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Leasing as a Mitigation of Financial Accelerator Effects

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Keywords: Leased capital, business cycles, financial accelerator, uncertainty, risk shocks
JEL Classification: E2, E3, G12

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1 Introduction

Leased capital is extensively used in capital markets and production, but its effects on macroeconomic dynamics has been largely overlooked in the literature on macro models with financial frictions, which assumes that firms do not have an option to rent capital. However, leased capital accounts for about 20% of the total physical productive assets used by US publicly listed firms, and its proportion is more than 40% among small and financially constrained firms. The leased capital ratio exhibits a strong counter-cyclical pattern over business cycles as well as a positive correlation with the volatility of cross-sectional idiosyncratic uncertainty. In this paper, we explicitly introduce leased capital into a stylized Bernanke-Gertler-Gilchrist financial accelerator model, and demonstrate a novel economic mechanism: that the increased usage of leased capital when financial constraints become tighter in bad states significantly mitigates the financial accelerator effects.

We start by presenting a set of motivating facts related to leasing activities on the aggregate level and across firms in the US economy. For our analysis, we focus on operating leases in which assets revert to lessors at the end of a lease's term[1]. First, we document that leased capital accounts for about 20% of the total physical productive assets used by US publicly listed firms, and the proportion is more than 40% among small and financially constrained firms. Second, we show that the leased capital ratio is strongly counter-cyclical, its cyclical components obtained by using the HP-filter have a correlation coefficient of -0.3 (t-stat = -1.97) with the cyclical components of natural log of US per capita real GDP. Third, we show that on the aggregate level, leasing activities exhibit a strong positive correlation with the volatility of cross-sectional idiosyncratic uncertainty measured by the dispersion of firm-level total factor productivity (TFP); in addition, the correlation coefficient between the two cyclical components is 0.42 with a t-stat of 2.82. In the cross section of firms, we show that firms significantly increase their use of leasing when the volatility of cross-sectional idiosyncratic uncertainty is higher, and a one-standard-deviation increase in volatility is associated with a 4%-6.9% increase in leased capital ratios, measured in different ways.

[1] There is another type of lease−capital lease, in which the lessee acquires ownership of the asset at the end of a lease's term. However, operating lease is much larger in magnitude than capital lease in the data and therefore is our main focus.

Based on these motivating facts, we argue that leasing can have significant mitigation effects for negative shocks (e.g., negative TFP shocks and risk shocks) in the economy with financial frictions. We follow Bernanke, Gertler, and Gilchrist (1999) (henceforth BGG) and Christiano, Motto, and Rostagno (2014) to develop a general equilibrium model with a financial accelerator mechanism and role for risk shocks[2], in which we explicitly incorporate firms' optimal choices between leased capital and owned capital [3]. As discussed in Eisfeldt and Rampini (2009), Rampini and Viswanathan (2013) and many other papers that study firms' leasing behaviors, leased capital differs from owned capital in two major aspects. First, according to US bankruptcy code, lessors have a stronger ability to repossess an asset than the creditors of secured lending. This repossession advantage is a major benefit of leasing, allowing a lessor to implicitly extend more credit than a lender whose claim is secured by the same asset. As a result, the debt capacity of leasing is larger than the debt capacity of secured lending, which makes leasing more valuable in states with tighter financial constraints and for financially constrained firms. Second, due to the separation of ownership and control rights, leasing is more costly due to agency problems.

In the model, we explicitly model these key features of leased capital. In doing so, we assume that lessors can fully obtain the resale value of leased capital when firms default while lenders can only recover a fraction of the resale value due to verification costs associated with default. Mean while, lessors must pay some additional monitoring costs upfront to make sure the lessee takes good care of leased capital in production. In bad states either with low TFP or that experience higher volatility of cross-sectional idiosyncratic uncertainty, the decrease in net worth and capital prices interact with each other to generate the financial accelerator effects as in Bernanke, Gertler, and Gilchrist (1999). In turn, the financial constraints become tighter, the benefit of larger debt capacity associated with leasing outweighs its higher cost, and firms increase their use of leased capital, although total capital (i.e., sum of leased capital and owned capital) stock still decrease, but the reallocation towards leased capital mitigates the decline in capital, investment, capital prices, and also net worth, thereby weakening the financial accelerator effects. To

[2] In their terminology, risk shocks are shocks to the volatility of cross-sectional idiosyncratic uncertainty.

[3] In the paper, we use "purchased capital" and "owned capital", "leased capital" and "rented capital" interchangeably

our best knowledge, this is the first paper which incorporates a explicit buy versus lease decision into the Bernanke, Gertler, and Gilchrist (1999) framework.

Due to this mechanism, our model can replicate the strong counter-cyclical pattern of leased capital ratio and also its strong positive correlation with the volatility of cross-sectional idiosyncratic uncertainty. In our quantitative analysis, we show that relative to a model without leasing, the increase in leased capital in response to either negative TFP shocks or risk shocks mitigates the decline in output, investment, and capital prices, as well as makes the financial constraint less tight; at the same time, leverage and external finance premium also increase by less, since leasing can serve as an additional source of external finance with larger debt capacity.

Finally, we provide additional empirical evidence to support our argument. First, we use firm-level regression analysis to show that financially constrained firms increase leased capital ratios more when the volatility of cross-sectional idiosyncratic uncertainty increases. Second, when we explore the role of heterogeneity in capital leasing activities across firms, we show that firms with more flexible leasing contracts - measured by leasing commitment duration- increase leased capital ratios more when the volatility of cross-sectional idiosyncratic uncertainty increases. Third, since credit spread is a well-known indicator of the financial condition in an economy, we offer an original empirical analysis that explores the relationship between aggregate-level leased capital ratio and credit spread; specifically, we show that leased capital ratio is positively related to credit spread, but in our sample with only 33 yearly observations without enough statistical power, the coefficient is insignificant. However, when we regress the leased capital ratio on the lagged credit spread, we obtain significant positive coefficients even when we include additional controls(e.g., aggregate leverage ratio, industrial output growth and so on), the time lag is likely due to the time-to-build feature of capital.

Related literature Our paper builds on the literature of macroeconomics and corporate finance models with financial frictions, which includes Gertler and Bernanke (1989); Carlstrom and Fuerst (1997); Bernanke et al. (1999); Kiyotaki and Moore (1997) and Elenev, Landvoigt, and Van Nieuwerburgh (2021); Schmid (2008) among others (see Brunnermeier, Eisenbach, and Sannikov (2012) and Quadrini (2011) for comprehensive reviews of this literature). These papers, although they study the role of credit market frictions induced by either limited contract enforcement or asymmetric information and agency problems in generating fluctuations over business cycles nonetheless overlook the role of leasing. In our study, we explicitly introduce a firm's lease versus buy decision into the model and study the mitigation effects associated with leasing. The most related paper to our approach is Gal and Pinter (2017), which also studies the mitigation effects of leasing in the dynamic model with borrowing constraints and financial shocks. However, we note that our paper differs from Gal and Pinter (2017) in two dimensions. First, our financial friction framework is based on Gertler and Bernanke (1989), Carlstrom and Fuerst (1997), and Bernanke et al. (1999), and we argue that leasing can have mitigation effects for the financial accelerator mechanism. Second, our framework allows us to study the interaction between leasing and uncertainty, Christiano et al. (2014) use a similar framework to study the business cycle implications of risk shocks, and they argue that risk shocks are the most important driving force for explaining business cycle fluctuations, while we show that the positive correlation between leasing and uncertainty can strongly mitigate the negative effects of risk shocks.

Our paper is also closely related to studies of corporate leasing decisions. The papers most related to our study are Eisfeldt and Rampini (2009) and Rampini and Viswanathan (2010, 2013), Gavazza (2011), Li and Tsou (2019), Li and Xu (2020) and Dou, Ji, Tian, and Wang (2021). We model lease-versus-buy decisions by following these papers, but our way of modeling differs in two dimensions. First, with respect to the model framework itself, Eisfeldt and Rampini (2009) use a static model, Rampini and Viswanathan (2010, 2013) use a dynamic model in partial equilibrium framework, and Li and Xu (2020) use a general equilibrium model with heterogeneous firms and collateral constraints, focusing on the asset pricing implications of leasing. Dou et al. (2021) introduce leasing into a continuous time heterogeneous agent model with financial frictions, but their focus is asset pricing implications generated by endogenous misallocation. Meanwhile, Li and Xu (2020) use a two-period general equilibrium framework to study the effect of leasing on capital misallocation. However, our model is a full dynamic general equilibrium model in which the financial friction is modeled as in Bernanke et al. (1999), and leasing fee is endogenous. Second, in terms of research questions, we focus on studying the mitigation of leasing for the financial accelerator effects on the aggregate level.

Our paper is also related to a large literature studying the effects of uncertainty. Bloom, Bond, and Van Reenen (2007) study how uncertainty affects firm investment. Bloom (2009) and Bloom, Floetotto, Jaimovich, Saporta-Eksten, and Terry (2018) study business cycle fluctuations generated by uncertainty. Alfaro et al. (2018) study how real and financial frictions amplify the impact of uncertainty shocks. Christiano, Motto, and Rostagno (2014) introduce risk shocks into a Bernanke-Gertler-Gilchrist financial accelerator model framework, and show that risk (uncertainty) shocks are the major driving force for explaining business cycle fluctuations. Finally, Park (2018) studies how a decrease in equity financing helps amplify risk shocks. Compared with these papers, our paper explicitly models firms' leasing activities that are overlooked in the literature, so we may study the mitigation effects induced by changing leasing activities in response to uncertainty shocks.

The rest of the paper is organized as follows. In section 2, we present motivating facts on the importance of leasing, it cyclical pattern over business cycles, and its correlation with the volatility of cross-sectional idiosyncratic uncertainty. In section 3, we describe our dynamic general equilibrium model in which firms are allowed to lease capital. In section 4, we present the quantitative analysis of our model. We use section 5 to provide additional supporting evidence for our model and robustness for our empirical results. We conclude this paper with section 6. Details on data construction and variable definitions are delegated to Appendix A.

2 Motivating Facts

This section provides aggregate and cross-sectional evidence with respect to the importance of leasing, its dynamic pattern over business cycles, and its correlation with the volatility of cross-sectional idiosyncratic uncertainty.

2.1 Importance of Leased Capital

To measure firm-level leasing activities, we follow Rampini and Viswanathan (2013) to capitalize rental expense from operating leases, and we refer this capitalized item as leased capital. We define the leased capital ratio as leased capital divided by the sum of leased capital and purchased tangible capital measured by Property, Plant, and Equipment-

Total (Net), i.e. PPENT. An alternative measure for leasing activities is rental share, as in Gal and Pinter (2017), and the rental share is defined as the ratio of rental fees and total expenditure (sum of capital expenditure and rental fee) for each year. We present the summary statistics of the leased capital ratio and rental share for the aggregate and cross-section of firms in Compustat in Table 1.

On the aggregate level, leased capital accounts for roughly 26% of overall productive assets. Using lease commitment and rental share yields slightly lower proportions: 16% and 20%, respectively. With respect to debt leverage, adjusting leasing or not can make a big difference: when we adjust for lease, leverage increases by 50% in the whole sample.

In the cross-section, we make three observations. First, for all three measures of leasing activities, small firms have higher values than large firms; for example, the average leased capital ratio (LCR1) for small firms (0.42) is more than twice as large as that of large firms (0.15). In other words, small firms lease more. Second, financially constrained firms lease more; for example, the average rental share of constrained firms (0.42) is much higher than that of unconstrained firms (0.19), and this same pattern holds for alternative measures of leasing activities as well. Third, the average debt leverage of small firms and financially constrained firms is much lower than that of large firms and unconstrained firms; however, when we adjust debt leverage by leasing, then lease-adjusted leverage ratios across different groups are fairly comparable to each other. These imply that leasing is an important source of external finance for small and financially constrained firms, and complements the financial debt. These patterns are consistent with the findings in Eisfeldt and Rampini (2009). According to US bankruptcy law, leasing has repossession advantages over secured lending. As a result, leasing has higher debt capacity and can server as an alternative way to relax financial constraints which proves valuable for constrained firms.

From our results in Table 1, we recognize that on the aggregate level, leasing accounts for a substantial portion of overall productive assets; therefore, its dynamic should significantly influence business cycle fluctuations. In the cross-section, leasing can be a more important channel of external financing activities for small and constrained firms, and it is the first-order determinant of the capital structure on firms' liability side.

2.2 Cyclical Pattern of Leased Capital

To study the variation of leased capital over business cycles, we focus on the rental share measure, which is essentially a cash-flow-based leased capital ratio [4]. In the top panel of Figure 1, we plot the time series of leased capital ratio (LCR1). In the bottom panel, we plot the cyclical components of leased capital ratio and output subtracted using the H-P filter. The output data is obtained from the website of Federal Reserve Bank of the St. Louis. The shaded areas in both panels indicate NBER-classified recessions. Clearly, the leased capital ratio rises whenever there is a recession. Also, it exhibits a strong countercyclical pattern as shown in the bottom panel, and has a negative correlation coefficient of -0.30 (t-stat=-1.97) with the cyclical component of output. Similar conclusions have been documented in Gal and Pinter (2017) and Zhang (2012).

