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Keywords: idiosyncratic volatility; financial constraint; leased capital; cross-section of expected returns; incomplete market
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1 Introduction

The influential study by Ang, Hodrick, Xing, and Zhang (2006, 2009) documents that stocks with high idiosyncratic return volatility (IVOL hereafter) exhibit puzzling low expected returns, which is contrary to conventional wisdom. Traditional asset pricing theories suggest that idiosyncratic volatility should not be priced if it can be fully diversified (e.g. CAPM model), or that it should be positively correlated with stock returns in the incomplete market content for compensation against undiversified risk (e.g. Merton (1987)). While several studies have attempted to explain this puzzle, few of them provide risk-based explanations. From firms' production aspect, we find this anomaly is mainly driven by financially constrained firms with access to leasing activities and is highly correlated with firms' buy-versus-lease decisions[1]. In this paper, we link idiosyncratic volatility with firms' leasing investment and provide a novel risk-based explanation as follows. First, firms with high idiosyncratic volatility tend to rent more capital. Second, leased capital can hedge for both idiosyncratic volatility shocks and aggregate shocks in the incomplete market in which risk in idiosyncratic volatility is negatively priced. Therefore, firms with higher idiosyncratic volatility are less risky and earn lower expected returns. Our study offers a unique, rational resolution to the puzzle, demonstrating that despite idiosyncratic risk being negatively priced in an incomplete market setting, a negative correlation persists between idiosyncratic volatility and expected returns. This can be attributed to the endogenous allocation of firms' assets between owned and leased capital, each characterized by distinct risk profiles.

In standard operating lease contracts, the lessor, who is the owner of the asset, grants to a capital borrower (or lessee) the exclusive right to use the capital for an agreed period of time in return for a periodic leasing fee, and the capital reverts to the lessor at the end of the lease term. It's important to notice that the ownership of the leased capital belongs to the lessor; therefore, the lessee is absent from the risk of capital price fluctuations during

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[1] Here we focus on operating lease. There is another type of lease, capital lease (i.e., financial lease), in which the lessee owns the assets at the end of a lease's term instead of returning the assets to the lessor. It is very similar to the credit-based purchase. However, since operating lease is much larger in magnitude than capital lease in the Compustat dataset, operating lease remains our main focus.

the contract term. Consequently, the leased capital is less risky from the lessee's perspective and can hedge for risk in asset prices. In the cross section, we find that high idiosyncratic volatility firms tend to rent more capital; using this finding, combined with the low riskiness of leased capital, we argue that leased capital can help explain the negative relation between idiosyncratic volatility and expected returns.

Empirically, we find that the idiosyncratic volatility puzzle is mainly driven by financially constrained firms with access to leasing activities. First, we document that the idiosyncratic volatility is significantly and positively correlated with financial constraint. Second, leasing activities are highly correlated with financial constraint and idiosyncratic volatility. For those financially constrained firms, leased capital is extensively employed in real production, which accounts for approximately 40-50% of total productive physical assets. In the cross-section, we observe a monotonic increase in the fraction of leased capital used in production and financial constraint content from the lowest to the highest idiosyncratic volatility quintile. The low riskiness of leased capital motivates us to further check the relation between leasing usage and the IVOL premium. Third, we confirm that the average excess return and risk-adjusted α's of the high-minus-low IVOL portfolio are only significantly negative for financially constrained firms, especially those with access to leasing activities. In contrast, for financially unconstrained firms and constrained firms that don't have easy access to leasing activities, the negative relation between IVOL and stock returns disappears. Motivated by our empirical evidence, we propose that leasing activities play a crucial role in explaining and understanding the idiosyncratic volatility puzzle.

Drawing on a framework akin to that of Bernanke, Gertler, and Gilchrist (1999), we construct an investment-based asset pricing model and explicitly incorporate firms' optimal choices between leased capital and purchased capital to rationalize our empirical findings. The key tradeoff between a buy-versus-lease investment is that leased capital has higher debt capacity, but charges compensation for the agency problem that originates from the separation of ownership and control rights. Specifically, during a leasing contract, the ownership of leased capital belongs to the lessor, while for the secured loan, the collateral assets belong to the borrower. Due to the repossession advantage that lessors possess according to Chapter 11 of the US bankruptcy code, when a firm files for bankruptcy, lessors have a stronger ability than lenders of secured lending to repossess assets. This repossession advantage is a main benefit of leasing, which allows a lessor to implicitly extend more debt than a typical lender. However, leased capital is more expensive due to additional compensation for the separation of ownership and control rights.

In our model, we adopt a "costly state verification" (CSV) framework, first proposed by Townsend (1979), to model financial frictions. Specifically, when a firm goes bankrupt, the lender must pay some costs to assess the true return of the capital in order to repossess assets. We model the repossession advantage of leasing by assuming that the lessor can fully obtain the value of leased capital without suffering such a cost of verification, similar to Li and Yu (2023). We then model the agency problem of leasing originated from the separation of ownership and control rights by assuming that lessors must pay additional monitoring costs upfront to ensure that the lessee takes good care of leased capital.

Our model explains the idiosyncratic volatility puzzle in three successive steps. First, we show that firms with high idiosyncratic volatility optimally choose a high fraction of leased capital in production. When firms experience high idiosyncratic volatility, which typically coincides with a high probability of bankruptcy and a consequently high loan rate, the benefit of leasing (i.e., saving costs of verification for potential bankruptcy) now outweighs its agency costs. Hence, firms with high idiosyncratic volatility increase their use of leased capital, even though total capital stock still decreases.

Second, we prove that in the incomplete market, leased capital is less risky than purchased capital, resulting in lower expected returns. In an incomplete market, the idiosyncratic volatility risk can't be diversified away and is negatively priced, as a positive innovation in idiosyncratic volatility will lead to a higher marginal value of net worth and utility. Additionally, idiosyncratic volatility shocks can bring fluctuations in the price of capital through affecting demands of capital. In contrast to purchasing capital with secured loans, since ownership of capital never changes hands in a leasing contract, it is the lessor who bears the risk of capital price fluctuations during the contract term. Thus, from the perspective of lessees or firms, the absence of fluctuations from capital resale value makes leased capital less risky and delivers lower expected returns. Our model not only echoes the finding of Li and Tsou (2019) that leased capital can hedge for aggregate shocks, but in our model leased capital can also hedge for idiosyncratic volatility risks.

Finally, as a result, the heterogeneity in idiosyncratic volatility translates into dispersion of equity returns in equilibrium. In our model, the equity return is an average of returns on leased capital and purchased capital, weighted by corresponding investments. Combining the positive correlation between idiosyncratic volatility and leased capital ratio with the lower expected returns of leased capital, firms with higher idiosyncratic volatility will result in lower expected returns. While our model maintains the assumption of an incomplete market setting where idiosyncratic risk is negatively priced, as in Merton (1987), it can nonetheless predict a negative correlation between idiosyncratic volatility and average stock returns. This prediction arises from a novel channel of endogenous asset allocations, emphasizing the choice between buying and leasing capital, each presenting distinct risk profiles.

In our quantitative analysis, our calibrated model matches conventional asset pricing moments and macroeconomics quantities well and is able to quantitatively account for the empirical relationship between idiosyncratic volatility, leasing activities, and expected returns. Our model can not only generate monotonically decreasing average stock returns across the portfolios sorted on idiosyncratic volatility, but can also predict a spread of -3.73% for the high-minus-low portfolio, which accounts for over 65% of the negative IVOL premium.

Our model also has some further testable implications. We empirically review the ability of idiosyncratic volatility to predict the leased capital ratio, and the positive relation only exists in firms with easy access to leasing activities. Additionally, we confirm that, all else being equal, firms with higher idiosyncratic volatility, who use a larger fraction of leased capital, have lower aggregate risk exposures and less negative idiosyncratic volatility risk exposures, due to the hedging effects of leased capital. Lastly, we show that idiosyncratic volatility risk is negatively priced in the cross-section.

In summary, our paper offers a novel risk-based explanation for the popular idiosyncratic volatility puzzle through firms' investment behaviors in leasing and purchasing. To save verification costs in potential bankruptcy of secured loans, firms with higher idiosyncratic volatility endogenously choose a higher fraction of leased capital. Meanwhile, leased capital is less risky relative to purchased capital. These two facts result in low expected returns for firms with high idiosyncratic volatility. Our paper verifies this economic mechanism both empirically and theoretically.

Literature review Our paper relates to the strand of research that examines the idiosyncratic volatility puzzle documented by Ang et al. (2006, 2009). Hou and Loh (2016) gives a comprehensive review for explanations, which can be classified into three groups. The first group of explanations attributes the idiosyncratic volatility puzzle to lottery preferences of investors; that is, investors tend to outweigh small chances of large gains. They point out that the IVOL anomaly is a manifestation of the predictive ability of expected idiosyncratic skewness (Boyer, Mitton, and Vorkink (2010)), speculative retail tradings (Han and Kumar (2013)), or maximum daily return over the past one month (Bali, Cakici, and Whitelaw (2011)). The second group of explanations concerns various forms of market frictions and microstructures, like the omission of the previous month's stock returns and a biased estimation of conditional idiosyncratic volatility (Fu (2009) and Huang, Liu, Rhee, and Zhang (2010)), small stock effects (Bali and Cakici (2008)), stock market illiquidity (Han and Lesmond (2011)), or arbitrage asymmetry (Stambaugh, Yu, and Yuan (2015)). In contrast to these two strands of literature, we understand the puzzle in terms of the neoclassical framework with a risk-based explanation. The third group contains other explanations, which contributes the predictive power of IVOL by negative earnings surprises predicted by IVOL (Jiang, Xu, and Yao (2009) and Wong (2011)) or exposures to the average variance component of the market variance (Chen and Petkova (2012)) and so on. The only risk-based explanation is Chen, Strebulaev, Xing, and Zhang (2021), which argues that firms in distress will strategically take on idiosyncratic volatility to decrease equity betas in bad times, and that the negative covariance between the equity beta and the market risk premium causes low returns for high IVOL firms. Different from Chen et al. (2021), we demonstrate that the IVOL puzzle is mainly driven by financially constrained firms especially firms with access to leasing markets and rationalize the negative spread from an investment aspect of firms by introducing buy-versus-lease decisions, which offers a novel risk-based explanation.

Our study contributes to the strand of literature that studies corporate finance frictions and corporate leasing decisions. Albuquerque and Hopenhayn (2004) study dynamic financing with limited commitment. Schmid (2008) considers the quantitative implications of dynamic financing with collateral constraints. Nikolov, Schmid, and Steri (2021) studies the quantitative implications of various sources of financial frictions on firms' financing decisions, including the collateral constraint. The papers most related to our study are Eisfeldt and Rampini (2009), Rampini and Viswanathan (2013), Li and Tsou (2019), and Li and Yu (2023). Seminal research by Eisfeldt and Rampini (2009) emphasizes the repossession advantage of leased capital by Chapter 11 relative to secured lending, which can extend the debt capacity of a lease. Schallheim, Wells, and Whitby (2013) concur and empirically show that leasing can expand firms' debt capacity, while Lim, Mann, and Mihov (2017) complement Schallheim et al. (2013) and find that leasing can expand credit capacity. With respect to asset pricing, Li and Tsou (2019) show that leased capital can provide the lessee a cheap "insurance" and is thus less risky than owned capital; they document that the premium for the highest quintile with respect to the lowest quintile sorted on leased capital is -7.35% per annum. The paper most related to ours is Li and Yu (2023). They study the mitigation of financial accelerator effects of leasing on the aggregate economy. That said, our paper differs from theirs in that we focus more on the cross-sectional asset pricing of leasing activities and the novel risk-sharing channel of leasing: hedging for idiosyncratic volatility risks.

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Our theoretical model is based on macroeconomics and corporate finance models with financial market frictions that generate fluctuations across business cycles (see Brunnermeier, Eisenbach, and Sannikov (2012) for an excellent survey). The papers most related to ours are those emphasizing the importance of the financial accelerator mechanism, especially Bernanke et al. (1999), Gertler and Kiyotaki (2010), and Christiano et al. (2014). These papers study the role of credit market frictions induced by asymmetric information and agency problems, but without the role of leasing. Our model follows them and uses a similar cost state verification approach, and we explicitly include buy and lease decisions into this framework to explore asset pricing implications.

Our paper contributes to the broader literature that connects firms' investments to the cross-section of expected returns, for which Kogan and Papanikolaou (2012) provide a comprehensive review. Zhang (2005) provides an investment-based explanation for the value premium. Li (2011) and Lin (2012) focus on the relationship between R&D investment and expected stock returns. Eisfeldt and Papanikolaou (2013) meanwhile develop a model of organizational capital and expected returns. Also, Belo, Lin, and Yang (2019) study implications of equity financing frictions on cross-sections of stock returns. Our paper explores how firms' leasing activities affect firms' risk profiles and proposes a risk-based investment explanation for the puzzling negative relation between idiosyncratic volatility and expected returns.

The rest of our paper is organized as follows. In Section 2, we summarize some empirical stylized facts on the relationship between financial constraint, idiosyncratic volatility, leased capital, and stock returns; we then document that the anomalously negative relation between idiosyncratic volatility and stock returns is mainly driven by financially constrained firms, especially those with access to leasing activities. This fact motivates us to construct an investment-based asset pricing model in Section 3. We analyze asset pricing implications of our model in Section 4. In Section 5, we provide our model's quantitative results both in the aggregate level and in the cross-section, and we provide additional supporting evidence of our model in Section 6. Section 7 concludes our paper. The Appendix contains further empirical results.

2 Empirical facts

2.1 Data Sources

Data on stock returns are from the Center for Research in Security Prices (CRSP), and accounting information is from the CRSP/Compustat Merged Annual Industrial Files. The sample is from July 1978 to June 2017 and includes firms with common shares (shrcd=10 and 11) and firms traded on NYSE, AMEX, and NASDAQ (exchcd=1, 2, and 3). We exclude firms whose primary standard industry classification (SIC) are between 4900 and 4999 (regulated firms), between 6000 and 6999 (financial firms), between 9000 and 9999 (public administrative firms), and firms that are classified as belonging in lessor industries, as suggested by Li and Tsou (2019). To mitigate the effects of outliers, all firm-level variables are winsorized at the top and bottom 1%.

Following Ang et al. (2006), we use the standard deviation of residuals from the annual Fama and French (1993) regression as a stock's idiosyncratic volatility. We follow Rampini and Viswanathan (2013) and Li and Tsou (2019) to capitalize leased capital, which is 10 times the rental expense in this paper.[2] We define leased capital ratio as the leased capital divided by PPENT plus leased capital, which measures the proportion of total capital input in a firm's production obtained from leasing activities. Rental share measures the spending on leased capital and is defined as rental expense (XRENT) over the sum of rental expense and capital expenditures(CAPX). For the financial constraint measure, we follow Whited and Wu (2006) to calculate the Whited-Wu index (WW index hereafter) of firms and classify firms with the WW index above the median relative to their industry peers as financially constrained ones.[3] To account for the access to leasing activities, we use the average leased capital ratio of the previous 3 years to measure the degree of access to leasing. We define firms with a lagged 3-year average LCR higher than 20 percentile relative to peers within the same industry as ones with easy access to leasing activities. We also use asset redeployability, following Kim and Kung (2017), as an alternative measure for access to leasing. The intuition is that if the asset is highly redeployed, it will be easy to be leased. Thus, suggested by Eisfeldt and Rampini (2009), firms with higher asset redeployability are expected to have more access to leasing activities.

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[2] According to Rampini and Viswanathan (2013), capitalization uses multiples of 5, 6, 8, and 10 × rental expense, depending on the industry. We use 10 in this paper.

[3] We also tried other financial constrained measures, including the size and age index (SA index), following Hadlock and Pierce (2010), and the dividend payment dummy (DIV). Detailed information regarding the construction of these indexes follows Farre-Mensa and Ljungqvist (2016).

