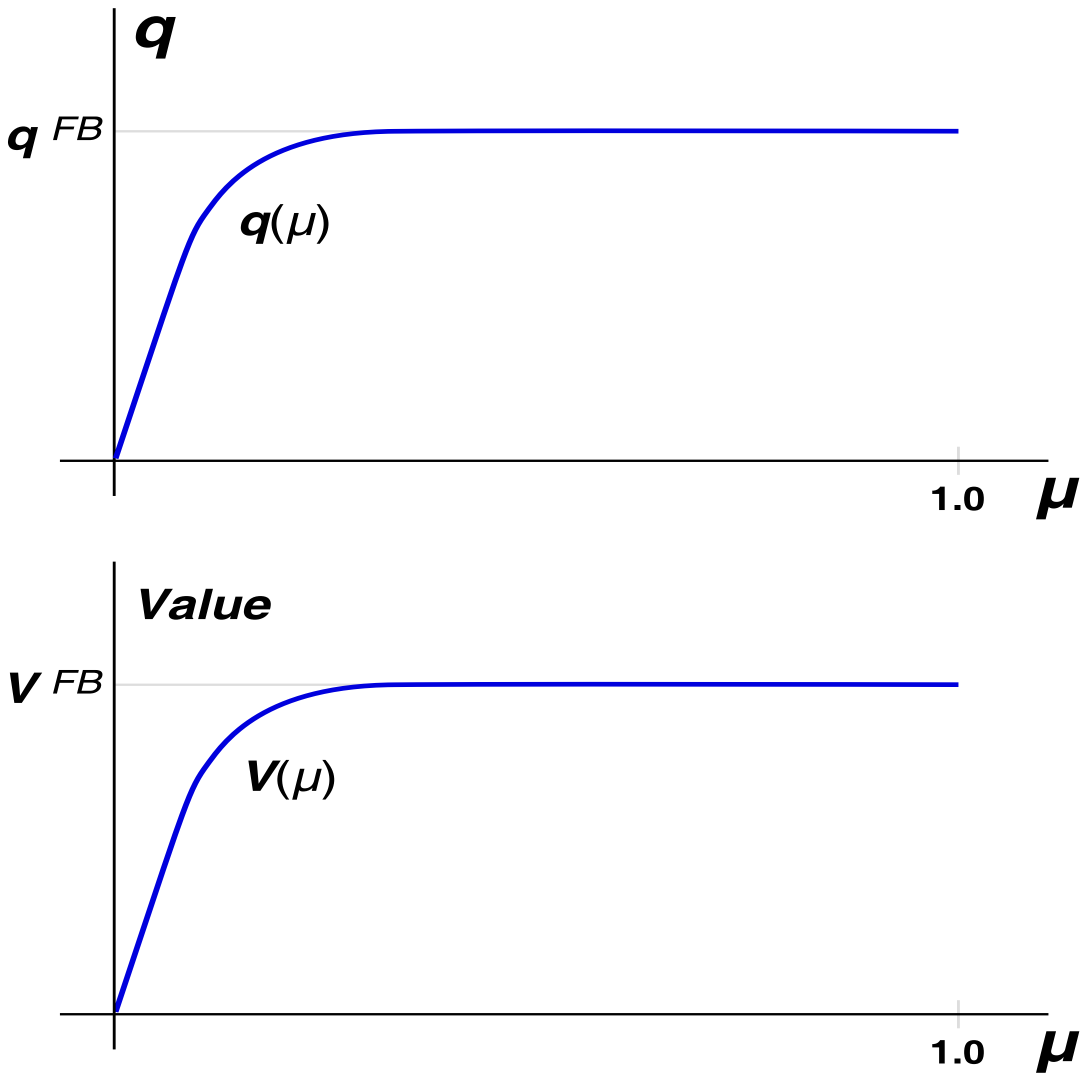

FIGURE 2: Value and size functions for different levels of μ.