2.3 Leasing and the Volatility of Cross-sectional Idiosyncratic Uncertainty

Christiano et al. (2014) introduces shocks to the volatility of cross-sectional idiosyncratic uncertainty into the Bernanke-Gertler-Gilchrist financial accelerator setting, and shows that time varying volatility of cross-sectional idiosyncratic uncertainty can be the most important driving force for explaining business cycles. In this section, we present evidence on the relationship between leasing activities and the volatility of cross-sectional idiosyncratic uncertainty.

To construct the uncertainty measures that are consistent with the concept of the volatility of cross-sectional idiosyncratic uncertainty in Christiano et al. (2014), we adopt a bottom-up approach. We first estimate the firm-level productivity following the procedures detailed in Ai et al. (2013), and then compute the cross-sectional standard deviation of firm-level productivity for each year as the measure of the volatility of cross-sectional idiosyncratic uncertainty. In doing so, we follow a similar approach used in Bloom (2009) and Park (2018). As a robustness check, in section 5, we construct an alternative measure using the cross-sectional dispersion of firm-level profit growth following Bloom et al.

[4] Using the capital-stock-based leased capital ratio also produces negative correlation with output, but less significant. This is because flow-based measure is naturally more sensitive to macroeconomic fluctuations, while stock-based measure is less sensitive due its time-to-build features.

(2007).

2.3.1 Aggregate-level Evidence

To show how leasing activities vary with the volatility of cross-sectional idiosyncratic uncertainty, we plot in figure 2 the cyclical components of rental share and the volatility of uncertainty obtained using the H-P filter. Clearly, the rental share and uncertainty measure both rise whenever there is a recession. Moreover they have a correlation coefficient of 0.42 (t-stat=2.82), which implies that firms lease more when volatility is high, consistent with the finding in Gavazza (2011).

2.3.2 Firm-level Analysis

To further understand how firms' leasing activity responds to the volatility of cross-sectional idiosyncratic uncertainty, we present firm-level panel regressions in this section. Our firm-level data comes from Compustat, which is available from WRDS. The details on sample selection and variable definitions are in Appendix A. The main regression specification is:

$$Y_{i,t} = \eta_i + \beta_u \text{VOL}_t + \gamma X_{i,t} + \sum_{p=0}^{G} \psi_p A_{t-p} + \epsilon_{i,t}, \tag{1}$$

in which the dependent variable $Y_{i,t}$ is firm i's rental share or leased capital ratio at year t. We include the firm fixed effect η_i to control for time-invariant, firm-specific factors that could affect capital leasing behavior. VOL_t is the the volatility of cross-sectional uncertainty at time t. $X_{i,t}$ is a vector of firm-level control variables, which includes cash flow, Tobin's Q, sales growth, asset growth, leverage ratio, firm size, and financial constraint measures. The details of the variable construction are in Appendix A. A_t include aggregate-level control variables, such as the real GDP growth rate.

In Table 2, we summarize our estimation results of equation (1). In specifications 1 and 2, the dependent variable is the leased capital ratio (LCR1), and the difference between these two specification is that we use different measures of financial constraints as the control variable. Specifically, in specification 1, we use dividend payout dummy as the financial constrain measure while in specification 2, we use the WW index as the financial constraint measure. In both specifications, we obtain significant and positive coefficients of uncertainty volatility measure (TFP dispersion). Our results are similar for the leased capital ratio (LCR2) and rental share, and the coefficients of the volatility measure are significant at the 1% level for all cases. The economic significance is also non-negligible, as a one-standard-deviation increase of the volatility measure is associated with a $4\% - 5.2\%$ increase in leased capital ratio and a $6.8\% - 6.9\%$ increase in rental share. All specifications suggest that capital leasing activities are negatively associated with current and lag GDP growth, which further prove the counter-cylcality of leasing over business cycles. Moreover, leasing activities are negatively correlated with debt leverage ratio, cash flow, sales growth, asset growth, and size, consistent with the pattern in Eisfeldt and Rampini (2009), while the relation between Tobin Q and leasing activities is relatively weaker and insignificant in most cases. For two financial constraint measures, dividend payout is strongly negatively related to leasing activities, while the WW index is strongly positively correlated with leasing measures, consistent with the fact that financially constrained firms lease more.

In summary, from the results in this section, we recognize that leasing accounts for a substantial portion of productive capital, serves as an important source of external finance for firms, exhibits counter-cyclical dynamics over business cycles, and is positively correlated with the volatility of cross-sectional idiosyncratic uncertainty in the economy. These facts motivate us to quantitatively study the macroeconomic implications of leasing in the standard model with financial frictions. The financial accelerator model in Bernanke et al. (1999) provides us with an ideal setting to study the interaction between leasing, financial frictions and volatility of uncertainty simultaneously. In our next section, we introduce capital leasing explicitly to the financial accelerator model and describe the model ingredients one by one.

3 The Model

In this section, we describe the ingredients of our quantitative general equilibrium model with capital leasing. The model closely follows the financial accelerator model as in Bernanke et al. (1999). The key difference is that we differentiate between owned capital and leased capital, so we may analyze the important role that leased capital plays with respect to business cycle fluctuations.

3.1 Household's Problem

Time is discrete and infinite. There is a continuum of identical households in this economy. Each household consists of two types of family members: workers and entrepreneurs. Workers supply labor and return wages to the household. Each entrepreneur operates a firm and transfers earnings back to the household. Thus, the household effectively owns the firm that its entrepreneur operates. Within the family, there is perfect consumption insurance, such that consumption decisions are all made by the head of the family within the same household. The household's derive utility from consumption and leisure from following utility function:

$$U\left(C_t, H_t\right) = \ln(C_t) + \zeta \ln\left(1 - H_t\right), \tag{2}$$

Every period, the individual household can save money D_t in the bank, and the period-by-period budget constraint is given by:

$$C_t + D_t = W_t H_t + R_t D_{t-1} + \Pi_t. \tag{3}$$

Where C_t is consumption, H_t is household's labor supply, W_t is wage and D_t is deposit household invest in financial intermediary. Π_t is the profit from entrepreneurs. Solving household's utility maximization problem yields two Euler equations, and the optimal condition of saving is given by:

$$\frac{1}{C_t} = E_t\left\{\beta \frac{1}{C_{t+1}}\right\} R_{t+1}, \tag{4}$$

We can further define the stochastic discount factor (SDF) as $M_{t+1} = \beta\left(\frac{C_{t+1}}{C_t}\right)^{-1}$, and we then have the standard Euler equation $1 = E_t(M_{t+1})R_{t+1}$. Additionally, the optimal labor supply implies:

$$W_t \frac{1}{C_t} = \zeta \frac{1}{1 - H_t}. \tag{5}$$

3.2 Production

There is a continuum of firms, indexed by j, in which $j \in [0,1]$. All firms produce the same final consumption goods with an identical constant return to scale Cobb-Douglas technology. Labor is perfectly mobile across firms. Each firm j produces final output Y_t^j using the following production function:

$$Y_t^j = A_t \left(\omega_t^j K_t^j\right)^{\alpha} \left(L_t^j\right)^{1-\alpha} \tag{6}$$

in which K_t^j is the total amount of capital used in production and contains two components, owned capital and leased capital; for simplicity, we assume they are perfect substitute in production such that:

$$K_t^j = K_{o,t}^j + K_{l,t}^j. \tag{7}$$

L_t^j is the labor input and represents the composite of workers' labor and entrepreneurs' labor. A_t is the aggregate productivity. The idiosyncratic shock ω_t^j affects the efficiency units of a firm's capital and transforms capital K_t^j into efficiency units $\omega_t^j K_t^j$. We assume the idiosyncratic shock ω follows a log-normal distribution with mean φ_t and standard deviation σ_t, and we further impose $\varphi_t = -\frac{1}{2}\sigma_t^2$ such that the mean of the idiosyncratic shock ω in cross-section is equal to one. As we discuss later, we allow σ_t to vary over time and follow an exogenous AR(1) process, and we interpret it as risk shock as in Christiano et al. (2014).

Due to the homogenous-of-degree-one property of the production function and freely mobile labor, all the firms will choose the same ratio of effective capital over labor, i.e $\frac{\omega_t^j K_t^j}{L^j}$ such that the marginal product of capital MPK_t will be equalized across all firms.

3.3 Entrepreneur, Creditor and Debt Contracts

Balance sheet condition At the end of period t, after production, each entrepreneur is matched with a firm indexed by j, and is then responsible for its operation at time $t+1$. To operate the firm j in the next period, the entrepreneur needs to either purchase or rent capital for use at $t+1$, while her own available resource for the expenditure is her net worth N_t^j. To finance the difference between her expenditures on capital goods and her net worth, she must borrow an amount B^j_{t+1} from a financial intermediary. The balance sheet condition is given by:

$$B^j_{t+1} + N^j_t = Q_t K^j_{o,t+1} + \tau_{l,t} K^j_{l,t+1}, \tag{8}$$

in which $K^j_{o,t+1}$ denotes the quantity of purchased capital, $K^j_{l,t+1}$ denotes the quantity of leased capital, Q_t is the price of owned capital, and $\tau_{l,t}$ is the rental fee of leased capital. Since both the owned capital and leased capital are homogeneous, their prices are the same for the entrepreneurs.

Going to period $t+1$, the entrepreneur receives the idiosyncratic shock that turns her total K^j_{t+1} into $\omega^j_{t+1} K^j_{t+1}$ effective units; after production, the entrepreneur must liquidate her own capital after depreciation $\omega^j_{t+1}(1-\delta)K^j_{o,t+1}$ to the capital good producer, and return the amount of leased capital $\omega^j_{t+1}(1-\delta)K^j_{l,t+1}$ to capital lessors. Thus, the total capital gain for entrepreneur j is $\omega^j_{t+1}\left(MPK_{t+1}K^j_{t+1} + (1-\delta)\,Q_{t+1}K^j_{o,t+1}\right)$. We define the return on owned capital as:

$$R_{K,t+1} = \frac{MPK_{t+1} + (1-\delta)\,Q_{t+1}}{Q_t}, \tag{9}$$

and the return of leased capital as:

$$R_{l,t+1} = \frac{MPK_{t+1}}{\tau_{l,t}}. \tag{10}$$

Payoff to two parties The entrepreneur's break-even condition determines the default cutoff value $\bar{\omega}^j_{t+1}$,

$$\bar{\omega}^j_{t+1}\left(MPK_{t+1}K^j_{t+1} + (1-\delta)\,Q_{t+1}K^j_{o,t+1}\right) = Z^j_{t+1}B^j_{t+1}. \tag{11}$$

Note that both Z^j_{t+1} and $\bar{\omega}^j_{t+1}$ depend on the aggregate state at time $t+1$, which leads to the lender's break even in every possible state at time $t+1$ as in Bernanke et al. (1999). When $\omega^j_{t+1} \geq \bar{\omega}^j_{t+1}$, the entrepreneur recieves:

$$N^j_{t+1} = \omega^j_{t+1}\left(MPK_{t+1}K^j_{t+1} + (1-\delta)\,Q_{t+1}K^j_{o,t+1}\right) - Z^j_{t+1}B^j_{t+1}, \tag{12}$$

while the lender recieves the loan payment $Z^j_{t+1} B^j_{t+1}$.

When $\omega^j_{t+1} < \bar{\omega}^j_{t+1}$, the entrepreneur defaults, and receives 0. Meanwhile, the bank must pay the versification cost that is proportional to the entrepreneur's payoff; therefore, in the case of an entrepreneur's default, the bank receives:

$$(1-\mu)\,\omega^j_{t+1}\left[MPK_{t+1}K^j_{t+1} + (1-\delta)Q_{t+1}K^j_{o,t+1}\right].$$

Difference between leased capital and owned capital The equation above shows the key difference between leased capital and owned capital in the model. For owned capital, both output $MPK_{t+1}K^j_{o,t+1}$ and its resale value $(1-\delta)Q_{t+1}K^j_{o,t+1}$ are subject to the bank's verification cost, but for leased capital, only its output $MPK_{t+1}K^j_{l,t+1}$ is subject to this verification cost, and the resale value $(1-\delta)Q_{t+1}K^j_{l,t+1}$ is obtained by the lessor. This difference is motivated by the fact that lessors have a repossession advantage according to US bankruptcy code, as it is much easier for a lessor to regain control of an asset than it is for a secured lender to repossess it, as discussed in Eisfeldt and Rampini (2009), Rampini and Viswanathan (2013). This advantage allows leasing to offer higher debt capacity than secured lending, thus makes leasing more attractive to financially constrained firms. Also since firms' financial constraints become tighter in bad times, so firms use more leased capital in bad times.