2.2 Firm Characteristics

Table 1 shows summary statistics of idiosyncratic volatility and leased capital ratio for the aggregate level and cross-sectional firms in Compustat. Panel A shows several salient facts. First, financially constrained firms on average tend to have higher idiosyncratic volatility. Second, constrained firms will tend to significantly rent more capital (52.3% versus 34.5%), which leads us to believe that leased capital may be important for explaining the IVOL puzzle. Also, constrained firms are mainly small firms and with low ROA.

[**Place Table 1 about here**]

In Panel B, we further sort firms into five quintiles based on their idiosyncratic volatility rankings, and show firm characteristics for each portfolio. First, we document that with the increase of idiosyncratic volatility, firms become more and more financially constrained. Second, across portfolios, firms' leased capital ratios monotonically increase, ranging from 0.320 to 0.501, and rental share increases from 0.200 to 0.371. Since Li and Tsou (2019) proves that leased capital is less risky, the positive relation between IVOL and leasing usage strengthens our intuition to use leasing activities to offer a risk-based explanation for the negative spread. Lastly, firm size decreases across portfolios, while ROA monotonically decreases.

Observations in Table 1 encourage us to believe that leasing activity is closely related to a firm's idiosyncratic volatility and thus can help to explain the IVOL puzzle. In the next section, we explore the relation between the IVOL puzzle and financially constrained firms further; we focus especially on those firms with easy access to leased capital, and show that access to leasing activities is an important factor for generating negative IVOL spread.

2.3 Double Sorting on Financial Constraint and Access to Leasing

In this section, we provide further empirical evidence to help us examine the role that leasing activity plays in the idiosyncratic volatility puzzle. Motivated by our previous section, we first focus on financially constrained firms and then focus on the subsample with access to leasing activities. We find that the anomaly is mainly driven by financially constrained firms with easy access to leasing activities.

We implement the standard sorting procedure in different samples and sort these firms into quintiles based on their IVOL. At the end of June of each year t, we sort on IVOL of each firm and then rank firms with breakpoints within 49 industries based on Fama and French (1997) classifications. We sort firms into five groups from low to high IVOL, and then form a long-short portfolio that takes a long position in the highest quintile of IVOL and a short position in the lowest quintile. After forming these portfolios, we calculate the value-weighted average monthly returns and hold these portfolios over the next year (from July in year t to June in the year $t+1$). We first implement the sorting procedure in the full sample to replicate the idiosyncratic volatility puzzle, and then we sort within the financially constrained (unconstrained) subsample and the subsample with (without) easy access to leasing activities to further study the negative idiosyncratic volatility premium.

In Table 2, we report the value-weighted average excess returns (annualized) and α's relative to CAPM and the Fama-French 3-factor model of the full sample and financially constrained (unconstrained) subsamples. Panel A shows replication results of the negative relation between idiosyncratic volatility and average returns, and the high-minus-low portfolio yields a -6.14% annual return on average. After risk adjustment by CAPM and the Fama-French 3-factor model, α monotonically decreases as idiosyncratic volatility increases, and the high-minus-low portfolio carries significantly negative α's of -10.49% and -10.32% respectively. Panel B shows similar patterns for financially constrained firms: average excess returns from the lowest to the highest IVOL group monotonically decrease and the high-minus-low portfolio also carries a significantly negative excess average return of -5.62%. α's across portfolios also monotonically decrease and are significantly negative for the long-short portfolio. However, when we refer to the financially unconstrained subsample in Panel C, the negative IVOL spread disappears. The fact that the negative idiosyncratic volatility spread mainly exists in the financially constrained subsample motivates us to explore this group further and link the IVOL puzzle with investment behaviors of firms.[4]

[Place Table 2 about here]

Motivated by the seminal work emphasizing the importance of leasing for financially constrained firms by Eisfeldt and Rampini (2009) and a recent work exploring cross-section implications of leased capital by Li and Tsou (2019), we further check whether leasing activities in the financially constrained subsample matter with respect to the IVOL puzzle. To confirm, we find that the anomaly is mainly driven by firms with easy access to leasing activities. We define firms with lagged 3-year average LCR higher than 20 percentile relative to peers within the same industry as those with easy access to leasing activities. This is because firms that have had prior experience with leasing activities are more likely to have established relationships and resources that enable them to easily access the leasing market. Following Kim and Kung (2017), we also use asset redeployability as an alternative measure for the degree of access to leasing. The asset that is highly redeployed will be easy to be leased. Thus, suggested by Eisfeldt and Rampini (2009), firms with higher asset redeployability are expected to have more access to leasing activities.

Results for controlling access to leasing activities are shown in Table 3, and we confirm that firms with access to leasing activities are indeed main drivers of the anomaly. There are four interesting observations in our findings. First, the upper panel of Panel A shows that among the subsample classified as firms having easy access to leasing activities, from the lowest IVOL portfolio to the highest IVOL portfolio, there exists the idiosyncratic volatility puzzle, and the high-minus-low portfolio delivers a significantly negative excess return of -6.33% per annum; the spread is more negative than that in the financially constrained subsample (-5.62%). Second, after the risk adjustment, α's also monotonically decrease across portfolios and are more negative for the high-minus-low portfolio, when compared with the entire group of financially constrained firms. Third, when we turn to the group of

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[4] The empirical results are consistent for the SA index and dividend payment dummy as an alternative financial constraint measure. See Table A.1 and Table A.2.

firms without easy access to leasing activities, the lower panel of Panel A shows the monotonic decreasing pattern of excess returns and α's are broken down. The spread and corresponding α's are not only insignificant but also much smaller than their counterparts of the constrained subsample. Fourth, when we use asset redeployability as an alternative proxy for the degree of access to leasing, our results are consistent with what we find in Panel A: the idiosyncratic volatility puzzle only exists for firms with easy access to leased capital. Our results are also robust when we use different cutoffs to classify firms with access to leasing activities[5].

[Place Table 3 about here]

To summarize, we find the idiosyncratic volatility puzzle is mainly driven by financially constrained firms–especially those with access to leasing markets. This intriguing fact encourages us to understand the puzzle from the investment side and thus take leased capital into consideration. In the next section, we construct a risk-based asset pricing model to rationalize our findings.

3 An Investment-Based Asset Pricing Model

In this section, we construct an investment-based asset pricing model, following Bernanke, Gertler, and Gilchrist (1999) and Gertler and Kiyotaki (2010), and we explicitly introduce leased capital into our model. The basic structure of the model is as follows: there are many isolated islands, and within each island, there exists a firm run by a local entrepreneur. Across islands, firms share common aggregate TFP shocks; meanwhile, they are also affected by their locally idiosyncratic volatility of productivity. Risk-averse entrepreneurs use their own equity and loans from local banks on the same island to finance projects, after which they choose capital structures for production to maximize lifetime utility.

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[5] Refer to Table A.3 for 30 percentile as cutoffs and Table A.4 for 50 percentiles. Our results are consistent with Table 3.

3.1 Production

In the economy, there's one continuum of islands, and within each island, there exist a firm i run by a local entrepreneur. The local firm i's output is not only affected by economy-wide TFP A_t, but also by the locally idiosyncratic volatility of its productivity, σ_t^i. In the spirit of Gomes et al. (2020), we assume that each firm owns one continuum of plants, indexed by j, in which $j \in [0, 1]$. These plants produce identical final goods with the same constant-to-scale production technology. Therefore, by aggregation over the plants, the firm-specific variable σ_t^i could represent a local determinant of the equity return.

Specifically, in our model, each plant j of firm i produces final output $Y_t^{i,j}$ as:

$$Y_t^{i,j} = A_t \omega_t^{i,j} K_t^{i,j} \tag{1}$$

in which $K_t^{i,j}$ [6] is the total amount of capital used in production and contains two components, owned capital $K_{o,t}^j$ and leased capital $K_{l,t}^j$. For the sake of simplicity, we assume they are perfect substitutes in production such that:

$$K_t^j = K_{o,t}^j + K_{l,t}^j. \tag{2}$$

A_t is the aggregate productivity. The plant-specific productivity shock ω_t^j affects the efficient units of a firm's capital and transforms capital K_t^j into efficient units $\omega_t^j K_t^j$. We assume that the plant-specific productivity shock ω_t^j is i.i.d. and follows a log-normal distribution with mean φ_t^i and standard deviation σ_t^i. We further impose $\varphi_t^i = -\frac{1}{2}(\sigma_t^i)^2$ such that the mean of plant-specific productivity shocks ω_t^j within an island is equal to one. Moreover, similar to Gomes et al. (2020), we allow σ_t^i to vary over time and evolve according to an exogenous Markov process.

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[6] We suppress the superscription i hereafter unless necessary.

3.2 Plants, Firms, Banks, and Debt Contracts

In this section, we'll first solve the optimization problem of each plant and then aggregate to the firm-level, which will help us focus on the effects of idiosyncratic volatility σ_t^i on stock returns.

Resource Constraint of Plants At the end of each period t, an existing plant will decide upon the capital structure for the next period: either purchasing owned capital $K_{o,t+1}^j$, or renting for leased capital $K_{l,t+1}^j$, with bank loans B_{t+1}^j and equity from last period N_t^j. The resource constraint for the plant j is:

$$B_{t+1}^j + N_t^j = Q_t K_{o,t+1}^j + \tau_{l,t} K_{l,t+1}^j \tag{3}$$

in which Q_t is the price of owned capital, and $\tau_{l,t}$ is the rental fee of leased capital.

In period $t+1$, the plant receives the plant-specific productivity shock ω_{t+1}^j that transforms its total K_{t+1}^j into $\omega_{t+1}^j K_{t+1}^j$ effective units. After production, the plant must liquidate its own capital after depreciation, which is equal to $\omega_{t+1}^j(1-\delta)K_{o,t+1}^j$, and return the amount of leased capital $\omega_{t+1}^j(1-\delta)K_{l,t+1}^j$ to capital lessors. Thus, the total capital gain for plant j is $\omega_{t+1}^j\left(MPK_{t+1}K_{t+1}^j + (1-\delta)Q_{t+1}K_{o,t+1}^j\right)$.

Payoff to Two Parties Following Bernanke et al. (1999), we assume that the plant can borrow from a bank based on tomorrow's cash flow from its own capital. Thus, the break-even condition for each plant determining the default cutoff value $\bar{\omega}_{t+1}^j$ is:

$$\bar{\omega}_{t+1}^j\left(MPK_{t+1}K_{o,t+1}^j + (1-\delta)Q_{t+1}K_{o,t+1}^j\right) = Z_{t+1}^j B_{t+1}^j \tag{4}$$

When $\omega_{t+1}^j > \bar{\omega}_{t+1}^j$, the plant j receives:

$$N_{t+1}^j = \omega_{t+1}^j\left(MPK_{t+1}K_{t+1}^j + (1-\delta)Q_{t+1}K_{o,t+1}^j\right) - Z_{t+1}^j B_{t+1}^j, \tag{5}$$

while the lender receives the loan payment $Z^j_{t+1}B^j_{t+1}$. When $\omega^j_{t+1} \leq \bar{\omega}^j_{t+1}$, the plant defaults, and receives 0. The bank will grab the control of the default plant, but he must pay an amount of versification costs that is proportional to the plant's payoff, denoted by μ. Therefore, when the unlucky plant is liquidated in default, the amount the bank can get back is:

$$(1-\mu)\omega^j_{t+1}\left[MPK_{t+1}K^j_{o,t+1} + (1-\delta)Q_{t+1}K^j_{o,t+1}\right] \tag{6}$$

Buy versus Lease Decision From these equations, we can find that when plants optimize their decisions, purchasing capital with bank loans suffers from verification costs of potential bankruptcy. As in Townsend (1979), the verification costs paid by banks in bankruptcy will reduce a borrower's debt capacity. Things are different, however, for leasing contracts when a firm goes bankrupt. Under Chapter 11 of the US bankruptcy code, lessors have a stronger and more advanced ability to repossess assets than do lenders of secured lending. The repossession advantage of lessors means that the leased capital saves verification costs, or equivalently $\mu = 0$ in the leasing contract; thus, leased capital can expand firms' debt capacity. However, the leased capital also acquires compensation from its own agency costs: due to the separation of ownership and control rights, lessors must pay an additional amount of money to ensure that lessees take good care of leased assets. The trade-off between these two agency costs lies at the core of buy-versus-lease decisions.

Lender's Break-Even Condition Similar to Bernanke et al. (1999), when a plant chooses the optimal loan contract, the value of $\bar{\omega}^j_{t+1}$ and Z^j_{i+1} are determined by the assumption that the financial intermediary receives an expected return equal to the opportunity cost of its funds. In this case, because the loan risk for the local bank is perfectly diversifiable among plants within the same island, the relevant opportunity cost to the bank is the risk-free rate,

$R_{f,t+1}$. Therefore, the loan contract must satisfy:

$$\begin{aligned} R_{f,t+1}B^j_{t+1} = & \left[1 - F_t\left(\bar{\omega}^j_{t+1}\right)\right] Z^j_{t+1}B^j_{t+1} \\ & + (1-\mu)\int_0^{\bar{\omega}^j_{t+1}} \omega^j_{t+1}\left(MPK_{t+1}K^j_{o,t+1} + (1-\delta)Q_{t+1}K^j_{o,t+1}\right) dF_t\left(\omega^j_{t+1}\right), \end{aligned} \tag{7}$$

in which $F_t(\cdot)$ is the cumulative density function for ω^j_{t+1} with σ_t as standard deviation. The right-hand side is the expected gross return on the loan to plant j and the left-hand side is the bank's opportunity cost of deposit. This break-even condition holds for all possible states at time $t+1$. To save unnecessary notations, we further define:[7]

$$\begin{gathered} G_t\left(\bar{\omega}^j_{t+1}\right) \equiv \int_0^{\bar{\omega}^j_{t+1}} \omega^j_{t+1} dF_t\left(\omega^j_{t+1}\right) \\ \Gamma_t\left(\bar{\omega}^j_{t+1}\right) \equiv \int_0^{\bar{\omega}^j_{t+1}} \omega^j_{t+1} dF_t\left(\omega^j_{t+1}\right) + \bar{\omega}^j_{t+1}\int_{\bar{\omega}^j_{t+1}}^{\infty} dF_t\left(\omega^j_{t+1}\right) = G_t\left(\bar{\omega}^j_{t+1}\right) + \left[1 - F_t\left(\bar{\omega}^j_{t+1}\right)\right]\bar{\omega}^j_{t+1} \end{gathered} \tag{8}$$

Later, we will show that for each unit of cash flow generated by owned capital, $1-\Gamma_t$ fraction is reserved by the entrepreneur, and $\Gamma_t - \mu G_t$ fraction is repaid to the bank.

Substituting out $Z^j_{t+1}B^j_{t+1}$ with equation (4), we can simplify the lender's valuation equation as:

$$R_{f,t+1}B^j_{t+1} = \left(MPK_{t+1}K^j_{o,t+1} + (1-\delta)Q_{t+1}K^j_{o,t+1}\right)\left(\Gamma_t - \mu G_t\right) \tag{9}$$

Plants' Optimization Problem When the entrepreneur optimizes plans for his plants, he inherits the stochastic discount factor M_{t+1} from the outside representative household for which the consumption is perfectly insured. Following Ai, Li, Li, and Schlag (2020), we assume that plants do not pay dividends for simplicity's sake. Instead, we introduce stochastic liquidity shocks that result in the net worth of the stochastically liquidated plants being given to the entrepreneur and then returned to the household.

In each period, based on the plant's net worth N^j_t, the entrepreneur will optimally choose

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[7] Hereafter we denote $G_t\left(\bar{\omega}^j_{t+1}\right)$ as G_t and $\Gamma_t\left(\bar{\omega}^j_{t+1}\right)$ as Γ_t respectively.