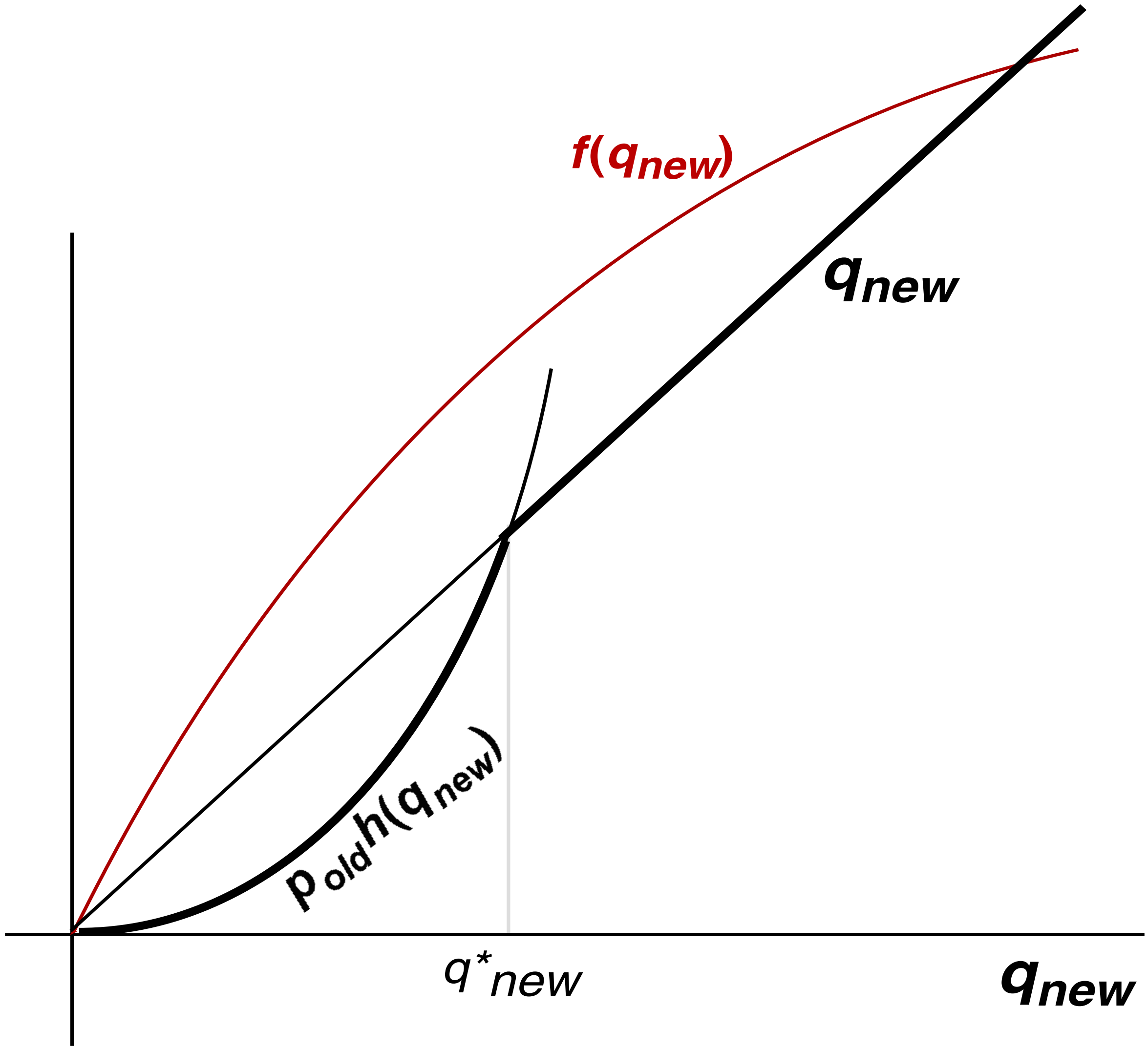

FIGURE 3A: Combined cost and revenue functions of new and old technologies.

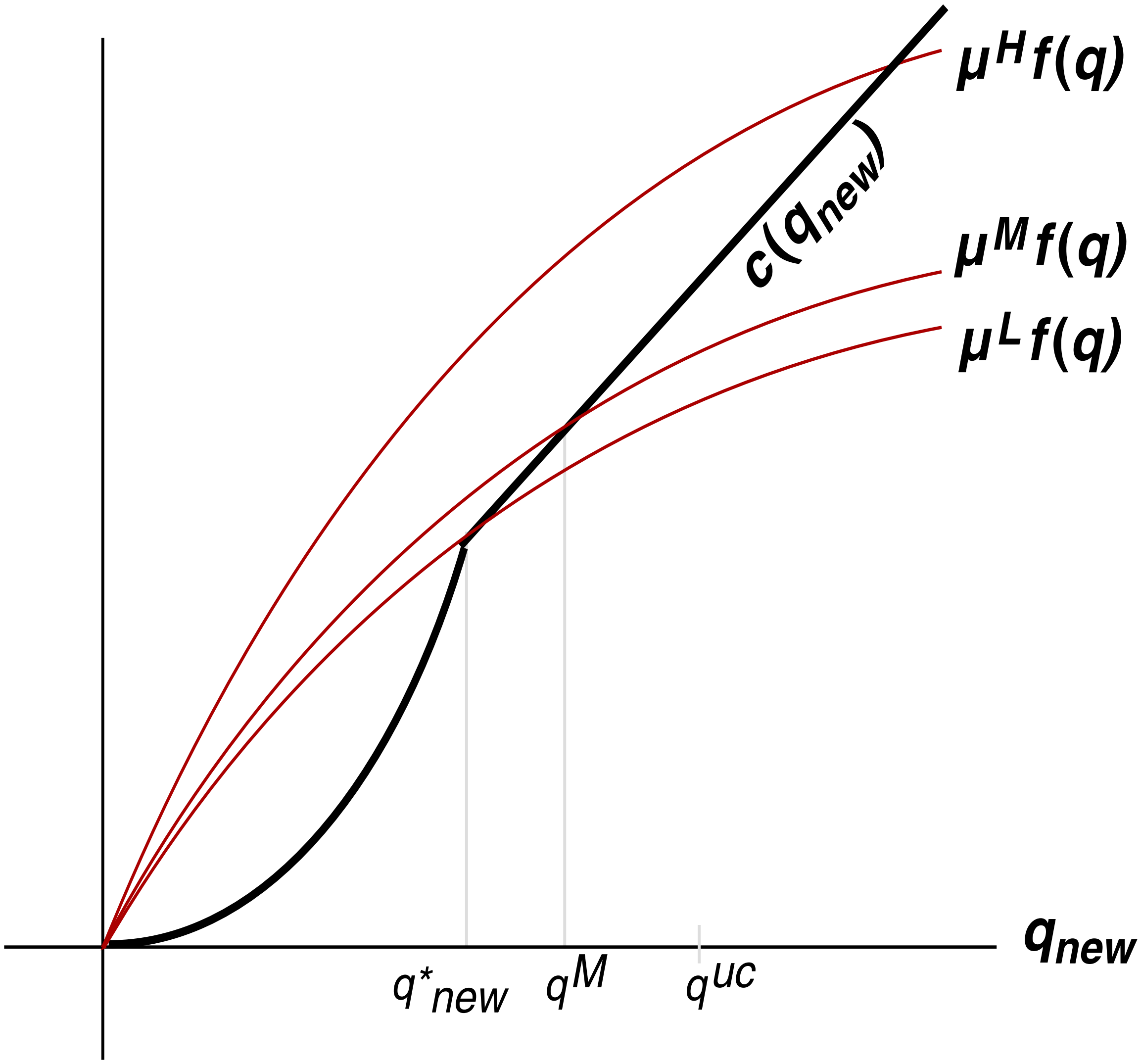

FIGURE 3B: Combined maximization problem of new and old technologies with financial constraint.