Lender's breakeven condition As in Bernanke et al. (1999), the value of $\bar{\omega}^j_{t+1}$ and Z^j_{i+1} under the optimal contract are determined by the requirement that the financial intermediary receives an expected return equal to the opportunity cost of its funds. Because the loan risk in this case is perfectly diversifiable, the relevant opportunity cost to the intermediary is the risk free rate, R_{t+1}. Accordingly, the loan contract must satisfy:

$$\left[1 - F_t\left(\bar{\omega}^j_{t+1}\right)\right] Z^j_{t+1} B^j_{t+1} + (1-\mu)\int_0^{\bar{\omega}^j_{t+1}} \omega^j_{t+1}\left(MPK_{t+1}K^j_{t+1} + (1-\delta)Q_{t+1}K^j_{o,t+1}\right) dF_t(\omega_{t+1}) = R_{t+1}B^j_{t+1}, \tag{13}$$

in which the left-hand side is the expected cross return on the loan to the entrepreneur and the right-hand side is the bank's opportunity cost of lending. This break even condition holds for all possible states at time $t+1$. Substituting out $Z^j_{t+1}B^j_{t+1}$ with Equation (11), we can simplify the lender's valuation equation as:

$$R_{t+1}B^j_{t+1} = \left(MPK_{t+1}K^j_{t+1} + (1-\delta)Q_{t+1}K^j_{o,t+1}\right)\left(\left[1 - F_t\left(\bar{\omega}^j_{t+1}\right)\right]\bar{\omega}^j_{t+1} + (1-\mu)\int_0^{\bar{\omega}^j_{t+1}} \omega dF_t(\omega)\right). \tag{14}$$

Entrepreneurs' optimization problem As in Bernanke et al. (1999), entrepreneurs are risk neutral. For every period, based on his/her available net worth N^j_t, the entrepreneur who operates firm j optimally chooses $\left(Z^j_{t+1}, B^j_{t+1}, K^j_{o,t+1}\right)$ to maximize the payoff in the next period:

$$E_t\left\{\int_{\bar{\omega}^j_{t+1}}^{\infty}\left[\omega_{t+1}\left(MPK_{t+1}K^j_{t+1} + (1-\delta)Q_{t+1}K^j_{o,t+1}\right) - Z^j_{t+1}B^j_{t+1}\right]dF_t(\omega)\right\} \tag{15}$$

subject to the lender's state-by-state breakeven condition in Equation (14). To simplify notation, we define two axillary functions:

$$\Gamma_t\left(\bar{\omega}^j_{t+1}\right) \equiv \int_0^{\bar{\omega}^j_{t+1}} \omega dF_t(\omega) + \bar{\omega}^j_{t+1}\int_{\bar{\omega}^j_{t+1}}^{\infty} dF_t(\omega) = G_t\left(\bar{\omega}^j_{t+1}\right) + \left[1 - F_t\left(\bar{\omega}^j_{t+1}\right)\right]\bar{\omega}^j_{t+1} \tag{16}$$

$$G_t\left(\bar{\omega}^j_{t+1}\right) \equiv \int_0^{\bar{\omega}^j_{t+1}} \omega dF_t(\omega) \tag{17}$$

We then have the share of average entrepreneurial payoff given by:

$$1 - \Gamma_t\left(\bar{\omega}^j_{t+1}\right) = \int_{\bar{\omega}^j_{t+1}}^{\infty}\left(\omega^j_{t+1} - \bar{\omega}^j_{t+1}\right)dF_t(\omega), \tag{18}$$

and the share of the average payoff to lender given by:

$$\Gamma_t\left(\bar{\omega}^j_{t+1}\right) - \mu G_t\left(\bar{\omega}^j_{t+1}\right) = \left[1 - F\left(\bar{\omega}^j_{t+1}\right)\right]\bar{\omega}^j_{t+1} + (1-\mu)\int_0^{\bar{\omega}^j_{t+1}} \omega dF_t(\omega). \tag{19}$$

Substituting out $Z^j_{t+1}B^j_{t+1}$ in the objective function with Equation (11) and using these two functions, we can write the entrepreneur's objective function and the lender's state-by-state break even condition as:

$$\max_{\bar{\omega}^j_{t+1}, K^j_{o,t+1}, K^j_{t+1}} E_t \left\{ \left(1 - \Gamma_t\left(\bar{\omega}^j_{t+1}\right)\right) \left(MPK_{t+1}K^j_{t+1} + (1-\delta)Q_{t+1}K^j_{o,t+1}\right) \right\} \tag{20}$$

$$R_{t+1}B^j_{t+1} = \left(MPK_{t+1}K^j_{t+1} + (1-\delta)Q_{t+1}K^j_{o,t+1}\right)\left(\Gamma_t\left(\bar{\omega}^j_{t+1}\right) - \mu G_t\left(\bar{\omega}^j_{t+1}\right)\right) \tag{21}$$

We replace the choice variables by $\bar{\omega}^j_{t+1}, K^j_{o,t+1}, K^j_{t+1}$ because of the linkage between $\bar{\omega}^j_{t+1}$ and Z^j_{t+1} in Equation (11), and the relationship between B^j_{t+1} and K^j_{t+1} in Equation (8).

As in Christiano et al. (2014), since the entrepreneur-specific state variable N^j_t enters the maximization problem in a linear way, we can easily normalize all the quantities $\left(K^j_{o,t+1}, K^j_{l,t+1}, B^j_{t+1}\right)$ by N^j_t, and we let the small case be the normalized quantities, $b^j_{t+1} = \frac{B^j_{t+1}}{N^j_t}$, $k^j_{o,t+1} = \frac{K^j_{o,t+1}}{N^j_t}$, $k^j_{l,t+1} = \frac{K^j_{l,t+1}}{N^j_t}$ and $k^j_{t+1} = \frac{K^j_{t+1}}{N^j_t}$. All entrepreneurs will make the same choice of $\bar{\omega}_{t+1}$, and will choose the same normalized quantities. These results allow us to achieve the aggregation on the macro level. Following these results, the leased capital ratio $\phi_t = \frac{K_{l,t+1}}{K_{t+1}}$, debt-to-net worth ratio b_t, and the leverage ratio $Lev_t = \frac{Q_t K_{t+1}}{N_t}$ will also be the same for all entrepreneurs, so we therefore omit superscript j in our following analysis.

Optimality Conditions With this simplification, we proceed to solve the maximization problem by deriving first-order conditions. We let λ_{t+1} be the Lagrangian multiplier of the break even condition. It is an ex pose variable conditioned on the realization of aggregate states. We can obtain the first-order condition with respect to $\bar{\omega}_{t+1}$ as:

$$\Gamma'_t\left(\bar{\omega}_{t+1}\right) = \lambda_{t+1}\left(\Gamma'_t\left(\bar{\omega}_{t+1}\right) - \mu G'_t\left(\bar{\omega}_{t+1}\right)\right). \tag{22}$$

The left-hand side is the marginal cost for an entrepreneur when we increase $\bar{\omega}_{t+1}$ by one unit, since it reduces an entrepreneur's share of payoff by $\Gamma'_t\left(\bar{\omega}_{t+1}\right)$. Meanwhile the right-hand side is the marginal benefit for an entrepreneur when we increase $\bar{\omega}_{t+1}$ by one unit, because an additional unit of $\bar{\omega}_{t+1}$ leads to an increase in the lender's share by $\left(\Gamma'_t\left(\bar{\omega}_{t+1}\right) - \mu G'_t\left(\bar{\omega}_{t+1}\right)\right)$, and generates marginal benefit $\lambda_{t+1}\left(\Gamma'_t\left(\bar{\omega}_{t+1}\right) - \mu G'_t\left(\bar{\omega}_{t+1}\right)\right)$ for an entrepreneur by relaxing the breakeven constraint.

Similarly, the first-order condition with respect to $k_{o,t+1}$ is given by:

$$E_t\left[\left(1-\Gamma_t\left(\bar{\omega}_{t+1}\right)\right)R_{k,t+1}\right]=E_t\left[\lambda_{t+1}\left(R_{t+1}-\left(\Gamma_t\left(\bar{\omega}_{t+1}\right)-\mu G_t\left(\bar{\omega}_{t+1}\right)\right)R_{k,t+1}\right)\right]. \tag{23}$$

The equation can be interpreted in the same way, as one unit of additional $k_{o,t+1}$ allow the entrepreneur to obtain $E_t\left[\left(1-\Gamma_t\left(\bar{\omega}_{t+1}\right)\right)R^k_{t+1}\right]$ unit of marginal benefit, although it also generates additional benefits to lender, $\left(\Gamma_t\left(\bar{\omega}_{t+1}\right)-\mu G_t\left(\bar{\omega}_{t+1}\right)\right)R^k_{t+1}$ in the next period; that said, it require the entrepreneur to borrow an additional amount with payment R_{t+1}, so the net amount multiplied by λ_{t+1} on the right-hand side is simply the marginal cost to an entrepreneur.

The first-order condition with respect to $k_{l,t+1}$ is almost identical to that of $k_{o,t+1}$, except that we must replace the return of owned capital,i.e, $R_{k,t+1}$ by the return of leased capital, i.e., $R_{l,t+1}$, so our interpretation is similar and thus omitted here.

$$E_t\left[\left(1-\Gamma_t\left(\bar{\omega}_{t+1}\right)\right)R_{l,t+1}\right]=E_t\left[\lambda_{t+1}\left(R_{t+1}-\left(\Gamma_t\left(\bar{\omega}_{t+1}\right)-\mu G_t\left(\bar{\omega}_{t+1}\right)\right)R_{l,t+1}\right)\right]. \tag{24}$$

3.4 The Capital Goods Producer

Each period, entrepreneurs will sell capital after production and depreciation, and buy new capital for the next period's production from the capital goods producer. The capital goods producer uses I_t amount of consumption goods to produce new capital with the technology $\Phi\left(\frac{I_t}{K_t}\right)K_t$, and we follow Bernanke et al. (1999) to use a standard functional form for capital production:

$$\Phi\left(\frac{I_t}{K_t}\right)=\left[\frac{a_1}{1-\frac{1}{\xi}}\left(\frac{I_t}{K_t}\right)^{1-\frac{1}{\xi}}+a_2\right]. \tag{25}$$

The law of motion of aggregate capital is then given by:

$$K_{t+1}=\Phi\left(\frac{I_t}{K_t}\right)K_t+(1-\delta)K_t. \tag{26}$$

The optimal choice of investment will pin down the price of a unit of capital Q_t, which is given by:

$$Q_t = \left[\Phi'\left(\frac{I_t}{K_t}\right)\right]^{-1} = \frac{1}{a_1}\left(\frac{I_t}{K_t}\right)^{\frac{1}{\xi}}. \tag{27}$$

3.5 The Capital Lessor

A competitive lessor maximizes profits taking the equilibrium leasing fee τ_l and capital price Q as given. To provide an amount of capital $K_{l,t+1}$ to the entrepreneur as the lessee, the lessor must purchase the capital $K_{l,t+1}$ at the price Q_t at time t. Since there is no deadweight cost when the lessor repossesses the capital, without a loss of generality, we can assume that all leased capital is repossessed and the lessor will be able to sell the amount of capital $K_{l,t+1}(1-\delta)$ at a price of Q_{t+1} at the end of the next period, $t+1$. We further assume the lessor must pay the monitoring cost $Q_t\Theta\left(K_{l,t+1}, K_{t+1}\right)$ upfront at time t to make sure the lessee takes good care of leased capital $K_{l,t+1}$ in period $t+1$. This is consistent with the agency problem due to the separation of ownership and control rights.

Discounting future cash flows over the lessor's entire lifetime, the lessor's optimization problem is characterized as follows:

$$\max_{\{K_{l,i+1}\}_{i=t}^{\infty}} E_t \sum_{i=t}^{\infty} M_{t,i}\left(\tau_{l,i}K_{l,j+1} - Q_i K_{l,i+1} - Q_j\Theta\left(K_{l,t+1}, K_{t+1}\right) + E_i\left\{M_{i,i+1}Q_{i+1}K_{l,i+1}\left(1-\delta\right)\right\}\right). \tag{28}$$

Without a loss of generality, we impose the functional form of $\Theta\left(K_{l,t+1}, K_{t+1}\right)$ as follows:

$$\Theta\left(K_{l,t+1}, K_{t+1}\right) = \kappa K_{l,t+1} + \frac{d}{2}\left(\frac{K_{l,t+1}}{K_{t+1}} - \frac{K_l^{ss}}{K^{ss}}\right)^2 K_{t+1}, \tag{29}$$

in which K_l^{ss} and K^{ss} are the steady state value of leased capital and total capital stock[5]. Solving the lessor's optimization problem leads to the following optimality condition:

$$\tau_{l,t} = Q_t + Q_t\Theta'\left(K_{l,t+1}, K_{t+1}\right) - \left(1-\delta\right)E_t\left[M_{t+1}Q_{t+1}\right], \tag{30}$$

[5] In the quantitative analysis, we calibrate parameter κ and d to match the volatility of a relatively smooth leased capital ratio at the aggregate level.

in which $\Theta'(K_{l,t+1}, K_{t+1}) = \kappa + d\left(\frac{K_{l,t+1}}{K_{t+1}} - \frac{K_l^{ss}}{K^{ss}}\right)$. The leasing fee per unit of capital, or the user cost of leasing, is equal to the current price, Q_t, and the marginal monitoring cost $Q_t\Theta'(K_{l,t+1}, K_{t+1})$, minus the discounted resale value after depreciation $(1-\delta)E_t[M_{t+1}Q_{t+1}]$.