$\left(\bar{\omega}^j_{t+1}, Z^j_{t+1}, B^j_{t+1}, K^j_{o,t+1}, K^j_{l,t+1}\right)$ to maximize his utility:

$$E_t\left\{\int_{\bar{\omega}^j_{t+1}}^{\infty} M_{t+1}\left[\chi V_{t+1}(N^j_{t+1}) + (1-\chi)\, N^j_{t+1}\right] dF_t(\omega)\right\} \tag{10}$$

such that:

$$B^j_{t+1} + N^j_t = Q_t K^j_{o,t+1} + \tau_{l,t} K^j_{l,t+1} \tag{11}$$

$$R_{f,t+1} B^j_{t+1} = \left(MPK_{t+1} K^j_{o,t+1} + (1-\delta) Q_{t+1} K^j_{o,t+1}\right)(\Gamma_t - \mu G_t) \tag{12}$$

$$\bar{\omega}^j_{t+1}\left(MPK_{t+1} K^j_{o,t+1} + (1-\delta) Q_{t+1} K^j_{o,t+1}\right) = Z^j_{t+1} B^j_{t+1} \tag{13}$$

$$N^j_{t+1} = \begin{cases} 0, & \text{if } \omega^j_{t+1} \leq \bar{\omega}^j_{t+1} \\ \left(\omega^j_{t+1} - \bar{\omega}_{t+1}\right)\left[(MPK_{t+1} + (1-\delta) Q_{t+1}) K^j_{o,t+1}\right] + \omega^j_{t+1} MPK_{t+1} K^j_{l,t+1}, & \text{Otherwise} \end{cases} \tag{14}$$

in which $V_{t+1}(N^j_{t+1})$ denotes the value of plant j in the next period if the plant is not liquidated, N^j_{t+1} is the net worth of plant j in the next period, and χ is the stochastic liquidation probability. Equation (11) is the budget constraint of plant j, (12) is the break-even condition for banks, (13) is the equation for plant j's default threshold, and (14) is the net worth of plant j in period $t+1$.

Aggregation to Firm Level Similar to Christiano et al. (2014), plant-specific net worth N^j_t enters the optimization problem linearly, and the value of the plant is thus linear in its equity value N^j_t. Therefore:

$$V_t(N^j_t) = \eta_t N^j_t \tag{15}$$

in which η_t is the firm-specific marginal value of net worth and only depends on the firm-specific state variable σ^i_t and aggregate TFP A_t.

Additionally, we can normalize all the quantities $K^j_{o,t+1}, K^j_{l,t+1}, B^j_{t+1}$ by N^j_t. Due to the linearity of N^j_t, all plants belonging to the identical firm will make the same choices of normalized quantities $k_{o,t+1}, k_{l,t+1}, b_{t+1}$, and the same $\bar{\omega}_{t+1}$, which also only depend on the firm-specific idiosyncratic volatility σ_t^i and aggregate state variables. This means that plant-level heterogeneity can be averaged out by the law of large numbers, and the optimization of plants can be simplified to the optimization problem of the firm: we simply need to focus on the normalized variables for firm i. We can then aggregate the plants' choices to the firm-level quantities:

$$\begin{aligned} K_{o,t+1} &= \int_j K_{o,t+1}^j dj = \int_j k_{o,t+1} N_t^j dj = k_{o,t+1} \int_j N_t^j dj = k_{o,t+1} N_t \\ K_{l,t+1} &= \int_j K_{l,t+1}^j dj = \int_j k_{l,t+1} N_t^j dj = k_{l,t+1} \int_j N_t^j dj = k_{l,t+1} N_t \\ B_{t+1} &= \int_j B_{t+1}^j dj = \int_j b_{t+1} N_t^j dj = b_{t+1} \int_j N_t^j dj = b_{t+1} N_t \end{aligned} \tag{16}$$

The equity value of firm i, who owns all plants within the island, satisfies that:

$$\begin{aligned} N_{t+1} = \int_j N_{t+1}^j dj = &\{(1 - \Gamma_t(\bar{\omega}_{t+1}))\,(MPK_{t+1} + (1-\delta)Q_{t+1})\,k_{o,t+1} + \\ &[1 - \Gamma_t(\bar{\omega}_{t+1}) + \bar{\omega}_{t+1}(1 - F_t(\bar{\omega}_{t+1}))]\,MPK_{t+1} k_{l,t+1}\}\,N_t \end{aligned} \tag{17}$$

Optimality Conditions With this simplification, we can focus on the effect of the firm's idiosyncratic volatility σ_t^i. We proceed to solve the maximization problem by deriving first-order conditions. We let λ_{t+1} be the Lagrangian multiplier of a bank's break-even condition (9). It is an ex post variable conditioned on the realization of aggregate states A_{t+1} and firm-specific σ_{t+1}^i. We can obtain the first-order condition with respect to $\bar{\omega}_{t+1}$ as:

$$\begin{aligned} &(\chi\eta_{t+1} + 1 - \chi)\left[\Gamma_t^{'}\,(MPK_{t+1} + (1-\delta)Q_{t+1})\,K_{o,t+1} + \left(\Gamma_t^{'} - 1 + F_t + \bar{\omega}_{t+1}F_t^{'}\right) MPK_{t+1}K_{l,t+1}\right] \\ &\qquad = \lambda_{t+1}\left(\Gamma_t^{'} - \mu G_t^{'}\right)(MPK_{t+1} + (1-\delta)Q_{t+1})\,K_{o,t+1} \end{aligned} \tag{18}$$

in which $\Gamma_t^{'}, G_t^{'}$, and $F_t^{'}$ denote for the corresponding first-order derivatives with respect to $\bar{\omega}_{t+1}$. The left-hand side is marginal costs for the firm to increase $\bar{\omega}_{t+1}$ by one unit, which is the next period's net worth given up by the firm generating from the owned capital and leased capital, multiplied by the marginal value of net worth. The right-hand side is the marginal benefit of increasing one unit of $\bar{\omega}_{t+1}$: the additional fraction $\left(\Gamma_t' - \mu G_t'\right)$ of cash flow goes to the bank multiplied by the Lagrangian multiplier of the bank's break-even condition, which measures the shadow value of relaxing the borrowing constraint of the firm.

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

$$\begin{gathered} E_t\left\{M_{t+1}\left(1-\chi+\chi\eta_{t+1}\right)(1-\Gamma_t)(MPK_{t+1}+(1-\delta)Q_{t+1})\right\}+ \\ E_t\left\{M_{t+1}\lambda_{t+1}(\Gamma_t-\mu G_t)(MPK_{t+1}+(1-\delta)Q_{t+1})\right\}=\eta_t Q_t \end{gathered} \tag{19}$$

From equation (19), we can find that in equilibrium, one additional unit investment in owned capital can bring $(1-\Gamma_t)(MPK_{t+1}+(1-\delta)Q_{t+1})$ amount of next period cash flow, and can help relax the borrowing constraint by $\lambda_{t+1}(\Gamma_t-\mu G_t)(MPK_{t+1}+(1-\delta)Q_{t+1})$, through generating an additional fraction of cash flow to the lender. However, the plant must sacrifice an amount of $\eta_t Q_t$, the capital price multiplied by its shadow price, as marginal costs for the additional unit of investment.

Similarly, we can obtain the first-order condition for $k_{l,t+1}$:

$$E_t\left\{M_{t+1}\left(1-\chi+\chi\eta_{t+1}\right)\left[1-\Gamma_t+\bar{\omega}_{t+1}(1-F_t)\right]MPK_{t+1}\right\}=\eta_t\tau_{l,t} \tag{20}$$

in which the marginal gain of one unit investment in leased capital is a result of the additional cash flow reversed by the firm, while the marginal cost is measured by the shadow price of the leasing fee.

3.3 Stochastic Discount Factor

Following Zhang (2005) and Belo et al. (2019), we directly parameterize the pricing kernel without explicitly including the consumer's problem, which helps us focus on the production aspect. We assume that when the entrepreneur of the firm makes decisions, the entrepreneur inherits the stochastic discount factor from the outside household, for which there is perfect consumption insurance. The exogenous stochastic discount factor M_{t+1} satisfies:

$$\log(M_{t+1}) = \log\beta - \gamma\left[a_{t+1} - a_t\right] \tag{21}$$

in which M_{t+1} denotes the stochastic discount factor from time t to $t+1$, β is the time discount, γ is the price of aggregate TFP risk and $\gamma > 0$, and $a_{t+1} = \log(A_{t+1})$.

Also, we follow Merton (1987) and assume the market is incomplete; the entrepreneurs can only hold the equity on the island to which they belong, which means they can't diversify their portfolios across islands. Though Merton (1987) predicts a positive relation between idiosyncratic volatility and stock returns, as will be shown later, our model can nevertheless solve the puzzling negative relation.

3.4 The Capital Goods Producer

In each period, after production and depreciation, plants will sell the depreciated capital and then buy the new capital for the next period from the local capital producer within the same island. In the spirit of Gertler and Kiyotaki (2010) and also for simplicity's sake, we assume that the local capital producer only sells the capital to the plants and lessors within the same island. We follow Bernanke et al. (1999) and assume that the local capital producer uses amount I_t to produce new capital with technology $\Phi\left(\frac{I_t}{K_t}\right)$, for which:

$$\Phi\left(\frac{I_t}{K_t}\right) = \left[\frac{a_1}{1-\frac{1}{\zeta}}\left(\frac{I_t}{K_t}\right)^{1-\frac{1}{\xi}} + a_2\right] \tag{22}$$

The law of motion of the capital on the island is then given by:

$$K_{o,t+1} + K_{l,t+1} = \Phi\left(\frac{I_t}{K_{o,t} + K_{l,t}}\right)(K_{o,t} + K_{l,t}) + (1-\delta)(K_{o,t} + K_{l,t}) \tag{23}$$

The optimal choice of investment will pin down the price of a unit of capital Q_t:

$$\max_{I_t} Q_t \Phi\left(\frac{I_t}{K_{o,t}+K_{l,t}}\right)(K_{o,t}+K_{l,t}) - I_t \tag{24}$$

which is given by:

$$Q_t = \left[\Phi'\left(\frac{I_t}{(K_{o,t}+K_{l,t})}\right)\right]^{-1} = \frac{1}{a_1}\left(\frac{I_t}{(K_{o,t}+K_{l,t})}\right)^{\frac{1}{\zeta}} \tag{25}$$

3.5 The Capital Lessor

Similarly, we let the competitive lessors only lease to local plants within the same island. At the end of period t, lessors will purchase $K_{l,t+1}$ from the local capital producer and then lease the capital to local plants. Lessors maximize their profits and take the leasing fee, $\tau_{l,t}$ and capital price Q_t as given. Since lessors has the repossession advantage, we can assume that lessors receive their full value of $(1-\delta)K_{l,t+1}$ back from lessees and then sell it back to the local capital producer. However, due to the separation of ownership and control rights, we assume lessors must pay monitoring costs $Q_t\Theta\left(K_{l,t+1}, K_{t+1}\right)$ upfront at time t to make sure that lessees will take good care of leased capital.

The optimization problem of the lessor is:

$$\max_{\left\{K_{l,i+1}\right\}_{i=t}^{\infty}} E_t \sum_{i=t}^{\infty} M_{t,i}\left(\tau_{l,i}K_{l,i+1} - Q_i K_{l,i+1} - Q_i\Theta\left(K_{l,i+1}, K_{i+1}\right) + E_i\left\{M_{i,i+1}Q_{i+1}K_{l,i+1}(1-\delta)\right\}\right) \tag{26}$$

Following Li and Tsou (2019), we assume monitoring costs such that:

$$\Theta\left(K_{l,t+1}, K_{t+1}\right) = \kappa K_{l,t+1} + \frac{d}{2}\left(\frac{K_{l,t+1}}{K_{t+1}} - \frac{K_l^{SS}}{K^{SS}}\right)^2 K_{t+1} \tag{27}$$

for which K_l^{SS}, K^{SS} denotes leased capital and total capital in the steady state. The first-order condition for the lessor is:

$$\tau_{l,t} = Q_t + Q_t\Theta'\left(K_{l,t+1}, K_{t+1}\right) - (1-\delta)E_t\left[M_{t+1}Q_{t+1}\right] \tag{28}$$

for which $\Theta'\left(K_{l,t+1}, K_{t+1}\right) = \kappa + d\left(\frac{K_{l,t+1}}{K_{t+1}} - \frac{K_l^{SS}}{K^{SS}}\right)$. We find that the leasing fee, or the user cost of the leased capital, equals user costs without any friction, $Q_t - (1-\delta)E_t\left[M_{t+1}Q_{t+1}\right]$, plus marginal monitoring costs.

4 Equilibrium Asset Pricing

4.1 Negatively Priced Idiosyncratic Volatility Shocks

To illustrate our intuition more clearly, we introduce the augmented stochastic discount factor:

$$\widetilde{M}^i_{t+1} = M_{t+1}\frac{\chi\eta^i_{t+1} + 1 - \chi}{\eta^i_t} \tag{29}$$

which is used to price the equity of the firm on the island i, and:

$$\begin{aligned}
\log\widetilde{M}^i_{t+1} &= \log\beta - \gamma\left[a_{t+1} - a_t\right] + \log\left(\chi(\eta^i_{t+1} - 1) + 1\right) - \log\left(\eta^i_t\right) \\
&\approx \log\beta - \gamma\Delta a_{t+1} + \chi\left(\eta^i_{t+1} - 1\right) - \log\left(\eta^i_t\right) \\
&= \log\beta - \gamma\Delta a_{t+1} + \chi\Delta\eta^i_{t+1} + Const.
\end{aligned} \tag{30}$$

Since η^i_{t+1}, the marginal value of net worth, depends on A_{t+1}, σ^i_{t+1}, we can approximate $\Delta\eta^i_{t+1}$ as:

$$\Delta\eta^i_{t+1} = \frac{\partial\eta^i_{t+1}}{\partial\sigma^i_{t+1}}\Delta\sigma^i_{t+1} + \frac{\partial\eta^i_{t+1}}{\partial a_{t+1}}\Delta a_{t+1} \tag{31}$$

in which $\frac{\partial\eta^i_{t+1}}{\partial a_{t+1}} < 0, \frac{\partial\eta^i_{t+1}}{\partial\sigma^i_{t+1}} > 0$, which means the marginal value of equity increases when total TFP decreases or when idiosyncratic volatility increases. Combing these together, we can approximate the augmented stochastic discount factor as:

$$\log \widetilde{M}^i_{t+1} \approx \log \beta - \underbrace{\left[\gamma + \left(-\chi \frac{\partial \eta^i_{t+1}}{\partial a_{t+1}}\right)\right]}_{\gamma_a > \gamma} \Delta a_{t+1} - \underbrace{\left(-\chi \frac{\partial \eta^i_{t+1}}{\partial \sigma^i_{t+1}}\right)}_{\gamma_{IVOL} < 0} \Delta \sigma^i_{t+1} + Con. \tag{32}$$

We learn following two messages from Equation (32). First, due to costly state verification, which makes $\frac{\partial \eta^i_{t+1}}{\partial a_{t+1}} < 0$, the entrepreneur becomes more risk averse and requires a higher price of aggregate risk. Second, and more importantly, risk in idiosyncratic volatility, $\Delta \sigma^i_{t+1}$, is negatively priced, which is in the spirit of Merton (1987). Upon a positive idiosyncratic volatility shock, firms' debt capacity shrinks, and the interest rate increases. Both the marginal value of equity and marginal utility will increase; therefore, idiosyncratic volatility shock should carry a negative price of risk.

4.2 Leased Capital Spread

We define the returns on owned capital and leased capital respectively, and discuss their different risk exposures in the model. $R^{Lev}_{o,t+1}$, the leveraged return of the owned capital, is defined as:

$$R^{Lev}_{o,t+1} = \frac{(1-\Gamma_t)(MPK_{t+1} + (1-\delta)Q_{t+1})}{\phi_{o,t}} \tag{33}$$

in which the numerator is the fraction of tomorrow's cash flow for per unit of the owned capital going to the plant, after repaying the debt. $\phi_{o,t}$ is the essential down payment for the owned capital. It equals the purchased price subtracting the debt for per unit of owned capital:

$$\phi_{o,t} = Q_t - E_t \left\{ \frac{M_{t+1}\lambda_{t+1} (\Gamma_t - \mu G_t) (MPK_{t+1} + (1-\delta)Q_{t+1})}{\eta_t} \right\}, \tag{34}$$

Thus, $R^{Lev}_{o,t+1}$ is the levered return of the owned capital.