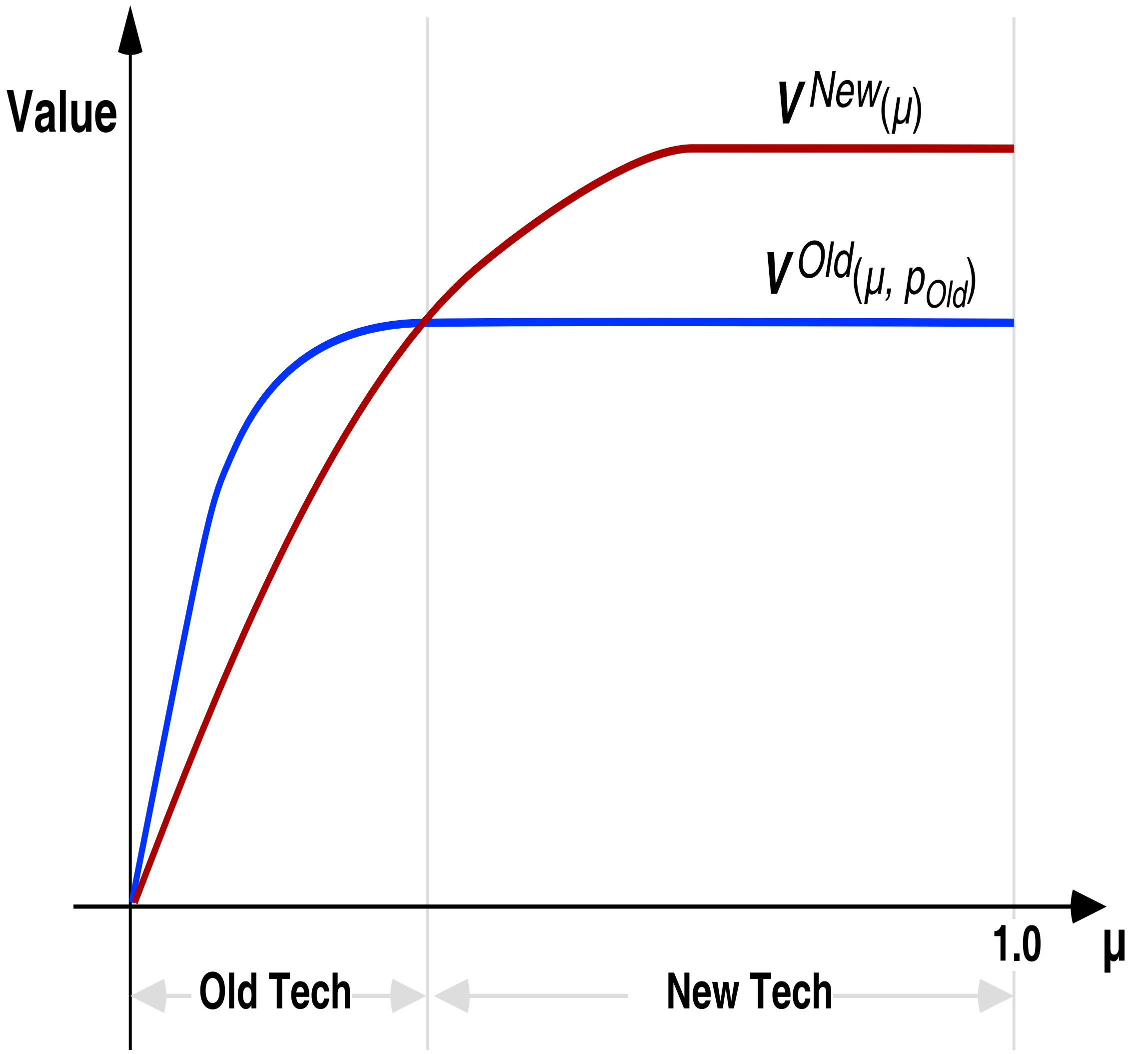

FIGURE 4: New and old technology value functions.

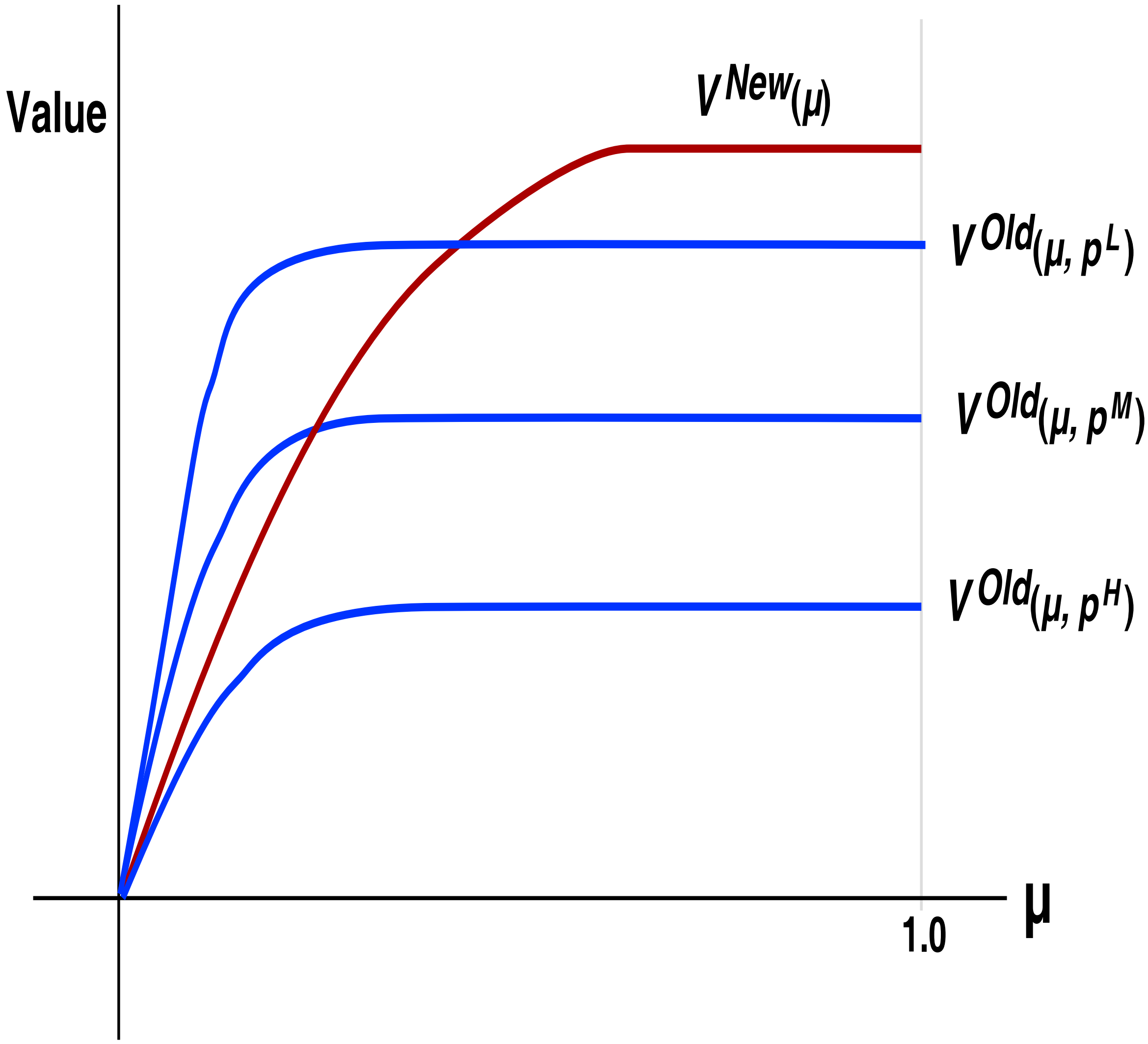

FIGURE 5: New and old technology value functions for varying levels of p_{old}.