3.6 Aggregation

Due to the homogeneity-of-degree-one property of the production function, the aggregate level output can be written as:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \tag{31}$$

in which $K_t = \int_j \omega_t^j K_t^j dj$ is the aggregate capital stock, and $L_t = \int_j L_t^j dj$ is the aggregate labor input. Thus, we can write the marginal product of capital as:

$$MPK_t = \frac{\alpha Y_t}{K_t}. \tag{32}$$

As a technical matter, to guarantee that each entrepreneur starts with a positive amount of net worth, i.e. $N_t^j > 0$ for all j, we follow Bernanke et al. (1999) to assume that each entrepreneur can supply one unit of labor H_t^e to the firm and collect some wage payment W_t^e for each period. Thus, the total labor input L_t is taken to be the following composite of household labor, H_t, and "entrepreneurial labor", H_t^e:

$$L_t = H_t^{\Omega}\left(H_t^e\right)^{1-\Omega} \tag{33}$$

The associated wage rate for household labor is given by:

$$W_t = (1-\alpha)\,\Omega\frac{Y_t}{H_t}, \tag{34}$$

and the wage rate for entrepreneur labor is given by:

$$W_t^e = (1-\alpha)(1-\Omega)\frac{Y_t}{H_t^e}. \tag{35}$$

To avoid the situation in which entrepreneurs accumulate enough wealth such that they do not need external finance, we assume that entrepreneurs will experience a liquidation shock with probability $1-\chi$ for each period. If a liquidation shock happens, then the entrepreneur will have to liquidate his net worth and return it back to the household. Thus, on the aggregate level, the total net worth's law of motion is given by:

$$N_t = \chi \left(1 - \Gamma_{t-1}\left(\bar{\omega}_t\right)\right)\left(MPK_t K_t + (1-\delta) Q_t K_{o,t}\right) + W_t^e \tag{36}$$

in which the first component on the right-hand side is the total profit from the operation of all surviving firms, and the second component is the total wage payment for all entrepreneurs.

3.7 The Competitive Equilibrium

A competitive equilibrium is a set of quantities for the household $\{C_t, D_t, H_t\}_{t=0}^{\infty}$, quantities for entrepreneurs $\left\{N_t^j, K_t^j, B_t^j, K_{o,t}^j, K_{l,t}^j, \bar{\omega}_t^j\right\}_{t=0}^{\infty}$, quantities for the bank $\{B_t\}_{t=0}^{\infty}$, quantities for the capital goods producer $\{I_t, K_t\}_{t=0}^{\infty}$ and prices $\{R_t, Q_t, \tau_{l,t}, R_{K,t}, R_{l,t}\}_{t=0}^{\infty}$, such that given prices, these quantities solve the household's, bank's, capital goods producer's and entrepreneurs' maximization problems, maximize firms' profits, and clear the market. The market clearing conditions are:

$$K_t = \int_j K_t^j dj, \tag{37}$$

$$H_t = \int_j H_t^j dj, \tag{38}$$

$$L_t = \int_j L_t^j dj, \tag{39}$$

$$D_t = B_t = \int_j B_t^j dj, \tag{40}$$

$$Y_t = C_t + I_t + \mu \int_0^{\overline{\omega}_t} \omega dF\left(\omega\right)\left(MPK_t K_t + (1-\delta) Q_t K_{o,t}\right) + Q_t \Theta\left(K_{l,t+1}, K_{t+1}\right) \tag{41}$$

4 Quantitative Predictions of the Model

In this section, we calibrate the model at quarterly frequency and evaluate its ability to replicate key moments of both macroeconomic quantities at the aggregate level. More importantly, we study the cyclical pattern of leased capital, and quantify its mitigation effects relative to the model without leasing.

4.1 Specification of Aggregate Shocks

In this section, we formalize the specification of the exogenous aggregate shocks in this economy. First, we assume that the natural log of aggregate productivity $\ln(A_t)$ follows:

$$\ln\left(A_t\right) = \rho_A \ln\left(A_{t-1}\right) + \sigma_A \epsilon_{A,t}, \tag{42}$$

in which $\rho_A \in (0,1)$ is the persistence parameter, σ_A is the standard deviation of the shock, and $\epsilon_{A,t}$ is a white noise term.

Second, as shown by Christiano et al. (2014), fluctuations in the volatility of cross-sectional idiosyncratic uncertainty σ_t are the most important shocks driving business cycles. We introduce this risk shock into our model, so we may study how leasing activities change in response to risk shocks, and also quantify its mitigation effects. Specifically, we assume an AR(1) process for σ_t as follows:

$$\ln(\sigma_t) - \ln(\overline{\sigma}) = \rho_\sigma \left(\ln(\sigma_{t-1}) - \ln(\overline{\sigma})\right) + \sigma_\sigma \epsilon_{\sigma,t}. \tag{43}$$

We further assume that the innovation terms of two shocks are correlated such that:

$$\begin{bmatrix} \epsilon_{A,t+1} \\ \epsilon_{\sigma,t+1} \end{bmatrix} \sim \text{Normal}\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho_{A,\sigma} \\ \rho_{A,\sigma} & 1 \end{bmatrix} \right) \tag{44}$$

in which the parameter $\rho_{A,\sigma}$ captures the correlation between these two shocks. In the benchmark calibration, we set $\rho_{A,\sigma} = -1$, meaning that a negative productivity shock is associated with a positive risk shock. This assumption is necessary to generate a positive correlation between consumption and investment growth that is consistent with our data. If only the risk shock is considered, given that capital stock is predetermined, output will have a smaller response then investment, as a result, the market clearing condition implies a counter-factually negative correlation between consumption and investment growth. Additionally, the assumption of perfect correlation is for parsimony's sake and enables the economy to effectively narrow down to one shock.

4.2 Calibration

We calibrate the model at quarterly frequency and present our parameters in Table 3. We categorize the parameters into three groups. The first group contains parameters that can be obtained from the previous literature. In particular, we set the capital share parameter α to 0.35, as in the standard real business-cycle literature. We follow Bernanke et al. (1999) and set parameter Ω to 0.9846 such that entrepreneurs' income share $(1-\alpha)(1-\Omega)$ is roughly 0.01 so that the inclusion of entrepreneur labor does not have a significant directly effect on our results.

The parameters in the second group are determined by matching the first moments of quantities and prices. We set the time discount parameter β to 0.995 to generate a low average real risk-free rate of 2% per year. The depreciation rate parameter δ is set to be 0.025 such that the annual capital depreciation rate is 10%, consistent with the real business cycle literature. We set the leisure utility parameter ζ to be 2.8 such that the implied labor supply elasticity is equal to 3, in line with the literature. Additionally, we choose parameters to jointly target the following steady state outcomes: 1) an annual risk spread, $R_k - R$, of around 250 basis points; 2) a leased capital ratio of 0.35, consistent with what we find in the data; 3) an annualized business failure, $F(\bar{\omega})$, of 3.5%, consistent with the data; and 4) the steady state debt-to-net worth ratio B/N of 1, approximately in line with the data. To obtain these steady state values, we set the survival rate of entrepreneur γ to be 0.98, set the steady state volatility of idiosyncratic ω shock $\bar{\sigma}$ to be 0.256, and set the fraction of monitoring cost μ to be 0.12, which is within the reasonable range discussed in Carlstrom and Fuerst (1997). We also set the monitoring cost parameter d of lessor to be 0.1.

The parameters in the third group are determined by second moments in our data. We set the persistence parameter of TFP shock ρ_A to 0.98, and set the persistence parameter of risk shock to 0.985, so that we may roughly match the auto-correlation of output growth.

As we discussed above, we impose a perfectly negative correlation between productivity and risk shock, meaning that $\rho_{A,\sigma} = -1$. The volatility parameter of TFP shocks and risk shocks are jointly determined to match the volatilities of consumption growth and output growth. The capital adjustment cost parameters are calibrated as in Jermann (1998), and the key parameter ξ is set to 2 to generate a high volatility of investment growth, which is broadly in line with our data.

4.3 Aggregate Moments

We solve the model using a second-order local approximation around the steady state, and the solution is computed using the Dynare++ package. We first solve and simulate the model for each quarter, then we aggregate the model-generated data to compute the annual moments. In Table 4, we present the key moments generated by the model and the counterpart computed from our data. We consider two models: the benchmark model is the full model with leased capital, while the no-leasing model is the model without leasing. As we can see, the model-simulated data are broadly consistent with the basic features of the aggregate macro-economy in terms of volatility, as well as in terms of correlations and persistence of output, consumption and investment. Specifically, our model produces a low volatility of consumption growth (2.61%), and a high volatility of investment growth (10.27%). Our model also almost replicate the mean of investment to output ratio and consumption to output ratio that are not the targets in calibration. Moreover, our model also matches well to the mean and volatility of leased capital ratio in the data.

Comparing the moments generated by the benchmark model with those of the no-leasing model can shed light on the mitigation effects provided by leasing. When we shut down the leasing channel, the volatility of consumption and investment increased by 21.8% (from 2.61 to 3.18) and 3.8% (from 10.27 to 10.66), respectively. This demonstrates the quantitatively important role that leasing activity plays in mitigating the financial accelerator effects.

Overall, our model maintains the success of real business cycle models in accounting for the dynamics of macroeconomic quantities, and allowing for leasing can significantly reduce the volatility of investment and output growth.

4.4 Impulse Response Analysis

In this section, we present impulse response functions of our model to show the dynamic of key macroeconomic variables in response to negative TFP shocks and positive risk shocks. Also, we quantitatively evaluate the mitigation effects of leasing by comparing the impulse response functions of the benchmark model to the model without leasing.

4.4.1 Dynamic Effects of TFP Shocks

We start with the response to negative TFP shocks. In Figure 3, we plot the percentage deviation of quantities and prices from the steady states in response to a negative TFP shock in period 1. Model parameters are calibrated as in Table 3.

Four sets of results emerge from Figure 3. First, in response to a negative TFP shock, the leased capital increases while the owned capital decreases, which leads to the positive responses of the leased capital ratio; in other words, our model replicates the counter-cyclical pattern of leased capital ratio.

Second, output and investment immediately drop in response to negative productivity shocks and remain persistently below steady states as in standard macro models. Additionally, the decline in demand for capital immediately reduces capital prices, and the lower capital price and marginal product of capital lead to negative response of entrepreneurs' net worth. Moreover, if we compare the red line with the black line, we observe a weak mitigation effects: the output, investment, and capital price all decrease by less in the model with leasing, while the net worth in the model with leasing decreases by less yet recovers more slowly than the net worth in the model without leasing. This is exactly due to the counter-cyclical pattern of the leased capital ratio, the increased use leased capital mitigates the negative effects on investment and capital stocks, thereby mitigating the decline in outputs, capital price, and net worth. However, in response to productivity shocks, the mitigation effect is weak, which is not surprising, because the macroeconomic literature well establishes that TFP shock alone can not generate enough variation in net worth such that we might only observe weak amplification effects; therefore, the mitigation effects are not strong as well.

Third, in response to negative productivity shocks, the default probability increases, and the breakeven constraint becomes tighter such that the Lagrangian multiplier increases. The increased use of leased capital mitigates the rise of both default probability and the tightness of constraint, but the effects are relatively small.

Fourth, as in Bernanke et al. (1999), we observe counter-cyclical leverage and external finance premium, which is central to generating the financial accelerator effects. In response to negative productivity shocks, the leverage increases because net worth decreases by more than debt, which derives up external finance premium and makes it more difficult for firms to raise external funds. In the model with leasing, negative productivity shocks make firms switch from purchasing owned capital with secured lending to leasing capital, which reduce debt further. In turn, this shift in demand for debt makes the leverage and external finance premium less responsive to negative shocks.

4.4.2 Dynamic Effects of risk shocks

We next study the dynamic effects of risk shocks. In Figure 4, we plot the percentage deviation of quantities and prices from the steady states in response to a positive risk shock in period 1. Model parameters are calibrated as in Table 3.

Four sets of results emerge from Figure 4. First, in response to a positive risk shock, the leased capital increases while owned capital decreases, which leads to the positive responses of leased capital ratio; in other words, our model replicates the positive comovement between the leased capital ratio and the volatility of cross-sectional idiosyncratic uncertainty.

Second, when the volatility of uncertainty rises, the effective payoff from capital investment becomes lower and depresses investment and labor demand, such that output drops. Comparing the black line with the red line in Figure 4, we observe strong mitigation effects when we introduce leased capital into our model. In the model without leasing, in period 1, the output drops by 0.87%, and investment drops by 4.9%, but in the model with leasing, the drops in output (0.56%) and investment (3.7%) are much smaller, these patterns persist for more than 10 periods. This is due to the increase in leased capital ratio (i.e., a 6.8% increase in period 1, which persists over time), as a result, the total decline in demand for capital decreases by less, and investment also decreases by less. As a result, the capital price decreases by less, which implies that the net worth decrease by less as well.