On the other hand, $R_{l,t+1}$ is the return of the leased capital:

$$R_{l,t+1} = \frac{(1 - \Gamma_t + \bar{\omega}_{t+1}(1 - F_t))MPK_{t+1}}{\tau_{l,t}} \tag{35}$$

in which $\tau_{l,t}$ is the per period leasing fee that must be paid upfront, and $(1 - \Gamma_t + \bar{\omega}_{t+1}(1 - F_t))MPK_{t+1}$ is the cash flow generated by each unit of leased capital with a normalization term.

Combining the Euler equations (19) and (33), we obtain a pricing function for owned capital:

$$E_t \left\{ \widetilde{M}_{t+1} R^{Lev}_{o,t+1} \right\} = 1 \tag{36}$$

and rearranging equations (20) and (35) gives the pricing function of leased capital:

$$E_t \left\{ \widetilde{M}_{t+1} R_{l,t+1} \right\} = 1 \tag{37}$$

Therefore, the expected return spread is equal to:

$$E_t \left(R^{Lev}_{o,t+1} - R_{l,t+1} \right) = -\frac{1}{E_t \left(\widetilde{M}_{t+1} \right)} \left(\mathrm{Cov}_t \left[\widetilde{M}_{t+1}, R^{Lev}_{o,t+1} \right] - \mathrm{Cov}_t \left[\widetilde{M}_{t+1}, R_{l,t+1} \right] \right) \tag{38}$$

Risk premiums are determined by covariances of the payoffs with respect to the stochastic discount factor. While returns of two assets have the same component MPK_{t+1}, returns for owned capital, $R^{Lev}_{o,t+1}$, have higher risk exposure due to fluctuations in the resale value of owned capital in the next period. However, after production, the firm will return capital back to the lessor; thus fluctuations in the resale value of leased capital are absent from the return of leased capital. Undoubtedly, the most variations of the returns are from the resale value of capital, rather than the marginal production. The absence of $(1 - \delta)Q_{t+1}$ in $R_{l,t+1}$ makes the leased capital less covaried with the pricing kernel, and therefore less risky than owned capital.

In contrast to Li and Tsou (2019), we argue that leased capital can hedge not only for aggregate shocks but idiosyncratic volatility shocks as well, since idiosyncratic volatility shocks can also bring additional fluctuations in capital prices. On the island with high idiosyncratic volatility, which can be considered a bad state for the firm, the demand of capital shrinks and the resale value of capital will be relatively low; meanwhile, the demand and capital price are high on the island with low idiosyncratic volatility. Hence, idiosyncratic volatility is negatively correlated with capital prices. On the other hand, interaction between financial constraints and idiosyncratic volatility makes the entrepreneur's stochastic discount factor positively covaried with idiosyncratic volatility. On the island with high idiosyncratic volatility, the marginal value of net worth and the augmented stochastic discount factor are much higher than their counterparts on the island with low idiosyncratic volatility. Therefore, even if there's no aggregate shock, with the component of capital resale price in its numerator, the return of owned capital is still more negatively correlated with the pricing kernel. Therefore, we can conclude that leased capital can hedge for idiosyncratic volatility risks and is thus less risky than owned capital.

4.3 Return Decomposition and Negative IVOL Spread

We can aggregate the resource constraint for each plant, equation (3), into the firm-level:

$$B_{t+1} + N_t = Q_t K_{o,t+1} + \tau_{l,t} K_{l,t+1} \tag{39}$$

When we include the break-even condition of the local bank (9) and the definition of the down payment of owned capital (34), we can rewrite firm i's budget constraint (39) as:

$$N_t = \phi_{o,t} K_{o,t+1} + \tau_{l,t} K_{l,t+1} \tag{40}$$

Combined with the linearity of the value function (15) and the definition of the value function (10), we have:

$$E_t \left\{ \widetilde{M}_{t+1} \left[\frac{\phi_{o,t} K_{o,t+1}}{N_t} R^{Lev}_{o,t+1} + \frac{\tau_{l,t} K_{l,t+1}}{N_t} R_{l,t+1} \right] \right\} = 1 \tag{41}$$

for which the equity return is the growth of its equity value:

$$R_{t+1} = \frac{N_{t+1}}{N_t} = \frac{\phi_{o,t} K_{o,t+1}}{N_t} R^{Lev}_{o,t+1} + \frac{\tau_{l,t} K_{l,t+1}}{N_t} R_{l,t+1} \tag{42}$$

From equation (42), we know that equity return R_{t+1} is a value-weighted average of owned capital return $R^{Lev}_{o,t+1}$ and leased capital return $R_{l,t+1}$. The weights $\frac{\phi_{o,t} K_{o,t+1}}{N_t}$ and $\frac{\tau_{l,t} K_{l,t+1}}{N_t}$ are corresponding proportions of the owned capital's down payment and the leasing fee with respect to the firm's net worth, respectively. Due to the resource constraints of the firm, (40), the weights add up to 1.

This decomposition guides our cross-sectional asset pricing implications. From equation (42), we have:

$$E_t \left\{ R_{t+1} \right\} = \frac{\phi_{o,t} K_{o,t+1}}{N_t} E_t \left\{ R^{Lev}_{o,t+1} \right\} + \frac{\tau_{l,t} K_{l,t+1}}{N_t} E_t \left\{ R_{l,t+1} \right\} \tag{43}$$

Firms with different level of idiosyncratic volatility will choose different combinations of these two types of assets and, thus, have different risk profiles and expected returns. Specifically, firms with higher idiosyncratic volatility will use more leased capital. This is because with a higher idiosyncratic volatility in productivity, the firm will have a higher probability of entering a bad state and declaring bankruptcy. The higher bankruptcy probability corresponds to higher expected bankrupt costs. The costly state verification in bankrupt shrinks their debt capacity; as a result, these firms evaluate the enlarged debt capacity from leased capital more than costs of leasing and choose a higher fraction of leased capital investment, $\frac{\tau_{l,t} K_{l,t+1}}{N_t}$. As we discussed in Section 4.2, leased capital is less risky and delivers lower expected returns. Therefore, firms with higher idiosyncratic volatility will carry lower average returns, which is exactly what the idiosyncratic volatility puzzle conveys to us. As we show in the next section, our quantitative results match well with our empirical findings, and our mechanism can be well validated by testable implications.

5 Quantitative Model Implications

This section shows the quantitative results of our dynamic model. Our model is calibrated at annual frequency and can replicate key moments of both macroeconomic quantities and asset prices at the aggregate level. Moreover, our model behaves well when we quantitatively account for key features of firm characteristics and produce a negative idiosyncratic volatility premium cross-sectionally. For macroeconomic quantities, we focus on a long sample of U.S. annual data from 1930 to 2016. All macroeconomic variables are real and per capita. Output and physical investment data are from the Bureau of Economic Analysis (BEA).

5.1 Specification of Aggregate Shocks and Idiosyncratic Volatility Shocks

In our model, all firms share a common exogenous aggregate shock in productivity. Specifically, log aggregate productivity $a \equiv \log(A)$ follows:

$$a_t = a_{ss}\left(1-\rho_A\right)+\rho_A a_{t-1}+\sigma_A \varepsilon_{A,t} \tag{44}$$

in which a_{ss} is the log aggregate TFP in steady state, ρ_A is the persistence parameter, σ_A is the standard deviation of the shock, and $\epsilon_{A,t}$ is a white noise term. Following Belo et al. (2019), to focus more on idiosyncratic volatility shocks, we assume that $\rho_A = 0$, which means that deviation from the steady state is an i.i.d. process.

Second, we specify firms' exogenous process of idiosyncratic volatility in productivity, σ_t^i, to investigate how firms' leasing activities change in response to shocks to idiosyncratic volatility and also to quantify the cross-section implications of leased capital. Specifically, following Bernanke et al. (1999) and Gomes et al. (2020), we assume an AR(1) process for each firm's σ_t^i as follows:

$$\ln\left(\sigma_t^i\right)-\ln(\bar{\sigma})=\rho_\sigma\left(\ln\left(\sigma_{t-1}^i\right)-\ln(\bar{\sigma})\right)+\sigma_\sigma \varepsilon_{\sigma,t}^i \tag{45}$$

in which $\varepsilon^i_{\sigma,t}$ is i.i.d. across different periods and different firms, and is independent of $\varepsilon_{A,t}$ for parsimony's sake.

5.2 Calibration

We calibrate our model at annual frequency and and show our parameters in Table 4. We categorize these parameters into two groups. The first group of parameters are broadly in line with the literature and determined by matching a set of first moments of quantities and prices to their empirical counterparts. We set the time discount factor to 0.981, set a capital depreciation rate δ as 0.135, and set a survival rate for an entrepreneur as 0.859 (roughly matching to an average Compustat age of 10 years for financially constrained firms), set a lender's monitoring cost κ as 0.027 (consistent with Li and Yu (2023)), set capital adjustment costs as 0.5, and set the monitoring cost parameter μ to be 0.246, which is within the reasonable range discussed in Carlstrom and Fuerst (1997). We choose other parameters to jointly target the following steady state outcomes: (1) an annualized business failure, $F(\bar{\omega})$, of 3%, consistent with the data; and (2) a leased capital ratio of 0.52 for financially constrained firms, corresponding to what we find in the data. These targets give us a steady state TFP A_{ss} of 0.242, and also give us a steady state volatility of idiosyncratic volatility σ_{ss} of 0.313. We normalize the net worth of firms in the steady state to 1 by choosing the startup transfer from household, $\bar{N}$ to be 0.265. As a byproduct of these choices, our model implies a steady state debt-to-net worth ratio B/N of 0.623, which is approximately in line with the data.

The second group contains the parameters determined by second moments in the data. We set the persistence of TFP shocks $\rho_A = 0$ to focus more on idiosyncratic volatility shocks, following Belo et al. (2019), and set the persistence parameter of idiosyncratic volatility shocks ρ_σ to 0.97. We set the monitoring cost parameter d of lessor to be 0.1 to roughly match the volatility of aggregate leased capital ratio in the data. To be consistent with the volatility of investment growth and output growth, we set the volatility parameters σ_A, σ_σ

as 0.024 and 0.12. This set of parameters also can generate a reasonable spread of IVOL in the cross-section. Finally, we set the price of TFP shocks as 3 to roughly match the market premium.

[Place Table 4 about here]

5.3 Numerical Solution and Simulation

Dou, Fang, Lo, and Uhlig (2021) observes that when a model has the financial accelerator mechanism and an occasionally binding financing constraint, the solution method matters for the dynamic model. However, in our model, as in Bernanke et al. (1999) and Christiano et al. (2014), financial constraints facing entrepreneurs and the break-even conditions of banks are always binding with equality at every possible contingency in the next period. Thus, we can solve our model by using a local perturbation method due to the absence of occasionally binding financing constraints with a high enough accuracy. We use the Dynare package with second-order approximation to solve and simulate the model.

We solve the model and report the model-implied moments both in aggregate and cross-section, and then compare them with data. The model is simulated at annual frequency. We simulate the model for 240 periods and drop the first 40 periods to eliminate the effect of the starting point. In the cross-section, we simulate 5000 firms and then aggregate them to obtain our unconditional moments.

5.4 Unconditional Moments

In this section, we focus on the quantitative performance of our model on unconditional moments and show that our model can match a wide set of macroeconomic quantities and asset prices.

[Place Table 5 about here]

Table 5 reports key moments both from data and our model's simulation. In the upper panel, we show that simulated data from our model are broadly in line with the basic features of aggregate asset pricing moments, including market premium, the market Sharpe ratio, and risk-free rate. In the middle panel, we focus on aggregate-level real quantities, and our model can match several macroeconomic moments in terms of volatilities of output growth, investment growth, investment ratio, and the mean and volatility of leased capital ratio in the data. As for cross-sectional real quantities in the bottom panel, our results show that the signs of correlations in the data between IVOL with leased capital ratio, rental share, size, and investment growth are in line with the ones predicted by the model. Overall, the model's implications for the co-movements between IVOL and these quantities are broadly consistent with the data, even if we do not directly target these aggregate moments in our calibration.

5.5 Impulse Response Functions

The asset pricing implications of our model are best illustrated with impulse response functions. We next plot impulse response functions with respect to shocks of aggregate TFP and idiosyncratic volatilities.

[Place Figure 1 about here]

In Figure 1, we plot the percentage deviations of quantities and prices from the steady state in response to a one-standard deviation TFP shock (i.e., the shock to a). The corresponding parameters are listed in Table 4.

We summarize four observations as follows. First, as captured in the literature, when a negative TFP shock hits the economy, firms will face tighter financial constraints, which is represented by a higher Lagrangian multiplier of the break-even condition λ. The negative TFP shock works as a negative discount shock to the entrepreneur and spikes up the stochastic discount factor both by the direct effect of the original exogenous process of the pricing kernel and amplified by the increased marginal value of net worth in the multiplier of the augmented SDF.

Second, the negative TFP shock, which leads to the tightening of borrowing constraints, is translated into a lower equity value N_t and lower capital stock K_{t+1} of firms. In the setting with forward-looking entrepreneurs, we find that the negative shock to the real economy is persistent.

Third, consistent with the leasing literature (e.g. Li and Yu (2023)), when borrowing is more costly, leased capital is more attractive because of verification cost savings in bankruptcy and, therefore, higher debt capacity. In the third row of Figure 1, we find that leased capital spikes up when a negative shock occurs, while the firm will reduce investment in purchasing capital. In other words, the leased capital ratio ϕ_t increases.

Lastly, the last row of Figure 1 echos what we argue in Section 4.2: that leased capital can hedge for aggregate TFP shocks, due to the low risk profile resulting from the absence of the resale value. Capital price drops when a negative TFP shock occurs, and when compared to purchased capital, the return of leased capital responds much lower than does the return of owned capital, which can mitigate the drop of the firm equity.

[**Place Figure 2 about here**]

Figure 2 shows the hedging effect of the leased capital for idiosyncratic volitility shocks, which is one of the most important innovations of our paper. Similar to its counterparts in Figure 1, when a firm enters a higher idiosyncratic volatility state, which is a bad situation for the firm, the firm's borrowing constraint becomes tighter, and the augmented stochastic discount factor rises steeply due to the higher marginal value of net worth. The net worth and the total capital stock of the firm with high idiosyncratic volatility will decrease due to the tightening of borrowing constraints. Meanwhile, firms will switch from owning capital to renting capital (i.e., increasing their leased capital ratio), and the effect of the negative idiosyncratic volatility shock is persistent and large.

With respect to asset pricing implications, the last row of Figure 2 confirms our arguments in Section 4.2. When the idiosyncratic volatility increases, which acts as a second order negative shock, the capital price will drop due to contraction of the investment demand in response to the positive idiosyncratic volatility shock. As we emphasize in the first-order condition of owned capital (33) and leased capital (35), $R_{o,t}^{lev}$ contains an additional exposure to fluctuations of capital resale value, while $R_{l,t}$ does not, since the capital will return to the lessor when the leasing contract ends. This difference explains the different response of two returns on the hit of the shock at $t = 1$: $R_{l,t}$ almost stays flat, while $R_{o,t}^{Lev}$ drops sharply due to the decline of capital resale value. To summarize, the leveraged return of owned capital, $R_{o,t}^{Lev}$ is more procyclical than the return of leased capital, which predicts a large spread in expected returns between $R_{o,t}^{Lev}$ and $R_{l,t}$.