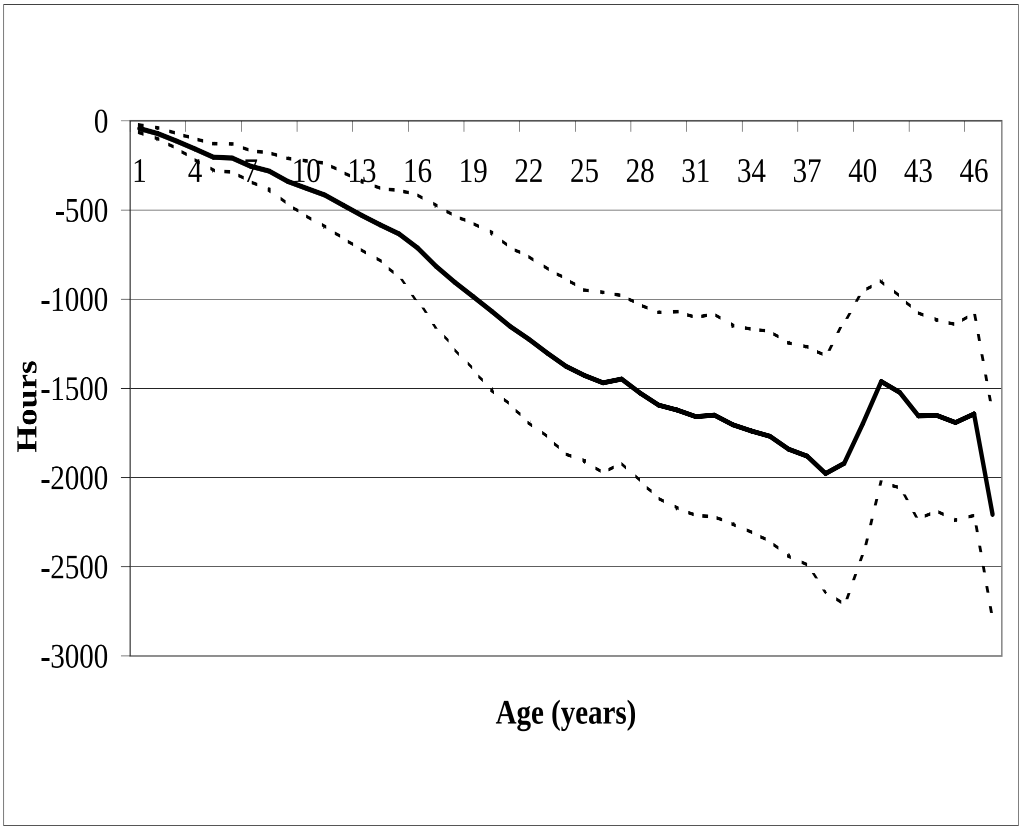

FIGURE 6: Annual hourly utilization as a function of aircraft age. Regression coefficients are calculated using year and aircraft-type fixed effects. 95% confidence intervals are calculated using standard errors that are clustered by aircraft type.

Table 1:
Summary Statistics

Panel A: Aircraft Age

	1978-1979	1980-1989	1990-1999	2000-2003	Full Sample	Commercial	Military
Aircraft age							
Minimum	0	0	0	0	0	0	0
25th Percentile	4	5	5	6	6	5	8
Mean	9.1	11.0	13.5	14.7	13.0	12.0	16.0
Median	10	11	12	13	12	11	15
75th Percentile	13	17	21	22	19	18	23
Maximum	32	42	52	56	56	56	47
Standard deviation	5.5	7.4	9.4	10.6	9.2	8.8	9.8
# of Aircraft types	96	136	196	202	219	161	200
# of Operators	969	2,134	4,051	3,133	5,987	5,437	893
# of Countries	89	102	129	129	129	129	115
# of Observations	18,953	129,427	238,327	107,946	494,653	373,261	121,392

Panel B: Technological Age

	1978-1979	1980-1989	1990-1999	2000-2003	Full Sample	Commercial	Military
Broad technological age (Narrow technological age)							
Minimum	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
25th Percentile	13 (9)	15 (10)	14 (11)	16 (13)	15 (11)	13 (10)	20 (15)
Mean	16.1 (12.6)	19.3 (15.3)	22.7 (19.0)	24.2 (20.7)	21.9 (18.2)	20.2 (16.7)	27.0 (22.6)
Median	16 (12)	20 (16)	24 (19)	22 (19)	21 (17)	20 (16)	27 (22)
75th Percentile	20 (17)	24 (20)	30 (27)	34 (30)	29 (25)	27 (23)	34 (30)
Maximum	32 (32)	43 (43)	52 (52)	56 (56)	56 (56)	56 (56)	47 (47)
Standard deviation	5.2 (5.1)	7.3 (6.9)	9.9 (9.5))	11.6 (11.1)	9.8 (9.4)	9.1 (8.8)	10.1 (10.0)
# of Aircraft types	96	136	196	202	219	161	200
# of Operators	969	2,134	4,051	3,133	5,987	5,437	893
# of Countries	89	102	129	129	129	129	115
# of Observations	18,953	129,427	238,327	107,946	494,653	373,261	121,392

Panel C: Country Characteristics

	Creditor rights	GDP per capita	English legal origin	French legal origin	German legal origin	Nordic legal origin	Socialist legal origin
Minimum	0	$82.16	0	0	0	0	0
25th Percentile	1	$2,109.9	0	0	0	0	0
Mean	1.65	$17,201.72	0.56	0.22	0.10	0.02	0.11
Median	1	$19,559.0	1	0	0	0	0
75th Percentile	2	$28,262.6	1	0	0	0	0
Maximum	4	$45,390.5	1	1	1	1	1
Standard deviation	1.01	$12,414.5	0.50	0.41	0.30	0.13	0.31
Number of Observations by legal origin			279,031	108,415	47,580	7,762	51,865

This table reports summary statistics for aircraft age, technological age (broad and narrow), and country characteristics. The summary statistics for aircraft age are reported for the periods 1978-1979, 1980-1989, 1990-1999, 2000-2003, as well as for the entire period. The table also reports summary statistics separately for commercial and military aircraft.