Third, in response to positive risk shocks, the default probability increases due to the increase in cutoff value $\bar{\omega}_t$ and the shift in distribution of ω. At the same time, the breakeven constraint becomes tighter such that the Lagrangian multiplier increases. The increased use of leased capital significantly mitigates the increase in default probability and the Lagrangian multiplier, highlighting the role that leasing plays in relaxing financial constraints.

Fourth, we observe counter-cyclical leverage and external finance premium, which are central for generating the financial accelerator effects. In response to negative productivity shocks, the leverage increases because net worth decreases by more than debt, which derives up external finance premium and makes it more difficult for firms to raise external funds. In the model with leasing, positive risk shocks make firms switch from purchasing owned capital with secured lending to leasing capital; thus, the debt decreases by more, as a result, the shift in demand for debt makes the external finance premium less responsive.

4.5 Buy versus Lease Decisions

We now follow Jorgenson (1963) and derive the user cost for both owned capital and leased capital. For owned capital, the user cost $\tau_{o,t}$ can be written as:

$$\begin{aligned} \tau_{o,t} &= Q_t - \frac{E_t\left\{\left[\left(1-\Gamma_t\left(\bar{\omega}_{t+1}\right)\right)+\lambda_{t+1}\left(\Gamma_t\left(\bar{\omega}_{t+1}\right)-\mu G_t\left(\bar{\omega}_{t+1}\right)\right)\right](1-\delta)Q_{t+1}\right\}}{E_t\left(\lambda_{t+1}\right)R_{t+1}} \\ &= \frac{E_t\left\{\left[\left(1-\Gamma_t\left(\bar{\omega}_{t+1}\right)\right)+\lambda_{t+1}\left(\Gamma_t\left(\bar{\omega}_{t+1}\right)-\mu G_t\left(\bar{\omega}_{t+1}\right)\right)\right]MPK_{t+1}\right\}}{E_t\left(\lambda_{t+1}\right)R_{t+1}} \end{aligned} \tag{45}$$

The right-hand side of the first equality comes from the definition. The user cost of owned capital is the price Q_t one must pay today minus the discounted resale value in the next period, due to the fact that the resale value of owned capital is shared by entrepreneurs and lenders, and the payoff to lenders can generate value for entrepreneurs by relaxing the break even constraint, so that the total expected payoff for entrepreneurs takes the complicated form as in the numerator of the term following Q_t. Also due to the presence of break even constraints, we must discount the future payoff by $E_t\left(\lambda_{t+1}\right)R_{t+1}$.

The second equality is derived from the first-order condition with respect to $k_{o,t+1}$, and the expression denotes the net benefit that one unit of owned capital can generate in time

$t+1$ discounted into present value with the augmented discount factor $E_t(\lambda_{t+1}) R_{t+1}$. An optimal choice of capital implies the net cost (the user cost) of the marginal unit of owned capital should equal the net benefit that it can generate.

Following the same logic, the optimal choice of leased capital should imply that the user cost of leased capital $\tau_{l,t}$ is equal to the net benefit that the unit of capital can generate; that is:

$$\begin{aligned}\tau_{l,t} &= \frac{E_t\left\{\left[\left(1-\Gamma_t\left(\bar{\omega}_{t+1}\right)\right)+\lambda_{t+1}\left(\Gamma_t\left(\bar{\omega}_{t+1}\right)-\mu G_t\left(\bar{\omega}_{t+1}\right)\right)\right] MPK_{t+1}\right\}}{E_t\left(\lambda_{t+1}\right) R_{t+1}} \\ &= Q_t + Q_t\Theta'\left(K_{l,t+1}, K_{t+1}\right) - (1-\delta) E_t\left[M_{t+1}Q_{t+1}\right].\end{aligned} \tag{46}$$

It is immediate that Equation (46) and Equation (45) imply that $\tau_{O,t} = \tau_{l,t}$, which should happen in the equilibrium with both owned capital and leased capital; otherwise entrepreneurs will not use the one with a higher user cost. Given this result, after plugging in the expression of $\Theta'\left(K_{l,t+1}, K_{t+1}\right)$, we obtain the following expression for leased capital ratio:

$$Q_t\Theta\left(K_{l,t+1}, K_{t+1}\right)' = (1-\delta)\left[E_t\left(M_{t+1}Q_{t+1}\right) - E_t\left(\tilde{M}_{t+1}Q_{t+1}\right)\right] \tag{47}$$

for which we have defined an alternative discount factor $\tilde{M}_{t+1}$ from the entrepreneur's perspective:

$$\tilde{M}_{t+1} = \frac{\left[\left(1-\Gamma_t\left(\bar{\omega}_{t+1}\right)\right)+\lambda_{t+1}\left(\Gamma_t\left(\bar{\omega}_{t+1}\right)-\mu G_t\left(\bar{\omega}_{t+1}\right)\right)\right]}{E_t\left(\lambda_{t+1}\right) R_{t+1}}. \tag{48}$$

The term on the right-hand side of Equation (47) is the marginal benefit of leasing, while the term on the left-hand side is the marginal agency cost associated with leasing. The optimal leased capital ratio is obtained when the marginal cost and marginal benefit are equalized. If we log-linearize Equation (47) around the steady state, we obtain:

$$\frac{\phi_{ss} d}{\kappa}\hat{\phi}_t = \widehat{Benefit}_t - \hat{Q}_t, \tag{49}$$

in which $\hat{\phi}_t$, $\widehat{Benefit}_t$ and $\hat{Q}_t$ are the percentage deviation of leased capital ratio, the benefit of leasing $Benefit = (1-\delta)\left[E_t\left(M_{t+1}Q_{t+1}\right) - E_t\left(\tilde{M}_{t+1}Q_{t+1}\right)\right]$ and capital price Q_t from their corresponding steady states. ϕ_{ss} is the steady state leased capital ratio, and κ and d are two parameters in the lessor's monitoring cost function. From Equation (49), we can see that both the increase in benefit and the reduction in cost can contribute to the increase in leased capital ratio. To quantify their contributions, we plot in Figure 5 the impulse response functions of the benefit term and the negative capital price (reduction in cost) to both TFP shock and risk shock. As we show in Figure 5, both in panels (a) and (b), the increase in benefit completely dominates the reduction in cost, and contributes to around 83% and 85% increase in leased capital ratio in response to TFP shocks and risk shocks, receptively.

To further understand the dynamic of the benefit term, we decompose the benefit term and obtain the following:

$$Benefit = (1-\delta)\left[\left(\frac{1}{R_{t+1}} - \frac{1}{R^I_{t+1}}\right) E_t\left(Q_{t+1}\right) + \left(Cov(M_{t+1}, Q_{t+1}) - Cov(\widetilde{M}_{t+1}, Q_{t+1})\right)\right], \tag{50}$$

in which $R^I_{t+1} = \frac{1}{E_t\left(\widetilde{M}_{t+1}\right)}$ is defined as a shadow interest rate for the borrowing and lending among entrepreneurs, and R_{t+1} is the risk-free rate determined by the household stochastic discount factor M_{t+1}.

The increase in this benefit comes from two channels. Firstly, in response to bad economic conditions, the financial constraint becomes more binding, cheaper household debt becomes inaccessible, and the shadow rate R^I_{t+1} increases relative to risk-free rate. Mathematically, then, the first term on the right-hand side of Equation (50) increases, economically, as documented in Eisfeldt and Rampini (2009) and Rampini and Viswanathan (2010, 2013), since leasing can save a premium on the borrowing cost for entrepreneurs, its benefit increases. Secondly, the dynamic of $\tilde{M}_{t+1}$ driven by the variation of tightness of constraint and default cutoff implies a higher "effective risk aversion" for entrepreneurs compared to that of households; as a result, the difference between two covariances increases in bad times, and this increase reflects the "cheap" insurance benefit of leasing as emphasized in Li and Tsou (2019).

5 Empirical Evidence

In this section, we present empirical evidence to further support our model predictions.

5.1 Cross-sectional Tests

As we show in our model, leasing activity increases in bad economic states because it provides firms with an alternative way to relax tightened financial constraints. If we bring this argument to the cross-section of firms, we should observe at the firm level that in response to increase in volatility of uncertainty, the financially constrained firms will increase leasing activities by more. To test this implication, we study the interaction between the firm-level financial constraint measure and the volatility of uncertainty. We add the interaction terms between firms' financial constraint indicator and uncertainty volatility measure into equation (1). In Table 5, we present our results of the cross-sectional tests.

Our results strongly support our arguments. For the interaction term between the WW index dummy and uncertainty volatility, we have significant positive coefficients indicating that high WW index firms (more constrained) increase leasing activities by more in response to greater volatility. With respect to the dividend payout dummy, we have strongly significant negative coefficients for the interaction terms, indicating that firms that pay dividends (less constrained) increase leasing activities by less.

Next, we explore the role of heterogeneity in capital leasing activities. All things equal, firms with more flexible leasing contracts should increase leasing activities by more in response to higher uncertainty volatility. To test this prediction, we construct the firm-level lease commitment duration to proxy the flexibility of a firm's leasing contracts. A lower lease commitment duration for a firm means that such a lessee firm has committed a fixed flow of lease payment into the far future, therefore, implies a lower operating leverage effect. We add the interaction term between uncertainty volatility and firms' commitment duration into the baseline regression. We present our results in Table 6.

As we see in Table 6, we obtain positive and significant coefficients for the interaction terms for all three measures of leasing activities and across all different specifications. In specification (1), the coefficient of the interaction term indicates that when a firm has a one-standard-deviation of higher commitment duration, its leased capital ratio response to uncertainty volatility by more than 6.8% (0.03 divided by 0.44). Our results are similar for our other specifications. Overall, our results are consistent with our prediction that firms with more flexible leasing contracts increase leasing activities by more when uncertainty increases.

5.2 Credit Spread and Rental Share

In this section, we present our empirical analysis of the relationship between cash-flow-based leased capital ratio and credit spread, both in our actual data and in the model-simulated data.

The key mechanism of the mitigation effects is the increased use of leased capital when financial constraints become tighter in bad states. Credit spread is a widely used measure for financial market conditions (e.g., Gilchrist and Zakrajšek (2012)), and it is strongly counter-cyclical; hence, establishing the relationship between credit spread and leased capital ratio can be a direct test for our theory.

To do so, we run time series regressions using both our actual data and model-simulated data of credit spread and leased capital ratio. In our actual data, the credit spread is the difference in yield between BAA and AAA rated bonds, and the leased capital ratio is cash-flow-based rental share. We also consider several standard predictors for credit spread and macroeconomic conditions, such as the aggregate leverage, the risk-free rate, and the output growth rate. Detailed data description can be found in Appendix A. Since our leased capital ratio measure has an annual frequency and the data quality is relatively poor before the early 1980s, we end up with a short time series sample with yearly data from 1985 to 2018. To draw direct comparison, we simulate our model for each quarter and then aggregate the data to annual level; thereafter, we use the counterpart variables from our simulated data to run the same regressions.

We present our results in Table 7. In column (1), we regress credit spread on the contemporaneous period leased capital ratio, and in column (2), we add the aggregate leverage, risk-free rate and output growth as controls into our baseline regression. As we can see, credit spread is positively related to leased capital ratio, but the coefficients are insignificant. Considering the fact that we only have a short sample, these results are understandable. We repeat the same regressions using simulated data in columns (3) and (4), and we obtain significant positive coefficients for leased capital ratio in both cases, a one-standard-deviation increase in the leased capital ratio is associated with a 0.96 to 0.99 standard deviation increase in credit spread. In columns (5) and (6), we consider alternative regression specifications; specifically, we regress leased capital ratio on a one year lagged credit spread with or without controls. Even in the short sample with only 32 observations, we obtain positive coefficients that are significant at the 1% level; economically, a one-standard-deviation increase in credit spread predicts a 0.33-0.48 standard deviation increase in the leased capital ratio in the next year, and this time delay is likely due to the fact that capital may simply take time to build. Again, we repeat the same regressions using simulated data in columns (7) and (8), and we obtain significant positive coefficients as in the data. Although the magnitude is somewhat different, this difference is driven by the one-factor natural of our model, in which we only have one aggregate shock that derives variation in the leased capital ratio and credit spread [6]. While the situation in reality is much more complicated, the two variables in our simulated data have a stronger correlation than that in our actual data.

5.3 Robustness

In this section, we show that our empirical results are robust to an alternative measure of uncertainty volatility. To be consistent with the concept of risk shocks, we follow Bloom et al. (2007) to measure uncertainty volatility by the cross-sectional dispersion of firm-level profit growth.

First, we replace the TFP dispersion measure with the profit growth dispersion measure in the main specification, and show that the results in Table 2 are robust to alternative measure. The results are presented in Table 8. As we can see, we obtain a positive relationship between profit growth dispersion and firm-level leasing activities, and a one-standard-deviation increase in profit growth dispersion is associated with a $1.2\%-1.6\%$ increase in leased capital ratios. Since profit growth dispersion is more volatile than TFP dispersion, we have similar results for two cases. For other control variables, our results are almost identical in two cases. Second, we repeat our cross-sectional tests in Table 5 and 6 using the alternative measure of uncertainty volatility. We present our results in Table 9 and 10. Overall, the results are consistent with our predictions, and are even stronger when compared to the case with TFP dispersion.