5.6 Buy versus Lease Decisions

In Figure 2, our model shows that when the firm's idiosyncratic volatility increases, it will optimally increase the leased capital ratio. In this section, we further analyze the firm's buy-versus-lease decisions from the perspective of user costs. Following Jorgenson (1963), we derive the user costs for both owned capital and leased capital. For owned capital, the user cost $\widetilde{\tau}_{o,t}$ can be written as:

$$\begin{aligned}\widetilde{\tau}_{o,t} &= Q_t - E_t\left\{\widetilde{M}_{t+1}(1-\Gamma_t)(1-\delta)Q_{t+1}\right\} - E_t\left\{\frac{M_{t+1}\lambda_{t+1}\left(\Gamma_t-\mu G_t\right)\left(MPK_{t+1}+(1-\delta)Q_{t+1}\right)}{\eta_t}\right\}\\ &= E_t\left\{\widetilde{M}_{t+1}(1-\Gamma_t)MPK_{t+1}\right\}\end{aligned} \tag{46}$$

The right-hand side of the first equality in (46) indicates that the user cost of owned capital equals the capital price Q_t minus the discounted resale value in the next period. Regarding the resale value, the fraction of $1 - \Gamma_t$ is received by the firm directly, while the fraction $\Gamma_t - \mu G_t$ shared by the lender can generate value for the firm by relaxing the break-even constraint.

The second equality represents the net expected benefit which one unit of owned capital can generate for the firm, since we know from the break-even condition, that only $1 - \Gamma_t$ fraction of the cash flow is shared by the firm. In the optimal scenario, the firm will make decisions such that the net benefit of one additional unit of owned capital equals to its user cost.

Following the same logic and to make the user costs comparable, we define the user cost of leased capital to generate the net benefit $E_t \left\{ \widetilde{M}_{t+1}(1-\Gamma_t)MPK_{t+1} \right\}$ as:

$$\begin{aligned}
\widetilde{\tau}_{l,t} &= E_t \left\{ \widetilde{M}_{t+1}(1-\Gamma_t)MPK_{t+1} \right\} \\
&= \tau_{l,t} - E_t \left\{ \widetilde{M}_{t+1}\bar{\omega}_{t+1}\left(1 - F_t\left(\bar{\omega}_{t+1}\right)\right) MPK_{t+1} \right\} \\
&= Q_t + Q_t\Theta'\left(K_{l,t+1}, K_{t+1}\right) - (1-\delta)E_t\left[M_{t+1}Q_{t+1}\right] - E_t \left\{ \widetilde{M}_{t+1}\bar{\omega}_{t+1}\left(1 - F_t\left(\bar{\omega}_{t+1}\right)\right) MPK_{t+1} \right\}
\end{aligned} \tag{47}$$

which equals the leasing fee $\tau_{l,t}$ minus a normalization term, similar as (35). By comparing equation (46) and (47), we can conclude that $\widetilde{\tau}_{o,t} = \widetilde{\tau}_{l,t}$, which implies that in the equilibrium with the leasing market, the user costs of different types of capital should be equal, otherwise one of the capital markets will shut down.

Combing equation (46) and (47), we can obtain the trade-off in buy-versus-lease decisions as:

$$\begin{aligned}
Q_t\Theta'\left(K_{l,t+1}, K_{t+1}\right) =& (1-\delta)E_t\left[M_{t+1}Q_{t+1}\right] - E_t \left\{ \widetilde{M}_{t+1}\left[(1-\Gamma_t)(1-\delta)Q_{t+1} - \bar{\omega}_{t+1}\left(1 - F_t\left(\bar{\omega}_{t+1}\right)\right) MPK_{t+1}\right] \right\} \\
&- E_t \left\{ \frac{M_{t+1}\lambda_{t+1}\left(\Gamma_t - \mu G_t\right)\left[MPK_{t+1} + (1-\delta)Q_{t+1}\right]}{\eta_t} \right\}
\end{aligned} \tag{48}$$

in which the left-hand side represents the monitoring costs in leased capital and the right-hand side is the marginal benefit of the leasing. The benefit arises from differences between the resale value of leasing contract and lending. For the leasing contract, the resale value is $(1-\delta)E_t\left[M_{t+1}Q_{t+1}\right]$, which is absent from the verification costs in potential bankruptcy due to the repossession advantage for lessors. For the lending contract, the resale value of capital consists of the monetary value directly returned to the firm (discounted by $\widetilde{M}_{t+1}$) and the value for the firm by generating benefits for the bank and relaxing its break-even constraint.

When the idiosyncratic volatility increases, the benefit of leasing will outweigh the monitoring costs, prompting the firm to optimally utilize more leased capital and choose a higher leased capital ratio. As idiosyncratic volatility rises, the default probability and expected verification costs in the bankruptcy associated with the lending contract will go up, directly reducing the benefits received by the bank. Consequently, the firm's debt capacity shrinks due to the break-even requirement of the bank. The firm will become more financially constrained at period t, which will reduce the expected next period value of the adjusted resale values. Taking these factors into account, the total adjusted resale value in the lending contract diminishes, and the benefit of leasing contract, represented by the difference between resale values of the leasing contract and the lending contract, will dominate monitoring costs of leased capital. Thus, the firm optimally increases its use of leasing when idiosyncratic volatility rises.

5.7 The Cross-Section of Leasing and Equity Returns

We next study the implications of our model on the cross-section of idiosyncratic volatility portfolios. We simulate firms from the model and sort them by their IVOL by using the same procedure in the data. In Table 6, we show the expected returns and several other characteristics for financially constrained firms both in the data and our simulated model.

[**Place Table 6 about here**]

As is the case with those in the data, firms with high idiosyncratic volatility deliver a significantly lower average return than those with low idiosyncratic volatility in our model. Quantitatively, our model not only replicates the monotonically decreasing pattern of returns across IVOL portfolios, but also predicts a sizable IVOL spread around -3.73%, which accounts for more than 65% of the spread in the data.

Table 6 also shows several other firm characteristics of IVOL-sorted portfolios that are related to the economic mechanism in our model. First, the idiosyncratic volatility is monotonically increasing for the IVOL-sorted portfolios by nature. Second, the leased capital ratio is increasing in idiosyncratic volatility, which is consistent with the data and the broader corporate finance literature that emphasizes the importance of leasing in firms' capital structure decisions (e.g., Eisfeldt and Rampini (2009), Rampini and Viswanathan (2013)). Although the dispersion in leased capital in our model is somewhat higher than that in the data, this finding is not surprising. As in our model, a shock to idiosyncratic volatility is the only factor that determines cross-sectional leased capital ratio, whereas many other determinants of the capital structure appear in reality. We admit that these factors themselves as well as their interactions with idiosyncratic volatility shocks all matter in reality.

6 Testable Implications

In this section, we present additional empirical evidence to further support our model mechanism. We first review the predictive power of idiosyncratic volatility in relation to the leased capital ratio, uncovering a positive correlation exclusively within firms with easy access to leasing activities. Secondly, we affirm that, all other factors being equal, firms experiencing higher idiosyncratic volatility that also utilize a larger fraction of leased capital, display reduced aggregate risk exposures and less negative idiosyncratic volatility risk exposures, a phenomenon attributable to the hedging effects of leased capital. Lastly, our findings show that idiosyncratic volatility risk is negatively priced in cross-sectional analysis.

6.1 Firm-level Analysis: IVOL and Leasing

As in our model, leased capital can relax the IVOL-induced financial constraint because of verification cost savings in bank loans. Firms with higher idiosyncratic volatility will be more financially constrained due to higher probabilities of default. Therefore, if they have easy access to leasing markets, then they tend to use more leased capital. Univariate sorting results in Table 1 have partially shown the positive relation between leased capital ratio and idiosyncratic volatility, and in this section, we provide further multivariate panel regressions to show that the positive relation is mainly driven by firms with access to leasing activities.

Our firm-level data come from Compustat, which is available from WRDS. All variables are winsorized at the 1st and 99th percentiles to reduce the impact of outliers, and independent variables are normalized to a zero mean and a one standard deviation after winsorization. The main regression specification is:

$$Y_{i,t} = b_0 + b_1 \times IVOL_{i,t} + b_2 \times L_{i,t} \times IVOL_{i,t} + b_3 \times L_{i,t} + \gamma \times X_{i,t} + \Gamma_s + \Gamma_t + \epsilon_{i,t} \quad (49)$$

in which the dependent variable $Y_{i,t}$ is firm i's leased capital ratio or rental share at year t. $IVOL_{i,t}$ is firm i's idiosyncratic volatility at year t. $L_{i,t}$ is the dummy variable representing firms that have easy access to leasing activities. Consistent with Table 3, it takes a value of 1 when a firm's lagged 3-year average leased capital ratio ranks in the top 80% with respect to its industry peers. We interact $IVOL_{i,t}$ and $L_{i,t}$ to explore whether this positive relation is mainly driven by firms with access to leasing markets. $X_{i,t}$ is a vector of firm-level control variables including the Whited-Wu index, size, the book-to-market ratio, the investment rate (I/K), profitability (ROA), the Altman's Z score, and the Tobin's Q. Since leasing activities are highly industry-specific, we control for industry (Γ_s) and year (Γ_t) fixed effects and cluster the standard error at the industry level.

[Place Table 7 about here]

We report our main findings in Table 7. First, in columns (1) and (3), we observe a significantly positive b_1, which indicates the positive predictive power of idiosyncratic volatility on leased capital ratio (rental share), controlling for other variables. Second, we find that the positive relation between idiosyncratic volatility and leased capital ratio or rental share is mainly driven by firms with easy access to leasing activity. A positive b_2 means that firms with easy access to leasing will more actively use leased capital when IVOL increases. When we compare regression (1) and (2), we find that b_2 is positive and significant, while b_1, the unconditional predicting coefficient of idiosyncratic volatility on leased capital ratio, becomes negative and insignificant. These two changes show that the positive relation only exists in firms with easy access to leasing. Third, our results are similar when we use rental share (RS) as the independent variable. Overall, our results are consistent with our prediction that the positive relation between idiosyncratic volatility and firms' leasing activities are mainly driven by firms with easy access to leasing markets.

6.2 Hedging Effects of Leasing Activities

In our model, we predict that firms with higher idiosyncratic volatility will have lower exposure to macroeconomic shocks and less negative exposure to idiosyncratic volatility shocks, due to larger usage of leased capital. First, leased capital can not only hedge for aggregate shocks but also for idiosyncratic volatility shocks, since the return of leased capital is absent from fluctuations of capital resale value induced by these shocks. Second, firms with higher idiosyncratic volatility use a larger fraction of leased capital to save verification costs associated with secured loans. Therefore, due to the hedging effect of leased capital, firms with high IVOL will be less exposed to macroeconomic shocks and be less negatively exposed to idiosyncratic volatility shocks, ceteris paribus.

We first show that firms with high IVOL are significantly less exposed to macroeconomic shocks and that this pattern is mainly driven by firms with access to leasing markets. Following Lin, Palazzo, and Yang (2020) and Donangelo, Gourio, Kehrig, and Palacios (2019), we proxy macroeconomic risk by the log change in utilization adjusted total factor productivity (ΔTFP) and the log change in real GDP growth (ΔGDP). For each IVOL-sorted portfolio, which is formed by using the procedure in Section 2, we regress its excess returns on market factor and macroeconomic shocks to obtain exposures to macroeconomic shocks for each portfolio.

[Place Table 8 about here]

Table 8 reports exposures to macroeconomic shocks of portfolios in different samples. First, both for firms with easy access to leasing (Panel A) and the full sample (Panel C), the high-minus-low IVOL-sorted portfolio has significantly negative exposure to GDP growth shocks, and when idiosyncratic volatility increases, firms' exposures to both GDP growth shocks and TFP growth shocks decrease on average. Second, when we focus on firms that don't have easy access to leasing markets (Panel B), the decreasing pattern becomes much flatter. Exposures for H-L portfolio decrease greatly relative to those of the full sample and to firms with easy access to leasing markets, and become only significant at the 10% level. Overall, Table 8 confirms our model's prediction that firms with high IVOL will have low macroeconomic shock exposure, due to large fractions of leasing use.[8]

With respect to exposure to idiosyncratic volatility shocks, we have similar results: firms with high IVOL are less negatively (i.e., more positively) exposed to idiosyncratic volatility shocks. Since the IVOL shock is a firm-specific idiosyncratic risk, this shock cannot be simply aggregated to calculate portfolio-level idiosyncratic volatility shocks. Instead, we focus on firm-level estimation in this section. Moreover, since risk exposure of a firm changes over time, we follow Donangelo et al. (2019) and estimate time-varing exposures for each firm and then aggregate this firm characteristic to the portfolio-level. To estimate time-varying exposures to idiosyncratic volatility shocks, we first define monthly idiosyncratic volatility shocks, $\Delta IVOL_{i,t}$, as the log difference between idiosyncratic volatility of month t and $t-1$.[9] We calculate firm-level conditional beta on IVOL shocks by rolling window regressions over the past 24 or 60 months. We then aggregate these exposures to the portfolio-level, value-weighted by their market value.

[Place Table 9 about here]

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[8] In untabulated results, we find that exposures to aggregate financial shocks show similar patterns, which also result from hedging effects of leased capital. Since we don't include financial shocks in our model, we don't report them.

[9] Following Ang et al. (2006), Fu (2009), and Hou and Loh (2016), we define monthly idiosyncratic volatility as the standard error of the Fama-French 3-factor model in monthly frequency. Our results are robust when we define idiosyncratic volatility shocks as residuals from the AR1 regression of monthly idiosyncratic volatility.

Table 9 supports our mechanism that firms with higher IVOL have less negative (i.e., larger) exposure to idiosyncratic volatility shocks. First, the average betas with respect to idiosyncratic volatility shocks for the H-L portfolios are significantly positive both in the group with easy access to leasing activities (Panel A) and the full sample (Panel C), which means that firms with high IVOL are significantly less negatively exposed to IVOL shocks. Second, when we compare across different subsamples, we find that for the H-L portfolios, positive exposures to IVOL shocks are mainly driven by firms with access to leasing markets. For those firms without access to leasing markets, the average IVOL shock exposures for the H-L portfolio drop around 40% (7.09 versus 4.14 for a 24-month estimation window; 5.64 versus 3.44 for a 60-month estimation window).

In summary, we confirm our prediction that firms with high IVOL will have lower macroeconomic risk exposures and less negative idiosyncratic volatility risk exposures because of their large fraction of leased capital use and corresponding hedging effects.

6.3 Market Price of Idiosyncratic Volatility Risk

In this section, we try to estimate the factor price of idiosyncratic volatility risk. Since we don't have a well-defined portfolio-level idiosyncratic volatility shock, as we mention in Section 6.2, we cannot directly estimate the factor price with a portfolio-level GMM procedure. Following Fama and MacBeth (1973) and Cochrane (2005) (revised edition) (pages 245-251), we instead run a two-step Fama-MecBeth procedure to estimate the price of idiosyncratic volatility risk.

We next describe the details of our estimation. First, we obtain time-varying betas from time series regressions, which are estimated in Section 6.2. Second, we regress stock returns on their corresponding time-varying betas. The second-step regression suggested by our model is given by:

$$r_{i,t} = \alpha + \lambda_{MKT} \times \hat{\beta}_i^{MKT} + \lambda_{\Delta TFP} \times \hat{\beta}_i^{TFP} + \lambda^i_{\Delta IVOL} \times \hat{\beta}_i^{IVOL} + \epsilon^i_t \qquad (50)$$

in which $\hat{\beta}_i^{MKT}, \hat{\beta}_i^{TFP}, \hat{\beta}_i^{IVOL}$ are time-varing covariances with corresponding shocks for firm i that are estimated in the previous section; $\lambda_{MKT}, \lambda_{\Delta TFP}$ stand for prices of market factor and TFP growth shocks; and $\lambda^i_{\Delta IVOL}$ represents the price of idiosyncratic volatility risk. In our model, we know that the price of idiosyncratic volatility risk, $-\chi \frac{\partial \eta_t^i}{\partial \sigma_t^i}$, varies with firms' idiosyncratic volatility; thus, the price $\lambda^i_{\Delta IVOL}$ should have superscript i. To reduce dimensions and make the estimation feasible, we assume the reduced form of $\lambda^i_{\Delta IVOL}$ as:

$$\lambda^i_{\Delta IVOL} = \lambda_{\Delta IVOL} + \gamma \times \left(\sigma_t^i - \bar{\sigma}_t\right), \tag{51}$$

in which $\lambda_{\Delta IVOL}$ is the average price of idiosyncratic volatility risk. The full regression model is:

$$r_t^i = \alpha + \lambda_{MKT} \times \hat{\beta}_i^{MKT} + \lambda_{\Delta TFP} \times \hat{\beta}_i^{TFP} + \lambda_{\Delta IVOL} \times \hat{\beta}_i^{IVOL} + \gamma \times \hat{\beta}_i^{IVOL} \times \left(\sigma_t^i - \bar{\sigma}_t\right) + \epsilon_t^i. \tag{52}$$

We aim to test whether $\lambda_{\Delta IVOL}$, the average price of idiosyncratic volatility risk, is negative, which is suggested by Section 4.1.