Table 2:
Countries with Most and Least Aircraft

Countries with Most Aircraft 1978-2003

	Country	Commercial	Military	Total	Share
1.	United States	147,880	37,596	185,476	37.50%
2.	Russian Federation	24,129	14,390	38,519	7.79%
3.	United Kingdom	15,396	4,681	20,077	4.06%
4.	Canada	15,356	3,144	18,500	3.74%
5.	France	10,441	3,400	13,841	2.80%
6.	China	9,499	3,250	12,749	2.58%
7.	Brazil	6,741	4,702	11,443	2.31%
8.	Japan	9,530	1,656	11,186	2.26%
9.	Germany	10,120	954	11,074	2.24%
10.	Spain	6,053	3,121	9,174	1.86%
11.	Australia	7,189	1,628	8,817	1.78%
12.	India	2,740	5,464	8,204	1.66%
13.	Indonesia	5,956	1,888	7,844	1.59%
14.	Ukraine	4,734	2,378	7,112	1.44%
15.	Mexico	4,846	1,029	5,875	1.19%
16.	Italy	4,807	1,036	5,843	1.18%
17.	Iran	2,097	2,422	4,519	0.91%
18.	Argentina	2,667	1,203	3,870	0.78%
19.	Netherlands	3,250	512	3,762	0.76%
20.	Saudi Arabia	2,128	1,551	3,679	0.74%

Countries with Least Aircraft 1978-2003

	Country	Commercial	Military	Total	Share
110.	Georgia	159	0	159	0.032%
111.	Uganda	155	0	155	0.031%
112.	Mali	99	53	152	0.031%
113.	Mauritania	97	47	144	0.029%
114.	Namibia	135	4	139	0.028%
115.	Lesotho	76	48	124	0.025%
116.	Cambodia	113	9	122	0.025%
117.	Sierra Leone	107	0	107	0.022%
118.	Chad	77	28	105	0.021%
119.	Slovenia	85	7	92	0.019%
120.	Macedonia	90	0	90	0.018%
121.	Burundi	87	0	87	0.018%
122-3.	Haiti	71	11	82	0.017%
122-3.	Benin	82	0	82	0.017%
124.	Rwanda	79	0	79	0.016%
125.	Central African Republic	67	0	67	0.014%
126.	Niger	17	49	66	0.013%
127.	Togo	18	44	62	0.013%
128.	Albania	49	0	49	0.010%
129.	Bosnia and Herzegovina	44	0	44	0.009%

This table ranks countries based on the total number of aircraft in the sample. Share is total aircraft divided by total aircraft in the sample.

Table 3:
Aircraft Vintage and Usage

Dependent Variable=	Hours (per year)	Hours (per year)	Hours (per year)	Hours (per year)	Hours (per year)	Hours (per year)
Age	-57.6	-51.9	-56.5	-56.5		
	(6.22)	(9.97)	(5.44)	(0.854)		
Tech Age					-31.9	-31.9
(broad)					(13.79)	(0.66)
Fixed-Effects						
Year	Yes	Yes	Yes	Yes	Yes	Yes
Aircraft Type	No	Yes	No	No	No	No
Aircraft	No	No	Yes	Yes	No	No
Clustering by	type	type	type	aircraft	type	aircraft
# of Aircraft Types	76	76	76	76	76	76
# of Aircraft	25,009	25,009	25,009	25,009	25,009	25,009
Adjusted R^2	0.20	0.57	0.79	0.79	0.08	0.08
Observations	179,836	179,836	179,836	179,836	179,836	179,836

The dependent variable is aircraft yearly usage in hours. Age is the age of the aircraft. Tech Age is the technological age of the aircraft. All regressions include an intercept (not reported) and year fixed effects. Standard-errors, reported in parenthesis, are clustered either by aircraft type or by individual aircraft.

Table 4:
Creditor Rights and Aircraft Vintage

Dependent Variable=	Age	Age	Age	Tech Age (broad)	Tech Age (broad)	Tech Age (broad)	Tech Age (narrow)	Tech Age (narrow)	Tech Age (narrow)
GDP per capita	-0.440 b	-2.385 a	-1.502 c	-0.801 a	-1.962 a	-0.482	-0.942 a	-2.845 a	-1.724 b
	(0.177)	(0.600)	(0.882)	(0.240)	(0.580)	(0.551)	(0.172)	(0.574)	(0.798)
Population	-0.470 b	8.994 a	2.460	-0.622 c	7.069 a	1.306	-0.513 b	6.526 a	1.380
	(0.229)	(2.399)	(1.492)	(0.327)	(2.424)	(0.618) b	(0.248)	(2.284)	(1.449)
Area	0.334	2.605	-0.142	0.384	-21.144 a	-0.388	0.389 c	-6.638	0.557
	(0.211)	(8.349)	(1.291)	(0.243)	(6.888)	(0.455)	(0.225)	(6.192)	(1.205)
Creditor rights	-0.451 b	-1.099 b	-0.929 b	-0.402 c	-0.928 b	-0.469 a	-0.550 c	-0.794 b	-0.500 b
	(0.225)	(0.436)	(0.388)	(0.222)	(0.368)	(0.174)	(0.229)	(0.358)	(0.242)
Fixed-Effects									
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country	No	Yes	No	No	Yes	No	No	Yes	No
Operator	No	No	Yes	No	No	Yes	No	No	Yes
# of Countries	129	129	129	129	129	129	129	129	129
# of Operators	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,987
Adjusted R^2	0.09	0.12	0.45	0.11	0.15	0.76	0.15	0.18	0.52
Observations	494,653	494,653	494,653	494,653	494,653	494,653	494,653	494,653	494,653

The dependent variable is the age of the aircraft (columns 1-3), broad technological age (columns 4-6), and narrow technological age (columns 7-9). GDP per capita is the natural logarithm of real GDP per capita. Population is the natural logarithm of the population, Area is the natural logarithm of the country surface in sq. km. Creditor rights is an index aggregating creditor rights, following Djankov et al. (2007). The index ranges from 0 (weak creditor rights) to 4 (strong creditor rights) and is constructed as of January for every year from 1978 to 2003. The first columns also includes dummies for French legal origin, German legal origin, Nordic legal origin, and Socialist legal origin (not reported for brevity). All regressions include an intercept (not reported) and year fixed effects. Standard-errors are clustered by country and reported in parentheses. a, b and c denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 5:
Creditor Rights and Aircraft Age: Commercial Vs. Military Aircraft

	Commercial Age	Military Age	Commercial Age	Military Age	Commercial Age	Military Age
GDP per capita	-0.653 a	0.763 a	-2.698 a	0.889	-2.179 a	-0.756
	(0.247)	(0.238)	(0.602)	(1.549)	(0.666)	(1.597)
Population	-0.718 a	0.070	8.269 a	4.071	1.607	4.521
	(0.276)	(0.290)	(2.513)	(4.830)	(1.411)	(4.993)
Area	0.512 b	-0.168	2.333	83.542 b	0.711	-7.586
	(0.236)	(0.239)	(7.205)	(34.527)	(1.044)	(6.555)
Creditor rights	-0.505 b	-0.306	-0.953 b	-0.644	-0.790 b	-0.760
	(0.236)	(0.415)	(0.454)	(0.813)	(0.358)	(0.848)
Fixed-Effects						
Year	Yes	Yes	Yes	Yes	Yes	Yes
Country	No	No	Yes	Yes	No	No
Operator	No	No	No	No	Yes	Yes
# of Countries	129	114	129	114	129	114
# of Operators	5,437	893	5,437	893	5,437	893
Adjusted R^2	0.10	0.14	0.14	0.19	0.50	0.32
Observations	373,261	121,392	373,261	121,392	373,261	121,392