[6] Although we have consider two shocks, but TFP shock and risk shock are perfectly correlated.

6 Conclusion

As an important proportion of productive assets and alternative external finance, leased capital has largely been ignored in the macroeconomic literature, due to the fact that it does not show up on firms' balance sheets under previous lease accounting standards. In this paper, we document that leased capital accounts for about 20% of the total physical productive assets among US publicly listed firms, and the proportion is more than 40% among small and financially constrained firms. The lease capital ratio exhibits a strong counter-cyclical pattern over business cycles and a strong positive correlation with the volatility of cross-sectional idiosyncratic uncertainty. We explicitly introduce firms' lease versus buy decisions into the stylized Bernanke-Gertler-Gilchrist financial accelerator model setting, and quantitatively show that the increased use of leased capital in bad states when financial constraints are tighter mitigates the financial accelerator effects and thus weakens the negative response of macroeconomic variables to negative TFP shocks and positive risk shocks. We provide empirical evidence to support our arguments; specifically, we show that financially constrained firms increase leasing by more when the volatility of cross-sectional idiosyncratic uncertainty increase, and that firms with more flexible leasing contracts measured by small commitment duration increase leasing by more as well. We also show that leased capital ratio and credit spread have a positive correlation and that the credit spread can significantly predict one-year ahead leased capital ratio, likely due to the fact that the capital may simply take time to build.

Figure 1

Capital Leasing: Time Series Variations and Cyclical Patterns

This figure shows the dynamic of rental share over time and over business cycles. In the top panel, we plot the leased capital ratio level over time. In the bottom panel, we plot the cyclical component of the H-P filtered leased capital ratio and log GDP. The blue line denotes the cyclical component of leased capital ratio. The red line denotes the cyclical component of log GDP. Shaded areas denote NBER business cycle recessions.

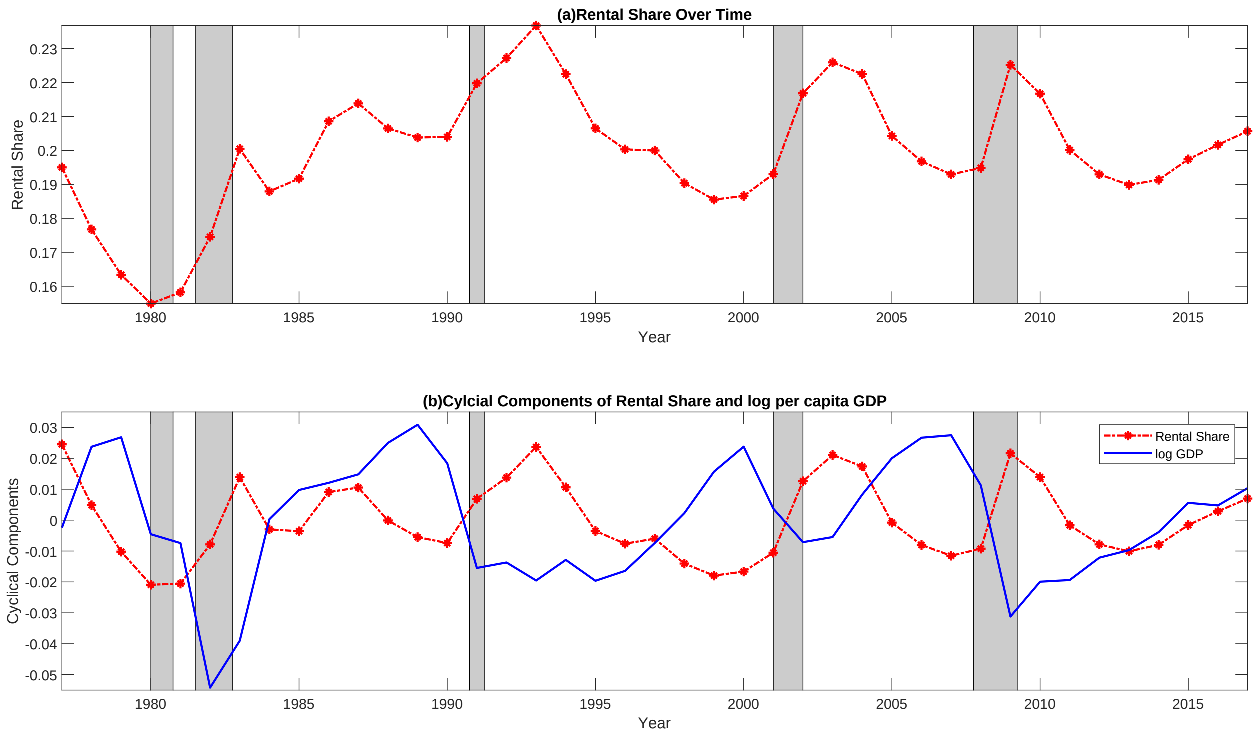

Figure 2

Capital Leasing and the Volatility of Cross-sectional Idiosyncratic Uncertainty

This figure plots the cyclical component of H-P filtered rental share and our volatility measure, the cross-sectional dispersion of firm-level productivity computed by following Ai et al. (2013). The red line denotes the cyclical component of rental share. The blue line denotes the cyclical component of volatility measure. Shaded areas denote NBER business cycle recessions.

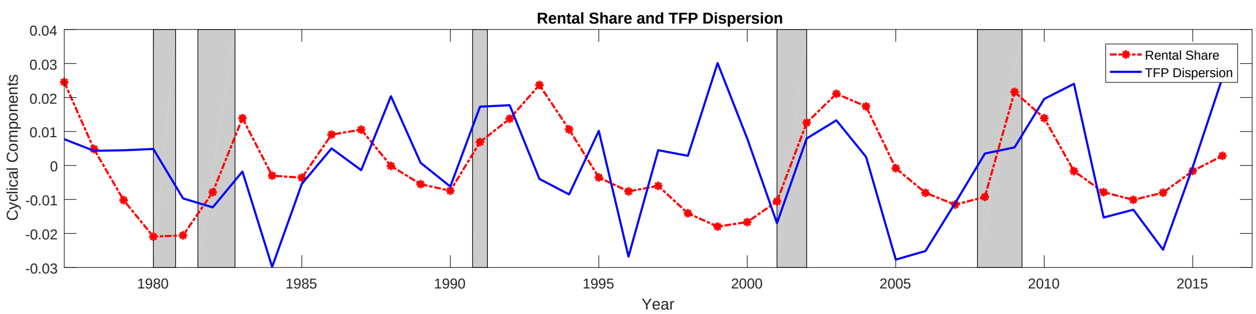

Figure 3

Impulse Response to the Negative TFP Shock

This figure plots the percentage deviation of TFP a, leased capital ratio ϕ, output Y, investment I, net worth N, capital price Q, default probability $F(\bar{\omega})$, Lagrangian multiplier λ, leverage ratio L, and external finance premium $E_t(R^k_{t+1}/R_{t+1})$. One period is a quarter. Model parameters are calibrated as in Table 3. The red dashed line denotes the model with leasing, and the black dashed line denotes the model without leasing.

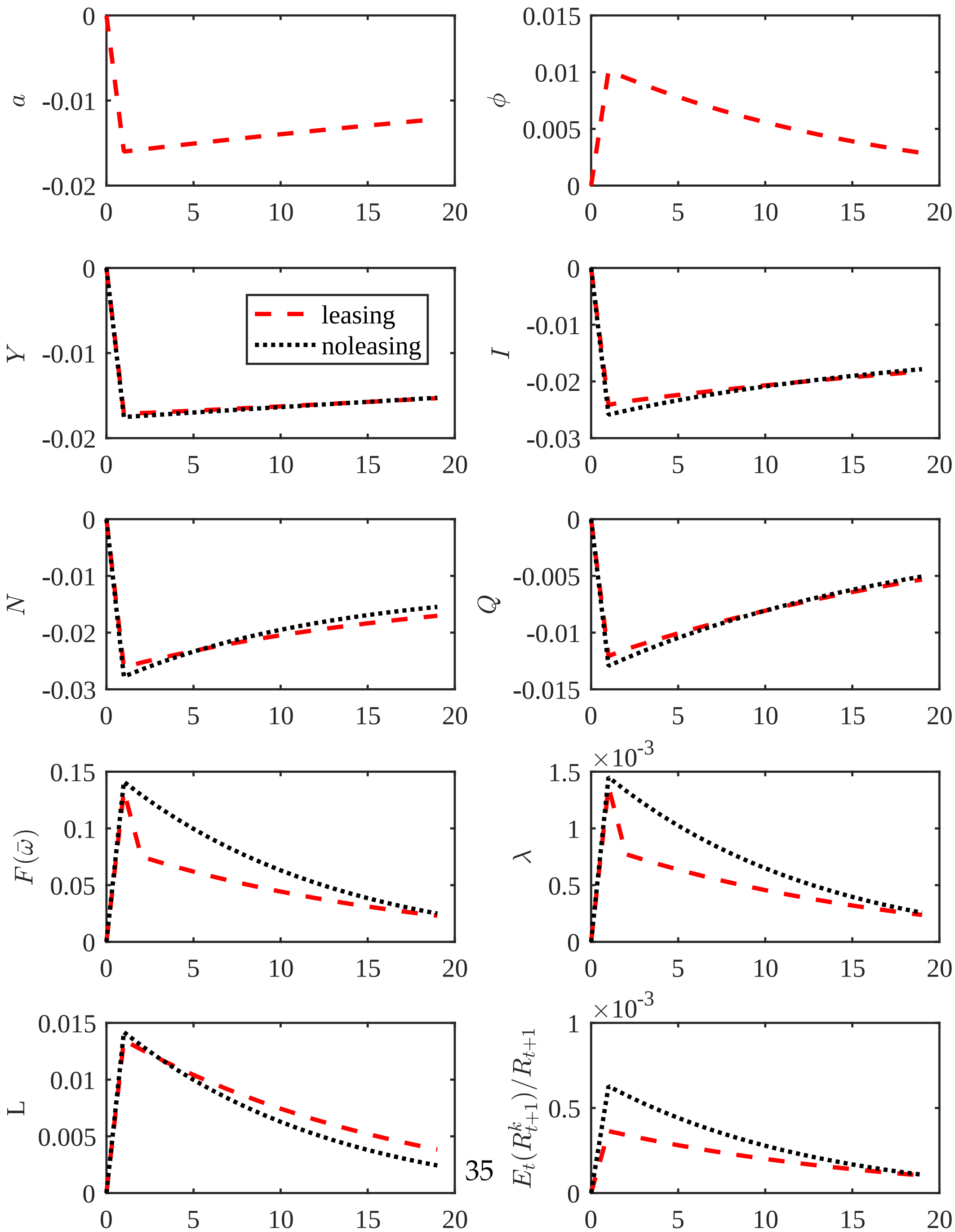

Figure 4

Impulse Response to Risk Shocks

This figure plots the percentage deviation from the steady state for σ_t, leased capital ratio ϕ, output Y_t, investment I_t, net worth N_t, capital price Q_t, default probability $F(\bar{\omega}_t)$, Lagrangian multiplier λ_t, leverage ratio L_t and external finance premium $E_t(R^k_{t+1})/R_{t+1}$. One period is a quarter. Model parameters are calibrated as in Table 3.