[Place Table 10 about here]

We show our estimation results in Table 10. First and most important, we find that the average price of idiosyncratic volatility shocks, $\lambda_{\Delta IVOL}$, is consistently negative and significant, no matter which betas we use. This is consistent with our theory that idiosyncratic volatility risk is negatively priced. Second, we notice a positive γ, which means that the price of idiosyncratic volatility risk, $\lambda^i_{\Delta IVOL}$, should be less negative when σ_t^i is higher. In our model, since the marginal value of equity η_t^i is a concave function of σ_t^i, the γ, which equals $-\chi \frac{\partial^2 \eta_t^i}{\partial \left(\sigma_t^i\right)^2}$, should therefore be positive. Overall, our estimation confirms our theoretical prediction that idiosyncratic volatility risk is negatively priced.

7 Conclusion

Leased capital, which is an important resource of productive assets and external financing, not only has critical implications with respect to corporate finance and macroeconomics, but also in terms of cross-section asset pricing. Our paper links different risk profiles between leased capital and purchased capital with the idiosyncratic volatility puzzle and offers a novel, risk-based explanation. We empirically find that the influential idiosyncratic volatility puzzle is mainly driven by firms with easy access to leased capital. We then construct an investment-based asset pricing model in the stylized Bernanke-Gertler-Gilchrist financial accelerator setting and explicitly introduce firms' investment decisions between purchasing and renting in order to rationalize our mechanism.

In our mechanism, our model first shows that leased capital is less risky and has lower expected returns, due to the absence of fluctuations in resale value caused by idiosyncratic volatility shocks and macroeconomic shocks. Second, given the benefit of leased capital (i.e. higher debt capacity from saving verification costs associated with potential default) outweighs its agency costs, firms with higher idiosyncratic volatility tend to optimally choose a larger fraction of leased capital. Therefore, firms with high idiosyncratic volatility will be less risky and deliver low expected returns.

Quantitatively, our model predicts a -3.73% annual average return for the high-minus-low portfolio, which accounts for over 65% of its counterpart in data (-5.62% per annum). Additionally, we provide further empirical evidence to support our arguments. We show that idiosyncratic volatility positively predicts firms' leased capital ratio even when we control for other variables, and this effect is mainly driven by firms with easy access to leasing activities. In terms of riskiness, we empirically demonstrate that idiosyncratic volatility risk is negatively priced. Ceteris paribus, firms with higher idiosyncratic volatility and that use a larger fraction of leased capital will have lower aggregate risk exposure and less negative idiosyncratic volatility risk exposure, due to the hedging effects of leased capital. Taken together, these facts lead to the conclusion that firms with high idiosyncratic volatility should have low expected returns.

In summary, our research presents a distinctive and logical solution to the idiosyncratic volatility puzzle, explaining the negative correlation between idiosyncratic volatility and expected returns, even in the face of negatively priced idiosyncratic risk within an incomplete market. This phenomenon can be attributable to firms' endogenous decision-making processes in allocating assets between owned and leased capital, each possessing unique risk profiles.

Tables and Figures

Table 1: Summary Statistics

This table reports summary statistics for the main firm characteristics of our sample. Idiosyncratic volatility (IVOL) is calculated as the standard deviation of residuals from the annual Fama and French (1993) 3-factor model, using daily stock return data from CRSP. Leased capital is defined as 10 times rental expense (XRENT), and leased capital ratio (LCR) is the ratio of leased capital over the sum of leased capital and purchased capital (PPENT). Rental share (RS) measures the spending on leased capital and is defined as rental expense (XRENT) over the sum of rental expense and capital expenditures (CAPX). Size is calculated as the natural logarithm of market capitalization at the end of each June. Return on assets (ROA) is operating income after depreciation (item OIADP) scaled by total assets. In Panel A, following Whited and Wu (2006), we split the full sample into a constrained subsample and unconstrained subsample at the end of June in each year, in which we define the firms with WW index higher than the median as financially constrained ones. We report pooled means of these variables value-weighted by firm market capitalization at fiscal year end. In panel B, we summarize the time-series mean of the cross-sectional averages for these firm characteristics across five portfolios sorted by their IVOL. The sample is from 1978 to 2017 and excludes financial, utility, public administrative, and lessor industries from the analysis.

	Panel A: Pooled Statsistics			Panel B: Firm Characteristics				
Variables	Full	Const.	Unconst.	Portfolios Sorted by IVOL				
	Mean			L(ow)	2	3	4	H(igh)
IVOL	1.687	3.064	1.608	1.416	2.139	2.543	3.662	5.491
WW	-0.466	-0.248	-0.473	-0.473	-0.385	-0.362	-0.293	-0.247
Lease Cap. Ratio	0.353	0.523	0.345	0.320	0.387	0.406	0.461	0.501
Rental Share	0.228	0.361	0.222	0.200	0.244	0.265	0.307	0.371
Size	16.990	13.249	17.162	16.801	15.087	14.552	13.296	12.366
ROA	0.119	0.032	0.123	0.132	0.105	0.094	0.036	-0.063

Table 2: Double Sorting - Financial Constraint Effects

This table shows asset pricing tests for portfolios sorted on firms' idiosyncratic volatility (IVOL) relative to their industry peers, as classified by Fama and French (1997), in the full sample, financially constrained subsample, and unconstrained subsample. We use monthly returns and rebalance portfolios at the end of each June. The time span is from July 1978 to June 2017. We exclude utility, financial, public administrative, and lessor industries from our analysis. We first report average excess returns over the risk-free rate (Exret) and α's relative to CAPM and the Fama and French (1993) 3-factor model across portfolios for the full sample in Panel A. We further split the full sample into financially constrained and unconstrained firms at the end of every June, as classified by the WW index, and then report average excess returns and α's for each subsample. Standard errors are estimated by Newey-West correction with ***, **, and * indicating significance at the 1, 5, and 10% levels, respectively. We include t-statistics in parentheses and annualize portfolio returns by multiplying monthly returns by 12. All portfolio returns correspond to value-weighted returns by firm market capitalization.

	L(ow)	2	3	4	H(igh)	H-L
Panel A: Full Sample						
Exret	8.21***	9.64***	8.51**	6.23	2.07	-6.14*
	(3.50)	(3.33)	(2.57)	(1.44)	(0.41)	(-1.73)
CAPM alpha	0.86*	0.28	-1.44	-5.37**	-9.62***	-10.49***
	(1.65)	(0.32)	(-1.12)	(-2.46)	(-3.33)	(-3.41)
FF3 alpha	1.33***	0.78	-1.18	-4.23**	-8.99***	-10.32***
	(3.31)	(1.18)	(-1.26)	(-2.53)	(-4.87)	(-5.23)
Panel B: Financially Constrained Sample						
Exret	10.99***	9.13**	7.19*	6.51	5.37	-5.62**
	(3.49)	(2.58)	(1.85)	(1.40)	(1.15)	(-2.03)
CAPM alpha	2.27	-1.10	-3.08	-5.41*	-4.91	-7.18**
	(1.21)	(-0.60)	(-1.43)	(-1.95)	(-1.55)	(-2.50)
FF3 alpha	2.42**	-0.35	-2.29**	-4.53***	-3.99**	-6.41***
	(2.31)	(-0.45)	(-2.18)	(-2.69)	(-1.98)	(-2.72)
Panel C: Financially Unconstrained Sample						
Exret	7.87***	9.03***	9.74***	8.82***	8.06**	0.18
	(3.39)	(3.48)	(3.39)	(2.66)	(2.33)	(0.09)
CAPM alpha	0.87	0.62	0.58	-1.41	-1.74	-2.61
	(1.20)	(0.83)	(0.67)	(-1.02)	(-1.32)	(-1.51)
FF3 alpha	1.39**	0.86	0.87	-1.20	-1.54	-2.93**
	(2.40)	(1.19)	(1.20)	(-1.06)	(-1.27)	(-1.98)

Table 3: Double Sorting - Effects of Access to Leased Capital

This table shows asset pricing tests for portfolios sorted on firms' idiosyncratic volatility (IVOL) relative to their industry peers, as classified by Fama and French (1997), in subsamples with (without) access to leasing activities. We use monthly returns and rebalance portfolios at the end of each June. The time span is from July 1978 to June 2017. We exclude utility, financial, public administrative, and lessor industries from our analysis. For Panel A, we split financially constrained firms into groups with (without) easy access to leasing activities as those whose lagged 3-year average leased capital ratio ranks above (below) 20 percentile relative to their industry peers at the end of every June. We then report average excess returns over the risk-free rate (Exret) and α's relative to CAPM and the Fama and French (1993) 3-factor model across portfolios for the group with (without) easy access to leasing activities. In Panel B, we follow Kim and Kung (2017) and use an alternative measure, asset redeployability, to measure the degree of leasing activity access and construct identical procedures as in Panel A. Standard errors are estimated by Newey-West correction with ***, **, and * indicating significance at the 1, 5, and 10% levels, respectively. We include t-statistics in parentheses and annualize portfolio returns by multiplying monthly returns by 12. All portfolio returns correspond to value-weighted returns by firm market capitalization.

Panel A: Leasing Access Measured by Lagged 3-Year Average LCR

		L(ow)	2	3	4	H(igh)	H-L
With Access to Lease	Exret	11.28***	9.15**	7.80**	7.13	4.95	-6.33**
		(3.38)	(2.38)	(2.00)	(1.59)	(1.06)	(-2.46)
	CAPM α	2.50	-1.29	-3.00	-4.06	-5.81**	-8.31***
		(1.14)	(-0.63)	(-1.32)	(-1.35)	(-2.04)	(-3.41)
	FF3 α	2.98**	-0.51	-2.67*	-3.26*	-5.53***	-8.51***
		(2.05)	(-0.42)	(-1.96)	(-1.81)	(-2.88)	(-3.79)
Without Access to Lease	Exret	11.47**	9.38**	11.85***	10.90**	11.19***	-0.28
		(2.55)	(2.58)	(2.99)	(2.37)	(3.27)	(-0.08)
	CAPM α	2.65	0.08	2.17	0.27	2.68	0.04
		(0.78)	(0.03)	(0.85)	(0.11)	(1.07)	(0.01)
	FF3 α	1.98	0.30	2.05	-0.20	2.02	0.03
		(0.63)	(0.14)	(0.98)	(-0.09)	(1.15)	(0.01)

Panel B: Leasing Access Measured by Asset Redeployability

		L(ow)	2	3	4	H(igh)	H-L
With Access to Lease	Exret	9.66***	9.66**	5.55	5.11	3.20	-6.46**
		(3.11)	(2.46)	(1.34)	(0.94)	(0.66)	(-2.24)
	CAPM α	1.74	0.09	-4.29*	-5.99*	-6.12**	-7.85***
		(0.81)	(0.04)	(-1.86)	(-1.72)	(-2.13)	(-2.72)
	FF3 α	1.69	0.96	-3.56**	-4.96*	-4.77**	-6.46**
		(1.33)	(0.70)	(-2.58)	(-1.90)	(-2.13)	(-2.53)
Without Access to Lease	Exret	8.99**	7.60*	7.15	3.97	5.86	-3.12
		(2.41)	(1.78)	(1.56)	(0.76)	(1.32)	(-1.16)
	CAPM α	0.32	-2.39	-3.07	-6.60*	-3.04	-3.36
		(0.13)	(-0.89)	(-1.06)	(-1.92)	(-0.87)	(-1.24)
	FF3 α	1.27	-1.13	-1.40	-4.98**	-2.43	-3.70
		(0.81)	(-0.80)	(-0.80)	(-2.41)	(-1.08)	(-1.46)

Table 4: Calibrated Parameter Values

We calibrate the model at the annual frequency. This table reports the parameter values and the corresponding moments (annualized) that we used in the calibration procedure.

Parameters	Symbol	Value
Time discount factor	β	0.982
Purchased capital dep. rate	δ	0.135
Survival rate of entrepreneurs	χ	0.859
Lessor's monitoring cost	κ	0.033
Capital adjustment cost parameter	ζ	0.500
Lender's Monitoring cost	μ	0.246
Mean productivity	A_{ss}	0.208
Steady state of idiosyncratic volatility	σ_{ss}	0.400
Transfer for startup	$\bar{N}$	0.265
Price of aggregate TFP shocks	λ	3.000
Lessor's monitoring cost	d	0.100
Persistence of TFP shocks	ρ_A	0.000
Persistence of IVOL shocks	ρ_σ	0.977
Vol. of TFP shocks	σ_A	0.024
Vol. of IVOL shocks	σ_σ	0.120

Table 5: Model Simulations and Aggregate Moments

This table presents the selected moments in the data as well as the corresponding ones implied by the model under the benchmark calibration. We simulate the economy at annual frequency with 5000 firms for 200 annual observations.The data moments are estimated from a sample from 1978 to 2017.

Moments	Data	Model
Asset prices		
Market premium	7.87	10.37
Market Sharpe ratio	0.51	0.53
Real risk-free rate	1.50	1.59
Real quantities: Aggregate level		
Std. dev. of output growth	0.03	0.03
Std. dev. of investment growth	0.10	0.05
Investment to Cap. Ratio	0.26	0.14
Leased Cap. Ratio (LCR)	0.53	0.52
Std. dev. of LCR	0.03	0.01
Real quantities: Cross-section		
Correlation: IVOL and LCR	0.25	0.85
Correlation: IVOL and RS	0.28	0.73
Correlation: IVOL and size	-0.51	-0.32
Correlation: IVOL and investment growth	-0.11	-0.03

Table 6: Firm Characteristics, Data, and Model Comparison

This table compares the moments in the empirical data (Panel A) and the model simulated data (Panel B) at the portfolio level. Panel A and Panel B show the time series average of the cross-sectional value-weighted average of firm characteristics at the end of each June, including idiosyncratic volatility (IVOL, which we normalize with IVOL for the 1st quintile), the leased capital ratio (LCR) and rental share (RS). We also report the value-weighted excess returns $E[R] - R_f(\%)$ (annualized by multiplying by 12, in percentage terms) for quintile portfolios sorted on idiosyncratic volatility relative to their industry peers. Standard errors are estimated by Newey-West correction. The sample represents financially constrained firms from July 1978 to December 2017 and excludes financial, utility, and public administrative industries, as well as lessor industries from the analysis.

Variables	L(ow)	2	3	4	H(igh)	H-L
			Panel A: Data			
IVOL	1.00	1.36	1.72	2.18	3.32	
LCR	0.46	0.49	0.51	0.53	0.57	-
RS	0.30	0.32	0.35	0.38	0.46	-
$E[R] - R_f$	10.99	9.13	7.19	6.51	5.37	-5.62
			Panel B: Model			
IVOL	1.00	1.58	2.13	2.87	4.71	
LCR	0.32	0.46	0.55	0.64	0.74	-
RS	0.21	0.26	0.30	0.34	0.40	-
$E[R] - R_f$	11.79	11.65	11.08	10.17	8.06	-3.73

Table 7: Predictive Regressions for Leasing

This table shows the impact of firms' idiosyncratic volatility (IVOL) on their leased capital ratio (LCR) or rental share (RS) decisions. The variable L is the dummy variable representing firms who have access to leasing activities. It takes the value 1 when firms' lagged 3-year leased capital ratio ranks above (below) 20% relative to their industry peers at the end of every June. Also, we incorporate the Whited and Wu Index (WW), size, the book-to-market ratio, the investment-to-capital ratio (I/K), ROA, Altman's Z score, and Tobin's Q in our regressions. All independent variables are normalized to a zero mean and a one standard deviation after winsorization at the 1st and 99th percentiles to reduce the impact of outliers. Standard errors are clustered in industries with ***, **, and * indicating significance at the 1, 5, and 10% levels, respectively. The sample is from July 1978 to June 2017 and excludes financial, utility, public administrative, and lessor industries from the analysis.