The dependent variable is the age of either commercial or military aircraft. GDP per capita is the natural logarithm of real GDP per capita. Population is the natural logarithm of the population, Area is the natural logarithm of the country surface in sq. km. Creditor rights is an index aggregating creditor rights, following Djankov et al. (2007). The index ranges from 0 (weak creditor rights) to 4 (strong creditor rights) and is constructed as of January for every year from 1978 to 2003. The first two columns also include dummies for French legal origin, German legal origin, Nordic legal origin, and Socialist legal origin (not reported for brevity). All regressions include an intercept (not reported) and year fixed effects. Standard-errors are clustered by country and reported in parentheses. a, b and c denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 6:
Creditor Rights and Technological Age: Commercial Vs. Military Aircraft

	Commercial Tech Age (broad)	Military Tech Age (broad)	Commercial Tech Age (broad)	Military Tech Age (broad)	Commercial Tech Age (narrow)	Military Tech Age (narrow)	Commercial Tech Age (narrow)	Military Tech Age (narrow)
GDP per capita	-3.005	-1.624	-2.263 a	-1.437	-2.228 a	-1.276	-1.665 a	-1.308
	(0.666) a	(1.520)	(0.613)	(1.643)	(0.812)	(1.555)	(0.599)	(1.649)
Population	6.591 a	-0.641	0.876	-0.278	7.785 a	-2.831	0.533	-2.835
	(2.439)	(3.481)	(1.352)	(3.545)	(2.610)	(3.584)	(1.318)	(3.551)
Area	-1.507	97.006 a	1.145	-1.853	-5.695	29.404	1.021	5.058
	(5.204)	(18.265)	(1.105)	(4.344)	(6.605)	(20.351)	(0.957)	(4.280)
Creditor rights	-0.841 b	0.359	-0.601 b	0.351	-0.978 a	0.209	-0.798 a	0.265
	(0.373)	(0.798)	(0.289)	(0.841)	(0.357)	(0.895)	(0.232)	(0.942)
Fixed-Effects								
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country	Yes	Yes	No	No	Yes	Yes	No	No
Operator	No	No	Yes	Yes	No	No	Yes	Yes
# of Countries	129	114	129	114	129	114	129	114
# of Operators	5,437	893	5,437	893	5,437	893	5,437	893
Adjusted R^2	0.23	0.25	0.53	0.41	0.18	0.30	0.49	0.48
Observations	373,261	121,392	373,261	121,392	373,261	121,392	373,261	121,392

The dependent variable is the broad technological age (columns 1-4), or narrow technological age (columns 5-8) of either commercial or military aircraft. GDP per capita is the natural logarithm of real GDP per capita. Population is the natural logarithm of the population, Area is the natural logarithm of the country surface in sq. km. Creditor rights is an index aggregating creditor rights, following Djankov et al. (2007). The index ranges from 0 (weak creditor rights) to 4 (strong creditor rights) and is constructed as of January for every year from 1978 to 2003. All regressions include an intercept (not reported) and year fixed effects. Standard-errors are clustered by country and reported in parentheses. a, b and c denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 7:
Creditor Rights and Age: Leased Vs. Non-Leased Aircraft

	Non-Leased Age	Leased Age	Non-Leased Age	Leased Age	Non-Leased Tech Age (broad)	Leased Tech Age (broad)	Non-Leased Tech Age (narrow)	Leased Tech Age (narrow)
GDP per capita	-3.380 a	-2.111 a	-2.696 a	-2.418 a	-1.912 a	-2.242 a	-2.760 a	-2.415 a
	(0.716)	(0.641)	(0.904)	(0.552)	(0.849)	(0.539)	(0.908)	(0.488)
Population	8.580 a	7.461 c	4.704 b	1.994	3.589	1.192	3.696	1.474
	(2.956)	(3.991)	(2.398)	(1.434)	(2.392)	(1.335)	(2.433)	(1.350)
Area	40.980 b	7.191	-3.556 c	1.284	-3.211 c	1.425 c	-2.628	1.532 b
	(18.484)	(5.317)	(1.830)	(0.792)	(1.692)	(0.749)	(1.803)	(0.775)
Creditor rights	-1.002 c	-0.501	-0.944 a	-0.375	-0.838 a	-0.551	-0.663 b	-0.394
	(0.571)	(0.499)	(0.365)	(0.489)	(0.301)	(0.358)	(0.312)	(0.461)
Fixed-Effects								
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country	Yes	Yes	No	No	No	No	No	No
Operator	No	No	Yes	Yes	Yes	Yes	Yes	Yes
# of Countries	128	129	128	129	128	129	128	129
# of Operators	3,746	3,601	3,746	3,601	3,746	3,601	3,746	3,601
Adjusted R^2	0.20	0.11	0.51	0.53	0.50	0.52	0.57	0.54
Observations	210,790	156,390	210,790	156,390	210,790	156,390	210,790	156,390

The dependent variable is aircraft age (columns 1-4), broad technological age (columns 5-6), or narrow technological age (columns 7-8) of either non-leased or leased aircraft. GDP per capita is the natural logarithm of real GDP per capita. Population is the natural logarithm of the population, Area is the natural logarithm of the country surface in sq. km. Creditor rights is an index aggregating creditor rights, following Djankov et al. (2007). The index ranges from 0 (weak creditor rights) to 4 (strong creditor rights) and is constructed as of January for every year from 1978 to 2003. French legal origin, German legal origin, Nordic legal origin, and Socialist legal origin are dummy variables that identify the legal origin of the Company law or Commercial Code of each country. All regressions include an intercept (not reported) and year fixed effects. Standard-errors are clustered by country and reported in parentheses. a, b and c denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 8:
Government Ownership and Aircraft Vintage: Evidence from 2003