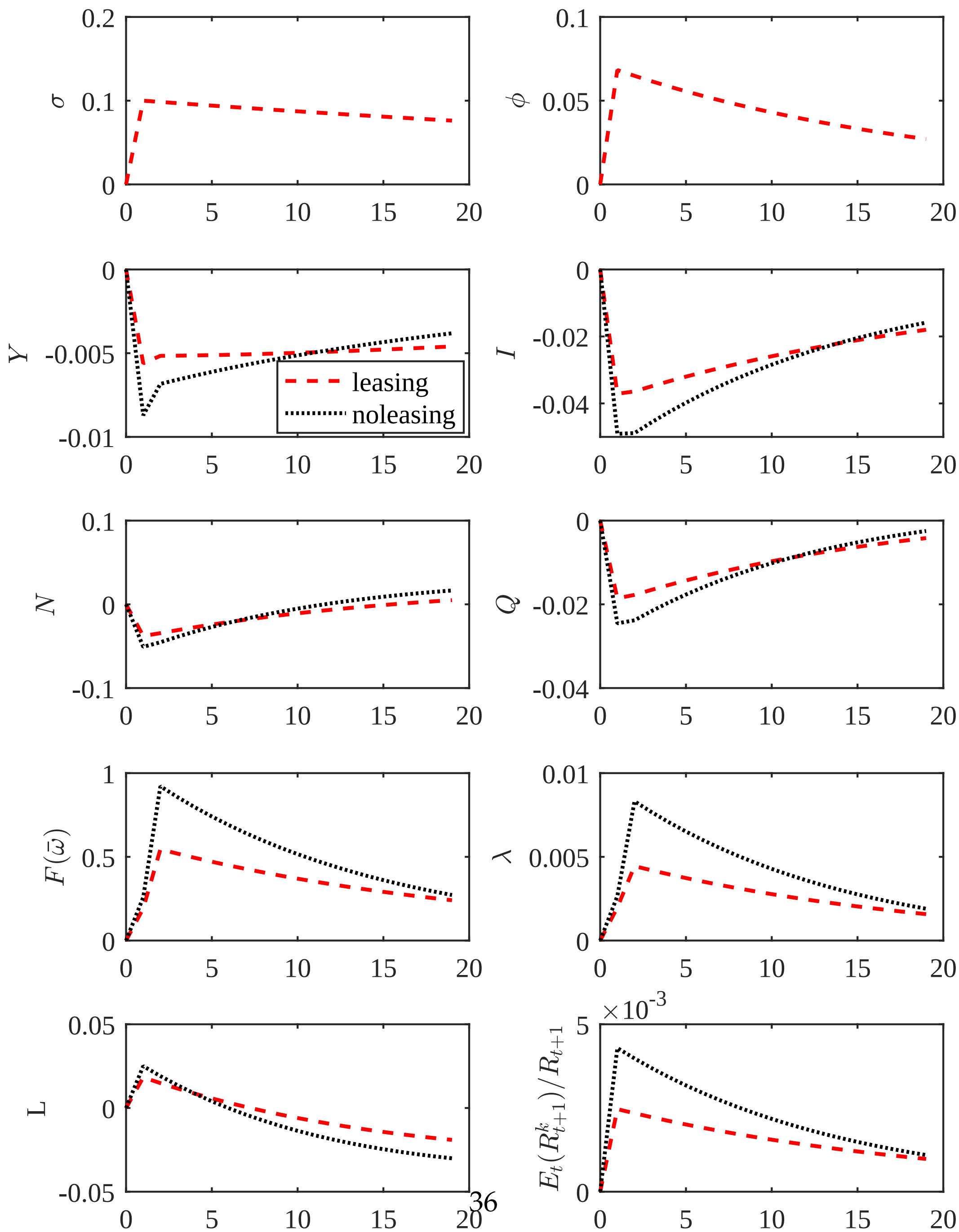

Figure 5

Impulse Responses of Benefit and Capital Price

This figure plots the impulse response functions of $Benefit$ and negative capital price $-Q_t$ to both TFP shock and risk shock, as well as the share contributed by increasing $Benefit$. Both variables are normalized by the constant $\frac{\phi_{ss}d}{\kappa}$ in equation(49). In each panel, the left y-axis corresponds to the impulse response functions, while the right y-axis corresponds to the share contributed by $Benefit$. In panel (a), we consider TFP shock, while in panel (b), we consider risk shock. Model parameters are calibrated as in Table 3.

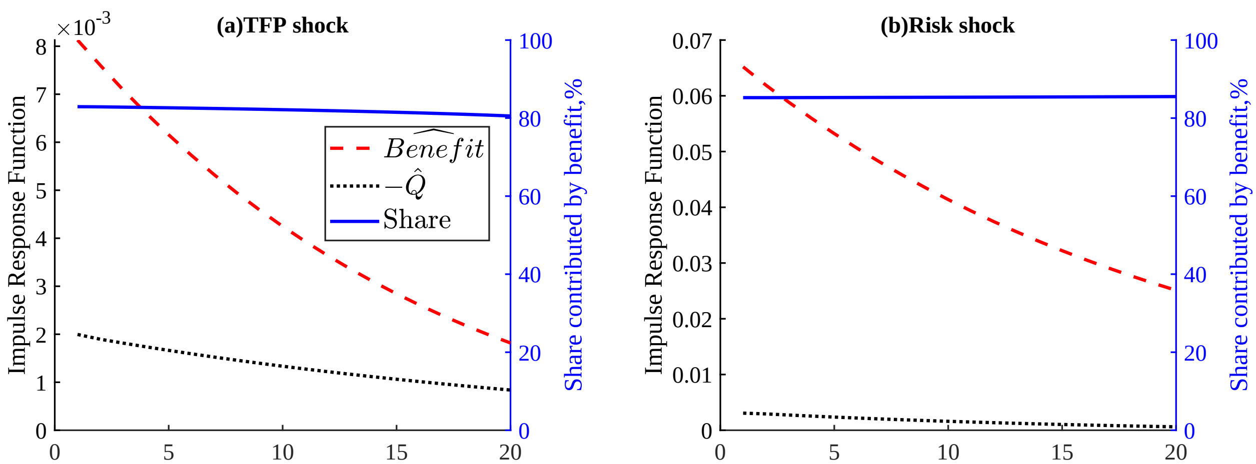

Table 1

Summary Statistics

This table presents summary statistics for the main outcome variables in our sample. Leased capital ratio is the ratio of leased capital over the sum of leased capital and purchased capital (PPENT). We consider two alternative measures of leased capital ratio, LCR1 and LCR2. In LCR1, leased capital(multiplier) is defined as 8 times the rental expense (XRENT), following Rampini and Viswanathan (2013). In LCR2, leased capital (commitment) is calculated using the present value of the sum of rental expense and the present value of future lease commitments, following Li and Tsou (2019). Rental share is defined as the ratio of rental expense and the sum of capital expenditure (CAPX) and rental expense. Debt leverage is the ratio of the long-term debt (DLTT) over the sum of leased capital and total assets (AT). Rental leverage is the ratio of leased capital (multiplier) over the sum of leased capital and total assets (AT). Leased adjusted leverage is the sum of debt leverage and rental leverage. Expect from the aggregate level mean, We also split the entire sample into subgroups according to their size and financial constraint level for each year. Size is defined by total assets, while the financial constrained level is classified by using the WW index, according to Whited and Wu (2006). We use 'S', 'M', 'L' to denote small, medium and large firm groups, respectively. We use 'UC', 'MC','C' to denote unconstrained, mildly constrained and constrained firm groups, respectively. We report time series averages of the cross-section averages weighted by total assets (AT) in the table. The sample is from 1977 to 2017 and excludes financial, utility, public administrative, and lessor industries from the analysis. Firms that are not incorporated in the US or do not report in US dollars are also eliminated.

	Aggregate	Size			WW Index		
Variables	Mean	S	M	L	C	MC	UC
LCR1	0.16	0.42	0.31	0.15	0.41	0.31	0.15
LCR2	0.26	0.54	0.43	0.25	0.53	0.42	0.25
Rental Share	0.20	0.40	0.33	0.19	0.42	0.33	0.19
Debt Leverage	0.21	0.14	0.23	0.21	0.14	0.24	0.21
Lease Adjusted Leverage	0.32	0.36	0.41	0.32	0.32	0.41	0.32

Table 2

Firm-level Regression: Leasing and TFP Dispersion

This table presents results of firm-level regressions with the specification in equation (1). The sample period is 1977−2017. See Appendix A for detailed definition of variables in the regressions. All specifications include firm fixed effects. The TFP dispersion, VOL-TFP, is standardized to facilitate interpretation. Standard errors are clustered at the 4-digit SIC level.

	LCR1		LCR2		Rental Share	
	(1)	(2)	(3)	(4)	(5)	(6)
VOL-TFP	0.050***	0.052***	0.040***	0.042***	0.068***	0.069***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
GDP Growth	-0.214***	-0.220***	-0.228***	-0.229***	-0.327***	-0.309***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.05)
Lag GDP Growth	-0.046	-0.036	-0.164***	-0.153***	-0.661***	-0.665***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.05)
Leverage Ratio	-0.043***	-0.046***	-0.054***	-0.056***	0.008	0.006
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Cash Flow	-0.009**	-0.010**	-0.023***	-0.026***	-0.061***	-0.071***
	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
Sale Growth	-0.005**	-0.002	-0.006**	-0.002	-0.045***	-0.043***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Asset Growth	-0.013***	-0.006**	-0.029***	-0.023***	-0.041***	-0.029***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Size	-0.026***	-0.015***	-0.033***	-0.022***	-0.034***	-0.019***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
TobinQ	0.000	0.000	-0.000	-0.000	-0.005***	-0.005***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Dividend Payout	-0.014***		-0.010***		-0.029***	
	(0.00)		(0.00)		(0.00)	
WW Index		0.244***		0.235***		0.362***
		(0.03)		(0.04)		(0.05)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.834	0.839	0.843	0.847	0.691	0.699
Observations	122,573	116,533	132,450	125,796	131,378	124,776

Table 3

Calibrated parameter values

Parameter	Symbol	Value
Capital share	α	0.35
Entrepreneur labor share	$(1-\alpha)(1-\Omega)$	0.01
Time discount rate	β	0.995
Depreciation rate	δ	0.025
Leisure utility parameter	ζ	2.88
Lender's Monitoring cost	μ	0.12
Entrepreneur death rate	γ	0.98
Standard deviation of ω shock	$\bar{\sigma}$	0.256
Lessor's monitoring cost	d	0.1
Lessor's monitoring cost	κ	0.006
Capital adjustment cost parameter	ξ	2
Persistence of TFP shocks	ρ_A	0.985
Vol. of TFP shocks	σ_A	0.016
Persistence of risk shocks	ρ_σ	0.985
Vol. of risk shocks	σ_σ	0.10
Correlation between two shocks	$\rho_{A,\sigma}$	-1

Table 4

Aggregate Moments: Model and Data

This table presents annualized moments from the model simulation and the data. Data refer to the US and span the period 1947−2020, unless otherwise stated. Numbers in parentheses are Newey-West-adjusted standard errors. To obtain our model implied moments, we simulate the model at quarterly frequency based on calibrated parameters in Table 3, and then we time-aggregate these quarterly observations to annual frequency. "Benchmark Model" corresponds to the full model with leased capital, while "No Leasing Model" indicates the model without leasing.

Moments	Data	Benchmark Model	No Leasing Model
$\sigma\left(\Delta y\right)$	3.05(0.60)	3.91	4.00
$\sigma\left(\Delta c\right)$	2.53(0.56)	2.61	3.18
$\sigma\left(\Delta i\right)$	10.3(2.36)	10.27	10.66
$corr\left(\Delta c, \Delta i\right)$	0.4(0.28)	0.94	0.95
$AC1\left(\Delta y\right)$	0.49(0.15)	0.21	0.24
$E\left(I_t/Y_t\right)$	0.14(0.01)	0.24	0.24
$E\left(C_t/Y_t\right)$	0.64(0.01)	0.67	0.67
$E\left(K_{l,t}/K_t\right)$	0.35(0.01)	0.36	
$\sigma\left(K_{l,t}/K_t\right)$	0.03(0.01)	0.10	

Table 5

Cross-sectional Tests: Financial Constraint and TFP Dispersion

This table presents results of our firm-level regressions with the interaction term between uncertainty volatility and firms' financial constraint indicator. The volatility of cross-sectional idiosyncratic uncertainty, VOL-TFP, is measured by the dispersion of firm-level TFP. The WW dummy is a dummy variable that equals 1 if the firm's WW index is above the median and 0 otherwise. The Div dummy is a dummy variable that equals 1 if the firm pays dividend and 0 otherwise. The sample period is 1977−2017. "Control" includes firm-level leverage ratio, cash flow, sales growth, asset growth, size, and Tobin's Q, and detailed definitions of variables in the regressions are in Appendix A. All specifications include firm fixed effects. TFP dispersion is standardized to facilitate interpretation. Standard errors are clustered at the 4-digit SIC level.

	WW Index Dummy			Dividend Payout Dummy		
	LCR1	LCR2	Rental Share	LCR1	LCR2	Rental Share
VOL-TFP	0.050***	0.040***	0.066***	0.051***	0.041***	0.069***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
WW dummy × VOL-TFP	0.002***	0.002***	0.003***			
	(0.00)	(0.00)	(0.00)			
Div dummy × VOL-TFP				-0.001***	-0.001***	-0.003***
				(0.00)	(0.00)	(0.00)
GDP Growth	-0.202***	-0.212***	-0.283***	-0.214***	-0.228***	-0.327***
	(0.03)	(0.03)	(0.05)	(0.03)	(0.03)	(0.05)
Lag GDP Growth	-0.021	-0.140***	-0.645***	-0.045	-0.164***	-0.661***
	(0.03)	(0.03)	(0.05)	(0.03)	(0.03)	(0.05)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.839	0.847	0.699	0.834	0.843	0.691
Observations	116,533	125,796	124,776	122,573	132,450	131,378

Table 6

Cross-sectional Tests: Commitment Duration and TFP Dispersion

This table presents results of firm-level regressions with the interaction term between uncertainty and firms' commitment duration. The sample period is 1977−2017. "Com" is the firm-level lease commitment duration. The volatility of the cross-sectional idiosyncratic uncertainty measure, "VOL-TFP" is the cross-sectional dispersion of firm level TFP. "Control" includes firm-level leverage ratio, cash flow, sales growth, asset growth, size, and Tobin's Q, and detailed definitions of variables in the regressions are in Appendix A. All specifications include firm fixed effects. VOL-TFP and Com are standardized to facilitate interpretation. Standard errors are clustered at the 4-digit SIC level.