	(1) LCR	(2) LCR	(3) RS	(4) RS
IVOL	0.013***	-0.010*	0.022***	0.002
	(3.60)	(-1.81)	(5.89)	(0.48)
L*IVOL		0.024***		0.021***
		(3.29)		(3.81)
L		0.322***		0.252***
		(21.61)		(18.93)
WW	0.046***	0.034***	0.040***	0.031***
	(5.50)	(6.64)	(5.69)	(6.86)
Log ME	-0.019***	-0.016***	-0.032***	-0.030***
	(-2.71)	(-3.43)	(-5.17)	(-6.54)
Log B/M	-0.018***	-0.009***	-0.011***	-0.004
	(-3.86)	(-2.72)	(-2.74)	(-1.22)
I/K	0.040***	0.018***	-0.076***	-0.093***
	(10.76)	(7.10)	(-26.55)	(-27.60)
ROA	-0.039***	-0.026***	-0.032***	-0.022***
	(-4.86)	(-4.97)	(-4.45)	(-4.26)
Altman_Z	0.019	0.009	0.008	0.001
	(1.63)	(1.21)	(0.78)	(0.07)
Tobin Q	-0.012**	-0.004	-0.004	0.002
	(-2.05)	(-0.89)	(-0.82)	(0.51)
Observations	79645	79645	79638	79638
Time×Industry FE	Yes	Yes	Yes	Yes
Cluster SE	Yes	Yes	Yes	Yes

Table 8: Exposure to Macroeconomic Shocks

This table shows exposures to macroeconomic shocks of portfolios sorted by their idiosyncratic volatility (IVOL) in the subsample with (without) access to leasing activities and the full sample. We classify firms with (without) access to leasing activities as those whose lagged 3-year average leased capital ratio ranks above (below) 20% relative to their industry peers at the end of every June. We first sort stocks into 5 portfolios by their idiosyncratic volatility and calculate the value-weighted returns as portfolio returns, and then regress portfolio excess returns on market factor and macroeconomic shocks (ΔTFP or ΔGDP) to get exposures of each portfolio. Standard errors are estimated by Newey-West correction with ***, **, and * indicating significance at the 1, 5, and 10% levels, respectively. The sample is from July 1978 to December 2017 and excludes financial, utility, and public administrative industries, as well as lessor industries from our analysis.

Shocks	L(ow)	2	3	4	H(igh)	H-L
Panel A: Firms with Access to Lease						
ΔGDP	0.67	0.10	0.32	-0.83	-2.23	-2.49***
	(0.83)	(0.08)	(0.19)	(-0.51)	(-1.41)	(-3.30)
ΔTFP	1.39	0.85	0.80	0.27	-1.89	-2.81
	(0.81)	(0.30)	(0.22)	(0.07)	(-0.51)	(-1.59)
Panel B: Firms without Access to Lease						
ΔGDP	-0.15	-0.94	-1.27	-1.43	-3.02	-2.15*
	(-0.13)	(-0.74)	(-0.77)	(-0.91)	(-1.31)	(-1.75)
ΔTFP	-0.97	-1.19	-1.82	-0.01	-2.36	-0.56
	(-0.46)	(-0.45)	(-0.55)	(-0.00)	(-0.46)	(-0.18)
Panel C: Full sample						
ΔGDP	0.37	-0.65	-0.65	-1.08	-2.98	-2.70***
	(0.39)	(-0.50)	(-0.39)	(-0.61)	(-1.55)	(-2.86)
ΔTFP	0.37	-0.49	-0.08	-0.40	-2.47	-2.06
	(0.20)	(-0.17)	(-0.02)	(-0.10)	(-0.56)	(-0.84)

Table 9: Exposure to Idiosyncratic Volatility Shocks

This table shows average exposures to idiosyncratic volatility shocks of portfolios sorted by their idiosyncratic volatility (IVOL) in the subsample with (without) access to leasing activities and the full sample. We classify firms with (without) access to leasing activities as those whose lagged 3-year average leased capital ratio ranks above (below) 20% relative to their industry peers at the end of every June. Following Donangelo et al. (2019), we first calculate firms' conditional exposure to idiosyncratic volatility shocks by rolling window regressions over the past 24 or 60 months, and then we calculate the value-weighted average of firm-level exposures for each portfolio. We calculate monthly idiosyncratic volatility as the standard error from monthly the Fama-French 3 factor model suggested by Ang et al. (2006) and then define firm-level idiosyncratic volatility shocks as the log difference between the idiosyncratic volatility of month t and $t-1$. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. The sample is from July 1978 to December 2017 and excludes financial, utility, and public administrative industries, as well as lessor industries from the analysis.

Window	L(ow)	2	3	4	H(igh)	H-L
Panel A: Firms with Access to Lease						
24 M	0.33**	1.17***	2.14***	3.76***	7.43***	7.09***
	(1.97)	(3.92)	(6.53)	(5.57)	(11.67)	(12.50)
60 M	0.20	1.22***	1.93***	3.43***	5.84***	5.64***
	(1.43)	(5.51)	(7.54)	(7.38)	(12.63)	(13.13)
Panel B: Firms without Access to Lease						
24 M	0.58***	1.14***	1.61***	2.83***	4.71***	4.14***
	(3.11)	(4.03)	(4.29)	(5.32)	(6.98)	(6.42)
60 M	0.34**	1.02***	1.54***	2.77***	3.78***	3.44***
	(2.44)	(4.43)	(6.11)	(8.03)	(7.84)	(7.31)
Panel C: Full Sample						
24 M	0.47***	1.06***	1.95***	3.86***	7.65***	7.18***
	(2.79)	(3.61)	(6.33)	(7.04)	(11.65)	(11.86)
60 M	0.28**	1.10***	1.74***	3.44***	5.91***	5.63***
	(2.09)	(5.48)	(6.74)	(8.89)	(14.90)	(14.47)

Table 10: Market Price of Idiosyncratic Volatility Risk

This table estimates the market price of idiosyncratic volatility risk. Following Fama and MacBeth (1973) and Cochrane (2005) (revised edition) (pages 245-251), we run a two-step Fama-MecBeth procedure to estimate the price of idiosyncratic volatility risk. First, we obtain time-varying betas from time series regressions using the log difference ($\Delta \ln(\sigma_t^i)$) of monthly idiosyncratic as IVOL shocks and 24/60 months for our estimation window, consistent with our approach in Section 6.2 and Table 9. Second, we regress stock returns on their corresponding time-varying betas along with the interaction between β_i^{IVOL} and the demeaned idiosyncratic volatility σ_t^i to estimate the average price of idiosyncratic volatility risk, $\lambda_{\Delta IVOL}$. The regression equation is given by (52).

	(1) r_t^e	(2) r_t^e	(3) r_t^e	(4) r_t^e
$\lambda_{\Delta IVOL}$		-0.059***		-0.101***
		(-11.43)		(-12.81)
γ		0.076***		0.107***
		(13.63)		(14.99)
λ_{MKT}	0.168	0.093	0.058	-0.083
	(1.25)	(0.73)	(0.36)	(-0.54)
$\lambda_{\Delta TFP}$	-0.092	-0.076	-0.176	-0.128
	(-0.81)	(-0.76)	(-1.25)	(-1.04)
Observations	1820892	1809805	1663439	1652157
β_i^{IVOL} window	24 M	24 M	60 M	60 M
R-square	0.060	0.109	0.038	0.091

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 1: Impulse Responses to the Productivity Shock

This figure plots the log-deviations from the steady state for the Lagrangian multiplier of the bank's break-even condition λ_t, augmented SDF $\widetilde{M}_t$, the net worth of the firm N_t, the capital amount including owned capital $K_{o,t+1}$, the leased capital $K_{l,t+1}$ and total capital K_{t+1}, leased capital ratio ϕ_t, capital price q_t and returns of owned capital $R^{Lev}_{o,t}$, leased capital $R_{l,t}$ and equity R_t, with respect to a one-standard-deviation shock to the log productivity a_t. One period is a year. All parameters are calibrated as in Table 4.

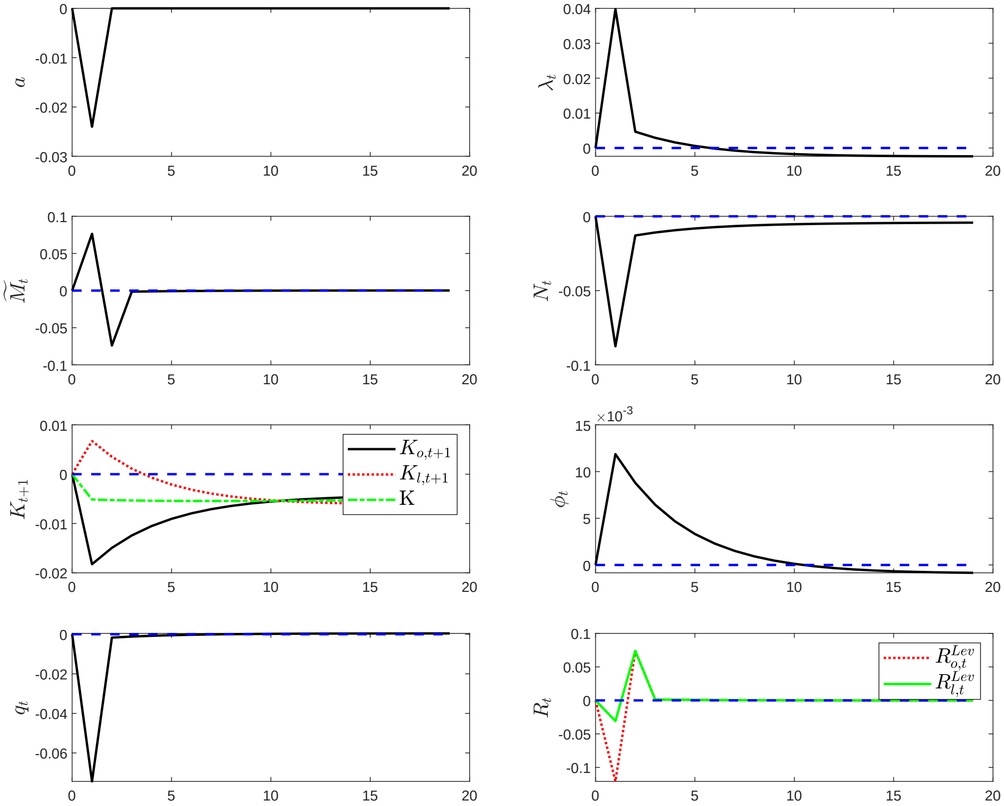
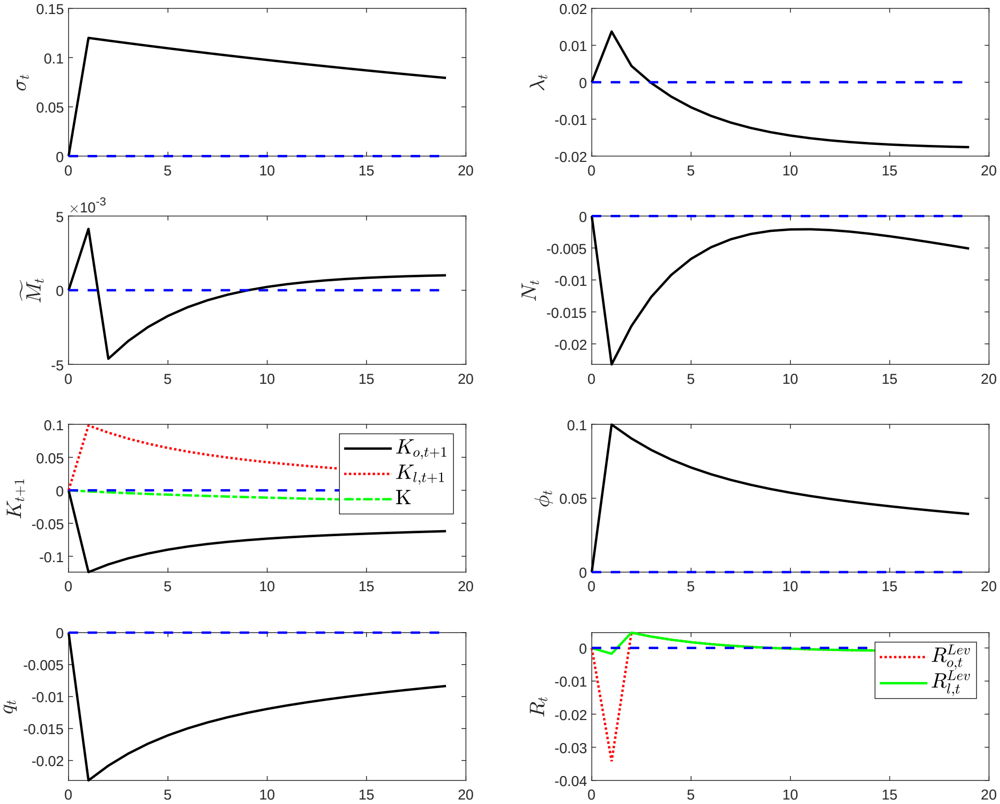


Figure 2: Impulse Responses to the Idiosyncratic Volatility Shock

This figure plots the log-deviations from the steady state for the Lagrangian multiplier of the bank's break-even condition λ_t, augmented SDF $\widetilde{M}_t$, the net worth of the firm N_t, the capital amount including owned capital $K_{o,t+1}$, the leased capital $K_{l,t+1}$ and total capital K_{t+1}, leased capital ratio ϕ_t, the capital price q_t and returns of owned capital $R^{Lev}_{o,t}$, leased capital $R_{l,t}$ and equity R_t, with respect to a one-standard-deviation shock to the idiosyncratic volatility σ. One period is a year. All parameters are calibrated as in Table 4.



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A Appendix: Additional Empirical Results

In this section, we provide additional empirical evidence to support our mechanism that leasing can help explain the idiosyncratic volatility puzzle.

A.1 Different Measure for Financial Constraints

To ensure the robustness of our results, we follow Farre-Mensa and Ljungqvist (2016) and calculate different financial constraint measures, including the size and age index (SA index) as suggested by Hadlock and Pierce (2010) and the dividend payment dummy (DIV), and then construct the double sorting procedures similar to Table 2 to investigate whether the idiosyncratic volatility puzzle is mainly driven by financially constrained firms. Specifically, a higher SA index means that firms are subject to financial constraints to a greater extent, and financially constrained firms have SA indexes that are larger than that of the cross-sectional median. As for the dividend payment dummy, we follow the literature and classify firms with non-dividend payments as financially constrained firms. After classifying such firms into a financially constrained (unconstrained) group, we sort these constrained (unconstrained) firms into quintiles by their idiosyncratic volatility.

We provide our results in Table A.1 and Table A.2. As is the case in Table 2, the high-minus-low portfolios for financially constrained firms have on average more negative stocks returns and risk-adjusted α's; meanwhile, the negative spread and α's for financially unconstrained firms are negligible relative to their counterparts in the constrained firms as well as in the full sample.

[Place Table A.1 about here]

[Place Table A.2 about here]

A.2 Controlling for Leasing Access - Different Cutoffs

In this section we construct robustness check to further confirm that the idiosyncratic volatility puzzle is mainly driven by firms with easy access to leasing activities. In Section 2.3, we classify firms with access to leasing activities as those whose lagged 3-year average leased capital ratio (or asset redeployability) ranks above (below) 20 percentile relative to their industry peers. In this section, we use 30 or 50 percentiles as cutoffs and construct identical procedure as in Table 3.

Table A.3 and Table A.4 show strong and consistent evidence that firms with access to leasing activities are main drivers for the negative spread. High-minus-low portfolios for those with easy access to leasing activities on average have more significantly negative returns and α's; in contrast, these patterns disappear for the group without easy access to leasing activities.