	Non-Leased Age	Leased Age	Non-Leased Age	Leased Age	Non-Leased Tech Age (broad)	Leased Tech Age (broad)	Non-Leased Tech Age (narrow)	Leased Tech Age (narrow)
GDP per capita	-1.488 a	-1.157 a	-1.729 a	-1.396 a	-1.811 a	-1.615 a	-1.778 a	-1.513 a
	(0.394)	(0.309)	(0.414)	(0.308)	(0.459)	(0.379)	(0.381)	(0.317)
Population	-1.870 a	-0.701 c	-1.879 a	-0.837 b	-1.851 a	-0.650	-1.706 a	-0.608
	(0.465	(0.364)	(0.455)	(0.348)	(0.446)	(0.461)	(0.446)	(0.402)
Area	1.173 a	0.607 c	1.046 a	0.481	0.931 a	0.417	1.033 a	0.501
	(0.348)	(0.313)	(0.355)	(0.298)	(0.281)	(0.427)	(0.343)	(0.360)
Government			-4.718 a	-4.762	-4.379 a	-4.124 a	-4.230 a	-4.070 a
			(0.806)	(0.792)	(0.983)	(0.925)	(0.953)	(0.886)
Creditor rights	-1.294 b	-0.089	-1.390 a	-0.325	-0.799 c	0.084	-1.245 a	0.011
	(0.498)	(0.328)	(0.439)	(0.297)	(0.448)	(0.382)	(0.448)	(0.327)
# of Countries	113	116	113	116	113	116	113	116
# of Operators	1,345	1,331	1,345	1,331	1,345	1,331	1,345	1,331
Adjusted R^2	0.17	0.07	0.19	0.09	0.18	0.09	0.22	0.10
Observations	10,619	11,489	10,619	11,489	10,619	11,489	10,619	11,489

The dependent variable is aircraft age (columns 1-4), broad technological age (columns 5-6), or narrow technological age (columns 7-8) of either non-leased or leased aircraft. GDP per capita is the natural logarithm of real GDP per capita. Population is the natural logarithm of the population, Area is the natural logarithm of the country surface in sq. km. Government is a dummy variable that equals 1 for airlines with some government ownership as of January 2003. Creditor rights is an index aggregating creditor rights, following Djankov et al. (2007). The index ranges from 0 (weak creditor rights) to 4 (strong creditor rights) and is constructed as of January 2003. All regressions also include dummies for French legal origin, German legal origin, Nordic legal origin, and Socialist legal origin (not reported for brevity). All regressions include an intercept (not reported). Standard-errors are clustered by country and reported in parentheses. a, b and c denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 9:
Creditor Rights, Financial Constraints and Aircraft Age of Non-Leased Aircraft

Dependent Variable=	Age	Age	Age	Age	Age	Age	Pr(Age>30)	Pr(Age>30)
GDP per capita	0.218	0.552	0.136	0.168	0.186	-0.293	-0.011 a	-0.011 a
	(0.831)	(1.792)	(1.730)	(0.842)	(1.803)	(1.607)	(0.002)	(0.003)
Population	0.876	-4.195	-3.340	0.868 b	-4.311	-1.318	0.007 a	0.006 a
	(0.340)	(11.573)	(10.358)	(0.335)	(12.600)	(10.368)	(0.002)	(0.002)
Area	0.212	27.634	42.246	0.215	23.452	32.898	0.009 a	0.009 a
	(0.316)	(86.867)	(100.182)	(0.317)	(85.231)	(96.367)	(0.002)	(0.002)
Creditor rights	0.256	1.929 a	0.208	0.090	1.450 c	0.316	0.007 a	0.007 a
	(0.651)	(0.688)	(0.526)	(0.752)	(0.825)	(0.711)	(0.002)	(0.003)
Leverage	5.658 b	7.982 a	-2.599 a				0.064 a	
	(2.362)	(2.121)	(0.924)				(0.014)	
Creditor rights	-2.909 b	-5.024 a	-1.477 b				-0.038 a	
×Leverage	(1.356)	(1.362)	(0.697)				(0.010)	
LT Debt				4.969	8.471 a	-4.364 a		0.071 a
				(3.790)	(2.886)	(1.173)		(0.017)
Creditor rights				-2.812 c	-5.228 a	-1.114		-0.046 a
×LT Debt				(1.630)	(1.849)	(0.885)		(0.010)
Fixed-Effects								
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country	No	Yes	No	No	Yes	No	No	No
Operator	No	No	Yes	No	No	Yes	No	No
# of Countries	29	29	29	29	29	29	21	21
# of Operators	67	67	67	67	67	67	53	53
Adjusted/Pseudo R^2	0.09	0.11	0.36	0.09	0.12	0.37	0.16	0.16
Observations	49,496	49,496	49,496	49,496	49,496	49,496	30,423	30,423

The dependent variable is either the age of the aircraft (columns 1-6), or a dummy variable that takes the value of one for aircraft older than 30 years (columns 7,8) . GDP per capita is the natural logarithm of real GDP per capita. Population is the natural logarithm of the population, Area is the natural logarithm of the country surface in sq. km. Creditor rights is an index aggregating creditor rights, following Djankov et al. (2007). The index ranges from 0 (weak creditor rights) to 4 (strong creditor rights) and is constructed as of January for every year from 1978 to 2003. Leverage is total debt divided by total assets. LT Debt is long-term debt divided by total assets. Columns 1,4,7 and 8 also include dummies for French legal origin, German legal origin, Nordic legal origin, and Socialist legal origin (not reported for brevity). All regressions include an intercept (not reported) and year fixed effects. Standard-errors are clustered by country and reported in parentheses. a, b and c denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 10:
Creditor Rights, Financial Constraints and Technological Age of Non-Leased Aircraft

	Tech Age (broad)	Tech Age (broad)	Tech Age (broad)	Tech Age (broad)	Tech Age (narrow)	Tech Age (narrow)	Pr(Tech Age (narrow))> 30)	Pr(Tech Age (narrow))> 30)
GDP per capita	-0.069	1.361	-0.153	0.988	1.306	0.889	-0.008 a	-0.009 a
	(0.676)	(1.854)	(0.676)	(1.804)	(1.894)	(1.860)	(0.002)	(0.002)
Population	0.925 b	-6.941	0.925	-6.541	-2.697	-2.459	0.005 b	0.005 b
	(0.442)	(9.101)	(0.400)	(9.589)	(7.539)	(8.403)	(0.002)	(0.002)
Area	-0.146	-13.251	-0.114	-18.393	0.097	-5.277	0.005	0.004
	(0.261)	(84.719)	(0.261)	(82.651)	(68.906)	(66.625)	(0.003)	(-.003)
Creditor rights	0.391	3.370 c	0.515	2.208	3.091 a	2.641 b	0.005	0.006
	(1.026)	(1.720)	(0.976)	(1.697)	(1.113)	(1.164)	(0.006)	(0.005)
Leverage	4.056 a	6.262 a			7.448 a		0.055 a	
	(2.480)	(2.208)			(2.017)		(0.014)	
Creditor rights	-1.840	-4.508 b			-5.115 a		-0.031 a	
×Leverage	(1.796)	(1.875)			(1.532)		(0.011)	
LT Debt			3.348	6.171 c		7.671 b		0.064 a
			(3.638)	(3.301)		(2.994)		(0.015)
Creditor rights			-2.276	-4.697 b		-5.286 a		-0.038 a
×LT Debt			(1.900)	(2.201)		(1.922)		(0.011)
Fixed-Effects								
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country	No	Yes	No	Yes	Yes	Yes	No	No
# of Countries	29	29	29	29	29	29	29	29
# of Operators	67	67	67	67	67	67	67	67
Adjusted /Pseudo R^2	0.04	0.08	0.04	0.08	0.14	0.11	0.18	0.19
Observations	49,496	49,496	49,496	49,496	49,496	49,496	44,012	44,012