	LCR1		LCR2		Rental Share	
	(1)	(2)	(3)	(4)	(5)	(6)
VOL-TFP	0.044***	0.046***	0.037***	0.039***	0.065***	0.066***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Com × VOL-TFP	0.003***	0.003***	0.002***	0.002***	0.002***	0.002***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
GDP Growth	-0.195***	-0.204***	-0.216***	-0.220***	-0.318***	-0.303***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.05)
Lag GDP Growth	-0.037	-0.030	-0.153***	-0.145***	-0.654***	-0.662***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.05)
Dividend Payout	-0.014***		-0.011***		-0.029***	
	(0.00)		(0.00)		(0.00)	
WW Index		0.249***		0.228***		0.363***
		(0.03)		(0.04)		(0.04)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.838	0.843	0.843	0.847	0.691	0.699
Observations	122,201	116,493	128,873	122,746	127,833	121,755

Table 7

Leased Capital Ratio and Credit Spread

This table presents the relationship between credit spread and leased capital ratio in the actual data and model simulated data. The actual data has an annual frequency that ranges from 1985 to 2017. We obtain 400 annual observations from our model simulation. "Data" indicates regressions with actual data, while "Model" indicates regressions with simulated data. LCR is the rental share in the data and leased capital ratio in the model. Credit spread is the percentage difference in yield between AAA and BAA rated bonds in the data, it is the difference between the loan rate and risk-free rate in the model. Leverage is the aggregate market leverage calculated as total liability divided by total assets in the non-financial corporate sector, and it is $\frac{B_t+N_t}{N_t}$ in the model. The risk-free rate is the 3-month Treasure bill rate in the data and the corresponding risk-free rate in the model. Output growth is the industrial output growth rate in the data, and it is the growth rate of output Y_t in the model. All control variables are standardized to facilitate interpretation.

	Dependent variable: Credit Spread				Dependent variable: LCR			
	Data		Model		Data		Model	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
LCR	0.220	0.166	0.959***	0.998***				
	(0.23)	(0.22)	(0.04)	(0.04)				
Credit Spread (−1)					0.477***	0.328***	0.916***	0.973***
					(0.17)	(0.11)	(0.04)	(0.04)
Leverage		0.281		0.340***		-0.029		0.314***
		(0.19)		(0.05)		(0.19)		(0.07)
Risk-free rate		0.021		0.406***		-0.553**		0.128**
		(0.17)		(0.05)		(0.20)		(0.07)
Output Growth		-0.425		-0.034***		-0.002		-0.063***
		(0.27)		(0.01)		(0.14)		(0.02)
R-Squared	0.049	0.372	0.920	0.942	0.241	0.524	0.834	0.882
Observations	33	33	400	400	32	32	399	399

Table 8

Firm-level Regression: Profit Growth Dispersion

This table presents results of firm-level regressions with the specification in eq.(1). VOL-Prof is the cross-sectional dispersion of firm-level profit growth. The sample period is 1977−2017. See Appendix A for detailed definitions of variables in the regressions. All specifications include firm fixed effects. Profit growth dispersion is standardized to facilitate interpretation. Standard errors are clustered at the 4-digit SIC level.

	LCR1		LCR2		Rental Share	
	(1)	(2)	(3)	(4)	(5)	(6)
VOL-Prof	0.013***	0.014***	0.012***	0.013***	0.015***	0.016***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
GDP Growth	-0.153***	-0.156***	-0.175***	-0.172***	-0.267***	-0.240***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.05)
Lag GDP Growth	-0.231***	-0.237***	-0.318***	-0.319***	-0.909***	-0.930***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.07)	(0.06)
Leverage Ratio	-0.045***	-0.048***	-0.055***	-0.057***	0.006	0.005
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Cash Flow	-0.016***	-0.019***	-0.029***	-0.033***	-0.071***	-0.082***
	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
Sale Growth	-0.004	-0.001	-0.004*	-0.001	-0.043***	-0.042***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Asset Growth	-0.012***	-0.005*	-0.028***	-0.022***	-0.039***	-0.028***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Size	-0.014***	-0.003	-0.023***	-0.012***	-0.017***	-0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
TobinQ	0.001**	0.001***	0.000	0.001	-0.003***	-0.004***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Dividend Payout	-0.023***		-0.018***		-0.042***	
	(0.00)		(0.00)		(0.00)	
WW Index		0.246***		0.235***		0.360***
		(0.04)		(0.04)		(0.05)
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.831	0.835	0.841	0.845	0.683	0.691
Observations	125,141	119,034	135,243	128,514	134,171	127,494

Table 9

Robustness: Financial Constraint and Profit Growth Dispersion

This table presents results of firm-level regressions with the interaction term between uncertainty volatility and firms' financial constraint indicator. The volatility of cross-sectional idiosyncratic uncertainty, VOL-Prof, is measured by the dispersion of firm-level profit growth. The WW dummy is a dummy variable which equals to 1 if the firm's WW index is above median and 0 otherwise. The Div dummy is a dummy variable that equals 1 if the firm pays dividend and 0 otherwise. The sample period is 1977−2017. "Control" includes firm-level leverage ratio, cash flow, sales growth, asset growth, size, and Tobin's Q, and detailed definitions of variables in the regressions are in Appendix A. All specifications include firm fixed effects. Profit growth dispersion is standardized to facilitate interpretation. Standard errors are clustered at the 4-digit SIC level.

	WW Index Dummy			Dividend Payout Dummy		
	(1)	(2)	(3)	(4)	(5)	(6)
VOL-Prof	0.009***	0.009***	0.010***	0.016***	0.015***	0.021***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
WW dummy × VOL-Prof	0.008***	0.007***	0.010***			
	(0.00)	(0.00)	(0.00)			
Div dummy × VOL-Prof				-0.007***	-0.005***	-0.012***
				(0.00)	(0.00)	(0.00)
GDP Growth	-0.144***	-0.161***	-0.223***	-0.145***	-0.168***	-0.251***
	(0.03)	(0.03)	(0.05)	(0.03)	(0.03)	(0.05)
Lag GDP Growth	-0.218***	-0.303***	-0.906***	-0.239***	-0.325***	-0.925***
	(0.04)	(0.04)	(0.06)	(0.04)	(0.04)	(0.07)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.835	0.845	0.691	0.831	0.841	0.683
Observations	119,034	128,514	127,494	125,141	135,243	134,171

Table 10

Robustness: Commitment Duration and Profit Growth Dispersion

This table presents results of firm-level regressions with the interaction term between the uncertainty volatility and firms' commitment duration. The sample period is 1977-2017. Com is firm-level lease commitment duration. The volatility of cross-sectional idiosyncratic uncertainty measure, VOL-Prof is the cross sectional-dispersion of firm-level profit growth, "Control" includes firm-level leverage ratio, cash flow, sales growth, asset growth, size, and Tobin's Q, and detailed definitions of variables in the regressions are in Appendix A. All specifications include firm fixed effects. VOL-Prof and commitment duration are standardized to facilitate interpretation. Standard errors are clustered at the 4-digit SIC level.

	LCR1		LCR2		Rental Share	
	(1)	(2)	(3)	(4)	(5)	(6)
VOL-Prof	0.009***	0.009***	0.010***	0.010***	0.012***	0.012***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Com × VOL-Prof	0.008***	0.008***	0.005***	0.005***	0.005***	0.005***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
GDP Growth	-0.137***	-0.141***	-0.165***	-0.166***	-0.261***	-0.237***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)	(0.05)
Lag GDP Growth	-0.204***	-0.213***	-0.298***	-0.301***	-0.886***	-0.912***
	(0.04)	(0.04)	(0.04)	(0.04)	(0.06)	(0.06)
Dividend Payout	-0.024***		-0.019***		-0.042***	
	(0.00)		(0.00)		(0.00)	
WW Index		0.256***		0.232***		0.366***
		(0.03)		(0.04)		(0.05)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.834	0.838	0.841	0.844	0.683	0.690
Observations	124,217	118,471	130,951	124,785	129,912	123,795

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A Appendix of Data Construction

A.1 Data Source

Our sample consists of firms in Compustat, available from WRDS. The sample period ranges from 1977 to 2017. We focus on firms with non-negative total assets (AT) and sales (SALE). We exclude utility firms that have 4-digit SIC codes between 4900 and 4999, finance firms that have SIC codes between 6000 and 6999 (finance, insurance, trusts, and real estate sectors), as well as public administrative firms that have SIC codes between 9000 and 9999. We also explicitly drop industries that serve as lessors, (i.e., SIC code 7377 and industries whose SIC begin with 735 and 751). We additionally eliminate firms that are not incorporated in the US and/or do not report in US dollars. Macroeconomic data are from the Federal Reserve Economic Data (FRED) maintained by the Federal Reserve in St. Louis. Our selection methods yields a sample with 17,378 firms and 175,149 firm-year observations. To mitigate the effects of outliers, all firm-level variables are winsorized at the top and bottom 1%. The summary statistics of variables are presented in Table 11.

A.2 Variable Definitions

Aggregate Variables The rental share is defined as the ratio between rental expense (XRENT) over the sum of capital expenditure (CAPX) plus rental expense. The leased capital ratio is defined as the leased capital divided by the sum of leased and purchased capital, following Eisfeldt and Rampini (2009) and Rampini and Viswanathan (2013). The TFP Dispersion is the standard deviation of firm-level productivity measures constructed by following Ai et al. (2013) and Park (2018). The Profit Growth Dispersion is the standard deviation of firms' profit growth rate constructed by following Bloom (2009). We use quarterly Compustat data to compute firms' profit growth rate, then take the average within each year. When constructing these two dispersion measures, to avoid entry and exit bias, we only consider firms with more than 25 years observations. The credit spread, which is the difference in yield between BAA and AAA rated bonds, is obtained from Amit Goyal's website. The risk-free rate is the 3-month Treasure bill rate obtained from the Federal Reserve Economic Data (FRED) maintained by the Federal Reserve in St. Louis. The aggregate market leverage is calculated as total liability divided by total assets in the non-financial corporate sector, and we obtain these data from Flow of Fund. The output growth is the growth rate of industrial production obtained from the FRED data.

Firm-level variables The LCR1 is defined as the leased capital divided by the sum of leased and purchased capital, following Eisfeldt and Rampini (2009) and Rampini and Viswanathan (2013). LCR2 is constructed by following Li and Tsou (2019); specifically, leased capital is computed by discounting the lease commitments over the following 10 years, for which the lease commitments in year one through five are items (MRC1-MRC5) in Compustat, while for rent payments reported beyond five years, there is an item on Compustat named 'MRCTA'; for this item, we discount future leased commitments by a constant discount rate 1.08, and our results are robust to discounting with the BAA bond rate. The rental share is defined as the ratio between rental expense (XRENT) over the sum of capital expenditure (CAPX) plus rental expense. Leverage ratio is the sum of debt in current liabilities (DLC) and long-term debt (DLTT) divided by lagged total assets (AT). Cash flow is the income before extraordinary items (IB) and net of depreciation and amortization (DP) divided by lagged total assets (AT). Sales growth is the one-year change in sales (SALE) divided by lagged total assets (AT). Asset growth is the growth rate of total assets (AT). Size is the natural log of lagged total assets (AT). TobinQ is computed as the product of common shares outstanding (CSHO) and Price Close (PRCC_F) plus preferred stock-liquidating value (PSTKL) and dividends (DVP) and total liabilities (LT) divided by lagged total assets. The Size-and-Age (SA) Index is constructed by following Hadlock and Pierce (2010) and the Whited-Wu (WW) Index is constructed as in Whited and Wu (2006). The lease commitment is constructed by following Li and Tsou (2019). All variables are deflated with US CPI data.

Table 11

Summary Statistics, 1977-2017

This table presents summary statistics for the main variables in the paper over the period 1977−2017. See Appendix A for detailed definitions of variables.

	Mean	SD	p25	p50	p75	Observations
LCR1	0.35	0.26	0.12	0.29	0.56	136,785
LCR2	0.47	0.27	0.23	0.46	0.71	149,035
Rental Share	0.36	0.25	0.16	0.31	0.54	147,842
Leverage Ratio	0.27	0.28	0.05	0.21	0.39	160,535
Cash Flow	-0.07	0.25	-0.09	-0.01	0.04	160,672
Sale Growth	0.14	0.40	-0.03	0.07	0.23	161,050
Asset Growth	0.19	0.59	-0.05	0.06	0.21	161,050
Size	5.14	2.25	3.50	4.97	6.67	161,050
TobinQ	2.52	3.11	1.05	1.53	2.57	158,542
SA Index	-0.33	1.81	-1.65	-0.35	0.93	175,149
WW Index	-0.25	0.11	-0.33	-0.25	-0.17	151,977
Commitment	343.15	1197.65	1.86	15.75	113.85	161,595
Debt Leverage	0.17	0.20	0.01	0.11	0.25	137,154
Rental Leverage	0.18	0.15	0.07	0.14	0.24	137,463