The dependent variable is broad technological age (columns 1-4), or narrow technological age (columns 5-8). GDP per capita is the natural logarithm of real GDP per capita. Population is the natural logarithm of the population, Area is the natural logarithm of the country surface in sq. km. Creditor rights is an index aggregating creditor rights, following Djankov et al. (2007). The index ranges from 0 (weak creditor rights) to 4 (strong creditor rights) and is constructed as of January for every year from 1978 to 2003. Leverage is total debt divided by total assets. LT Debt is long-term debt divided by total assets. Columns 1,3, 5 and 7 also include dummies for French legal origin, German legal origin, Nordic legal origin, and Socialist legal origin (not reported for brevity). All regressions include an intercept (not reported) and year fixed effects. Standard-errors are clustered by country and reported in parentheses. a, b and c denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 11:
Creditor Rights and Fleet Size: Commercial Vs. Military Aircraft

Size=	Commercial Number	Military Number	Commercial Seats	Military Seats	Commercial Weight	Military Weight	Commercial Wings	Military Wings
GDP per capita	0.223 a	0.347 a	0.602 a	0.686 c	0.638 a	0.984	0.500 a	0.815 a
	(0.045)	(0.097)	(0.128)	(0.400)	(0.136)	(0.392)	(0.105)	(0.246)
Population	0.101	0.056	0.344	0.078	0.355	-0.679	0.218	-0.079
	(0.125)	(0.179)	(0.299)	(0.631)	(0.315)	(0.875)	(0.281)	(0.447)
Area	-0.132	0.388	-0.248	0.607	-0.204	1.881 c	-0.238	1.004 c
	(0.096)	(0.239)	(0.249)	(0.739)	(0.255)	(1.021)	(0.230)	(0.555)
Creditor rights	0.067 c	-0.061	0.200 a	0.009	0.178 c	0.155	0.161 b	-0.053
	(0.037)	(0.039)	(0.075)	(0.101)	(0.096)	(0.134)	(0.077)	(0.069)
Fixed-Effects								
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Operator	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of Countries	129	110	129	110	129	110	129	110
# of Operators	5,276	743	5,276	743	5,276	743	5,276	743
Adjusted R^2	0.85	0.93	0.87	0.91	0.83	0.91	0.86	0.76
Observations	32,477	7,049	32,477	7,049	32,477	7,049	32,477	7,049

The dependent variable is fleet size defined as the logarithm of either 1) the sum of all aircraft operated, (2) the sum of the seat capacities of all aircraft in the fleet, (3) the sum of the maximal takeoff weight of all aircraft in the fleet, and (4) the sum of the wingspans of all aircraft in the fleet. GDP per capita is the natural logarithm of real GDP per capita. Population is the natural logarithm of the population, Area is the natural logarithm of the country surface in sq. km. Creditor rights is an index aggregating creditor rights, following Djankov et al. (2007). The index ranges from 0 (weak creditor rights) to 4 (strong creditor rights) and is constructed as of January for every year from 1978 to 2003. All regressions include an intercept (not reported), year fixed effects and operator fixed-effects. Standard-errors are clustered by country and reported in parentheses. a, b and c denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 12:
Creditor Rights, Financial Constraints and Fleet Size

Dependent Variable=	Number	Seats	Weight	Wings	Number	Seats	Weight	Wings
GDP per capita	0.628	1.500	1.525	1.356	0.612	1.479	1.519	1.343
	(0.185) a	(0.557) b	(0.526) a	(0.545) b	(0.162) a	(0.511) a	(0.504) a	(0.497) a
Population	0.452	2.539	2.358	1.840	0.581	2.686	2.380	1.978
	(0.807)	(2.649)	(2.181)	(2.536)	(0.774)	(2.619)	(2.200)	(2.509)
Area	5.488	9.872	8.511	10.632	5.604	10.114	8.647	10.889
	(0.944) a	(2.203) a	(2.590) a	(2.292) a	(0.867) a	(2.013) a	(2.371) a	(2.098) a
Creditor rights	0.098	0.258	0.316	0.228	0.087	0.194	0.216	0.180
	(0.119)	(0.307)	(0.319)	(0.288)	(0.116)	(0.276)	(0.265)	(0.251)
Leverage	0.438	0.839	0.919	0.924				
	(0.423)	(0.885)	(0.966)	(0.958)				
Creditor rights	-0.145	-0.236	-0.300	-0.259				
×Leverage	(0.221)	(0.491)	(-0.300)	(0.497)				
LT Debt					0.275	0.442	0.674	0.612
					(0.393)	(0.753)	(0.838)	(0.842)
Creditor rights					-0.126	-0.148	-0.238	-0.210
×LT Debt					(0.225)	(0.500)	(0.519)	(0.499)
Fixed-Effects								
Year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Operator	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# of Countries	29	29	29	29	29	29	29	29
# of Operators	72	72	72	72	72	72	79	72
Adjusted R^2	0.91	0.92	0.93	0.92	0.89	0.91	0.93	0.91
Observations	649	649	649	649	649	649	649	649

The dependent variable is fleet size defined as the logarithm of either 1) the sum of all aircraft operated, (2) the sum of the seat capacities of all aircraft in the fleet, (3) the sum of the maximal takeoff weight of all aircraft in the fleet, and (4) the sum of the wingspans of all aircraft in the fleet. GDP per capita is the natural logarithm of real GDP per capita. Population is the natural logarithm of the population, Area is the natural logarithm of the country surface in sq. km. Creditor rights is an index aggregating creditor rights, following Djankov et al. (2007). The index ranges from 0 (weak creditor rights) to 4 (strong creditor rights) and is constructed as of January for every year from 1978 to 2003. Leverage is total debt divided by total assets. LT Debt is long-term debt divided by total assets. All columns report marginal effects from estimating OLS regressions. All regressions include an intercept (not reported), year fixed effects, and operator fixed-effects. Standard-errors are clustered by country and reported in parentheses. a, b and c denote statistical significance at the 1%, 5%, and 10% levels, respectively.