[Place Table A.3 about here]

[Place Table A.4 about here]

A.3 IVOL Shocks - Proxy by Residuals of AR1 Regressions

This section shows robust empirical results confirming that firms with higher leased capital ratios have less negative exposure to idiosyncratic volatility shocks, and that IVOL shocks are negatively priced, using a different measure for IVOL shocks. In our model, we assume firms' idiosyncratic volatility follows an AR1 process, and thus we define IVOL shocks as residuals from the AR1 regression of monthly idiosyncratic volatility. We then construct a similar procedure as we show in Table 9 and Table 10.

Our empirical results are similar to those in Section 6. First, when we use AR1 residuals as high-frequency IVOL shocks, we find that in the group with easy access to leasing activities, high IVOL firms that tend to use a higher fraction of leased capital will have less negative exposure to IVOL shocks. Second, Table A.6 confirms that when we use an alternative measure, IVOL shocks are still negatively priced, which is exactly what our model suggests.

[**Place Table A.5 about here**]

[**Place Table A.6 about here**]

Table A.1: Double Sorting - Financial Constraint Effects (by SA index)

This table shows asset pricing tests for portfolios sorted on firms' idiosyncratic volatility (IVOL) relative to their industry peers, as classified by Fama and French (1997), in the full sample, financially constrained subsample, and unconstrained subsample. We use monthly returns and rebalance portfolios at the end of each June. The time span is from July 1978 to June 2017. We exclude utility, financial, public administrative, and lessor industries from our analysis. We first report average excess returns over the risk-free rate (Exret) and α's relative to CAPM and the Fama and French (1993) 3-factor model across portfolios for the full sample in Panel A. We further split the full sample into financially constrained and unconstrained firms at the end of every June, as classified by the SA index and following Hadlock and Pierce (2010), and then report average excess returns and α's for each subsample. Standard errors are estimated by Newey-West correction with ***, **, and * indicating significance at the 1, 5, and 10% levels, respectively. We include t-statistics in parentheses and annualize portfolio returns by multiplying by 12. All portfolio returns correspond to value-weighted returns by firm market capitalization.

	L(ow)	2	3	4	H(igh)	H-L
Panel A: Full Sample						
Exret	8.21***	9.64***	8.51**	6.23	2.07	-6.14*
	(3.50)	(3.33)	(2.57)	(1.44)	(0.41)	(-1.73)
CAPM alpha	0.86*	0.28	-1.44	-5.37**	-9.62***	-10.49***
	(1.65)	(0.32)	(-1.12)	(-2.46)	(-3.33)	(-3.41)
FF3 alpha	1.33***	0.78	-1.18	-4.23**	-8.99***	-10.32***
	(3.31)	(1.18)	(-1.26)	(-2.53)	(-4.87)	(-5.23)
Panel B: Financially Constrained Sample						
Exret	8.42***	7.88*	5.22	4.25	1.91	-6.51**
	(3.03)	(1.95)	(1.25)	(0.85)	(0.39)	(-2.04)
CAPM alpha	-0.23	-2.91	-5.84**	-7.45**	-8.17**	-7.94**
	(-0.15)	(-1.41)	(-2.56)	(-2.36)	(-2.48)	(-2.49)
FF3 alpha	0.14	-1.31	-4.66***	-5.77***	-6.90***	-7.04**
	(0.14)	(-0.86)	(-3.47)	(-2.89)	(-2.60)	(-2.48)
Panel C: Financially Unconstrained Sample						
Exret	7.93***	9.42***	9.43***	9.87***	7.40**	-0.52
	(3.37)	(3.60)	(3.24)	(2.75)	(2.14)	(-0.25)
CAPM alpha	0.86	0.91	0.27	-0.99	-2.44*	-3.29*
	(1.19)	(1.39)	(0.30)	(-0.61)	(-1.69)	(-1.73)
FF3 alpha	1.41**	1.07*	0.68	-0.55	-2.35**	-3.77***
	(2.54)	(1.68)	(0.84)	(-0.46)	(-2.11)	(-2.73)

Table A.2: Double Sorting - Financial Constraint Effects (by DIV Dummy)

This table shows asset pricing tests for portfolios sorted on firms' idiosyncratic volatility (IVOL) relative to their industry peers, as classified by Fama and French (1997), in the full sample, financially constrained subsample, and unconstrained subsample. We use monthly returns and rebalance portfolios at the end of each June. The time span is from July 1978 to June 2017. We exclude utility, financial, public administrative, and lessor industries from our analysis. We first report average excess returns over the risk-free rate (Exret) and α's relative to CAPM and the Fama and French (1993) 3-factor model across portfolios for the full sample in Panel A. We further split the full sample into financially constrained and unconstrained firms at the end of every June, as classified by the dividend payment dummy (DIV), and then report average excess returns and α's for each subsample. Standard errors are estimated by Newey-West correction with ***, **, and * indicating significance at the 1, 5, and 10% levels, respectively. We include t-statistics in parentheses and annualize portfolio returns by multiplying by 12. All portfolio returns correspond to value-weighted returns by firm market capitalization.

	L(ow)	2	3	4	H(igh)	H-L
Panel A: Full Sample						
Exret	8.21***	9.64***	8.51**	6.23	2.07	-6.14*
	(3.50)	(3.33)	(2.57)	(1.44)	(0.41)	(-1.73)
CAPM alpha	0.86*	0.28	-1.44	-5.37**	-9.62***	-10.49***
	(1.65)	(0.32)	(-1.12)	(-2.46)	(-3.33)	(-3.41)
FF3 alpha	1.33***	0.78	-1.18	-4.23**	-8.99***	-10.32***
	(3.31)	(1.18)	(-1.26)	(-2.53)	(-4.87)	(-5.23)
Panel B: Financially Constrained Sample						
Exret	10.90***	10.41**	7.44	4.11	3.04	-7.86**
	(2.92)	(2.40)	(1.64)	(0.80)	(0.52)	(-2.19)
CAPM alpha	0.67	-1.42	-4.81**	-8.42***	-9.29**	-9.97***
	(0.32)	(-0.57)	(-2.08)	(-2.70)	(-2.37)	(-2.97)
FF3 alpha	3.32**	1.30	-3.00*	-6.31***	-7.38***	-10.70***
	(2.28)	(0.78)	(-1.86)	(-2.69)	(-2.72)	(-3.78)
Panel C: Financially Unconstrained Sample						
Exret	8.05***	8.59***	9.82***	7.12**	7.35**	-0.71
	(3.64)	(3.48)	(3.66)	(2.25)	(2.37)	(-0.32)
CAPM alpha	1.41*	0.60	1.43	-2.39	-1.94	-3.35
	(1.91)	(0.72)	(1.27)	(-1.52)	(-1.07)	(-1.52)
FF3 alpha	1.55**	0.21	0.91	-3.50***	-2.28	-3.83**
	(2.53)	(0.23)	(0.86)	(-2.85)	(-1.49)	(-2.33)

Table A.3: Double Sorting - Effects of Access to Leased Capital (30 Percentile for Cutoffs)

This table shows asset pricing tests for portfolios sorted on firms' idiosyncratic volatility (IVOL) relative to their industry peers, as classified by Fama and French (1997), in subsamples with (without) access to leasing activities. We use monthly returns and rebalance portfolios at the end of each June. The time span is from July 1978 to June 2017. We exclude utility, financial, public administrative, and lessor industries from our analysis. For Panel A, we split financially constrained firms into groups with (without) access to leasing activities as those whose lagged 3-year average leased capital ratio ranks above (below) 30 percentile relative to their industry peers at the end of every June. We then report average excess returns over the risk-free rate (Exret) and α's relative to CAPM and the Fama and French (1993) 3-factor model across portfolios for the group with (without) access to leasing activities. In Panel B, following Kim and Kung (2017) we use an alternative measure, asset redeployability, to measure the degree of leasing activity access and construct identical procedures as in Panel A. Standard errors are estimated by Newey-West correction with ***, **, and * indicating significance at the 1, 5, and 10% levels, respectively. We include t-statistics in parentheses and annualize portfolio returns by multiplying by 12. All portfolio returns correspond to value-weighted returns by firm market capitalization.

Panel A: Leasing Access, Measured by Lagged 3-Year Average LCR

		L(ow)	2	3	4	H(igh)	H-L
With Access to Lease	Exret	10.00***	9.32**	7.68*	8.06*	5.04	-4.96*
		(2.87)	(2.44)	(1.84)	(1.83)	(1.06)	(-1.85)
	CAPM α	0.82	-0.90	-3.43	-3.21	-6.02**	-6.84***
		(0.37)	(-0.42)	(-1.32)	(-1.05)	(-2.17)	(-2.82)
	FF3 α	1.38	-0.00	-2.97*	-2.30	-5.86***	-7.24***
		(0.96)	(-0.00)	(-1.82)	(-1.12)	(-3.23)	(-3.31)
Without Access to Lease	Exret	13.48***	9.91***	10.61***	9.30*	10.67***	-2.82
		(3.82)	(2.81)	(2.61)	(1.96)	(3.24)	(-0.99)
	CAPM α	5.28**	0.61	0.87	-1.76	1.91	-3.37
		(2.06)	(0.27)	(0.33)	(-0.65)	(0.85)	(-1.12)
	FF3 α	5.00**	1.00	1.13	-2.04	1.69	-3.31
		(2.04)	(0.59)	(0.54)	(-0.87)	(1.04)	(-0.99)

Panel B: Leasing Access, Measured by Asset Redeployability

		L(ow)	2	3	4	H(igh)	H-L
With Access to Lease	Exret	10.83***	7.85**	7.04	4.86	4.31	-6.52**
		(3.38)	(2.01)	(1.63)	(0.91)	(0.92)	(-2.38)
	CAPM α	2.83	-1.74	-2.97	-6.07*	-4.82*	-7.65***
		(1.29)	(-0.81)	(-1.22)	(-1.83)	(-1.71)	(-2.79)
	FF3 α	2.80**	-0.95	-2.31	-5.08*	-3.51	-6.31**
		(2.10)	(-0.74)	(-1.62)	(-1.95)	(-1.64)	(-2.52)
Without Access to Lease	Exret	9.11**	7.20*	7.59*	4.38	5.95	-3.16
		(2.54)	(1.70)	(1.68)	(0.86)	(1.40)	(-1.39)
	CAPM α	0.52	-2.66	-2.55	-6.20*	-3.16	-3.68
		(0.21)	(-1.03)	(-0.92)	(-1.90)	(-1.02)	(-1.58)
	FF3 α	1.44	-1.46	-1.10	-4.41**	-2.28	-3.72*
		(0.96)	(-1.02)	(-0.70)	(-2.42)	(-1.12)	(-1.74)

Table A.4: Double Sorting - Effects of Access to Leased Capital (50 Percentile for Cutoffs)

This table shows asset pricing tests for portfolios sorted on firms' idiosyncratic volatility (IVOL) relative to their industry peers, as classified by Fama and French (1997), in subsamples with (without) access to leasing activities. We use monthly returns and rebalance portfolios at the end of each June. The time span is from July 1978 to June 2017. We exclude utility, financial, public administrative, and lessor industries from our analysis. For Panel A, we split financially constrained firms into groups with (without) access to leasing activities as those whose lagged 3-year average leased capital ratio ranks above (below) 50 percentile relative to their industry peers at the end of every June. We then report average excess returns over the risk-free rate (Exret) and α's relative to CAPM and the Fama and French (1993) 3-factor model across portfolios for the group with (without) access to leasing activities. In Panel B, following Kim and Kung (2017) we use an alternative measure, asset redeployability, to measure the degree of leasing activity access and construct identical procedures as in Panel A. Standard errors are estimated by Newey-West correction with ***, **, and * indicating significance at the 1, 5, and 10% levels, respectively. We include t-statistics in parentheses and annualize the portfolio returns by multiplying by 12. All portfolio returns correspond to value-weighted returns by firm market capitalization.

Panel A: Leasing Access, Measured by Lagged 3-Year Average LCR

		L(ow)	2	3	4	H(igh)	H-L
With Access to Lease	Exret	10.23***	8.42**	6.98*	7.76	4.88	-5.34**
		(2.99)	(2.28)	(1.69)	(1.64)	(1.09)	(-2.13)
	CAPM α	1.13	-1.91	-4.11	-4.01	-5.93**	-7.07***
		(0.51)	(-0.93)	(-1.63)	(-1.26)	(-2.33)	(-3.03)
	FF3 α	1.61	-1.37	-3.58**	-3.74	-5.64***	-7.25***
		(1.16)	(-1.25)	(-2.07)	(-1.59)	(-3.11)	(-3.22)
Without Access to Lease	Exret	12.98***	9.71**	8.51**	10.14**	10.30***	-2.68
		(3.64)	(2.57)	(2.15)	(2.17)	(2.78)	(-0.96)
	CAPM α	4.39*	0.11	-1.65	-0.78	1.33	-3.06
		(1.77)	(0.05)	(-0.71)	(-0.27)	(0.52)	(-1.05)
	FF3 α	4.82**	0.70	-1.52	-0.61	1.56	-3.25
		(2.30)	(0.44)	(-0.93)	(-0.29)	(0.83)	(-1.05)

Panel B: Leasing Access, Measured by Asset Redeployability

		L(ow)	2	3	4	H(igh)	H-L
With Access to Lease	Exret	10.06***	8.13**	5.77	4.08	3.50	-6.56**
		(3.16)	(2.08)	(1.22)	(0.77)	(0.74)	(-2.27)
	CAPM α	2.14	-1.33	-4.13	-6.32*	-5.42*	-7.56***
		(0.89)	(-0.61)	(-1.52)	(-1.96)	(-1.82)	(-2.62)
	FF3 α	1.92	-0.55	-3.90**	-5.74**	-4.45*	-6.37**
		(1.20)	(-0.39)	(-2.00)	(-2.17)	(-1.89)	(-2.14)
Without Access to Lease	Exret	9.22***	8.18**	8.52**	4.38	5.74	-3.48
		(2.71)	(2.03)	(1.99)	(0.85)	(1.31)	(-1.61)
	CAPM α	0.78	-1.51	-1.63	-6.73**	-3.39	-4.17*
		(0.34)	(-0.68)	(-0.63)	(-2.06)	(-1.12)	(-1.93)
	FF3 α	1.51	-0.34	-0.13	-5.00***	-2.33	-3.84**
		(1.20)	(-0.29)	(-0.09)	(-2.77)	(-1.28)	(-2.11)

Table A.5: Exposure to Idiosyncratic Volatility Shocks

This table shows average exposures to idiosyncratic volatility shocks of portfolios sorted by their idiosyncratic volatility (IVOL) in the subsample with (without) access to leasing activities and the full sample. We classify firms with (without) access to leasing activities as those whose lagged 3-year average leased capital ratio ranks above (below) 20% relative to their industry peers at the end of every June. Following Donangelo et al. (2019), we first calculate firms' conditional exposure to idiosyncratic volatility shocks rolling window regression over the past 24 or 60 months, and then calculate the value-weighted average of firm-level exposures for each portfolio. We calculate monthly idiosyncratic volatility as the standard error from the monthly Fama-French 3 factor model suggested by Ang et al. (2006) and define firm-level idiosyncratic volatility shocks as residuals from the AR1 regression of monthly idiosyncratic volatility. ***, **, and * indicate significance at the 1, 5, and 10% levels, respectively. The sample is from July 1978 to December 2017 and excludes financial, utility, public administrative industries, and lessor industries from the analysis.

Window	L(ow)	2	3	4	H(igh)	H-L
Panel A: Firms with Access to Lease						
24 M	0.21	0.85*	1.91***	4.45***	8.10***	7.90***
	(0.56)	(1.89)	(4.35)	(8.17)	(10.85)	(10.68)
60 M	0.24	1.02***	2.10***	4.28***	7.64***	7.40***
	(0.94)	(3.45)	(6.72)	(9.44)	(12.98)	(11.64)
Panel B: Firms without Access to Lease						
24 M	0.49	1.11***	2.42***	4.32***	6.3***	5.81***
	(1.44)	(3.08)	(5.29)	(7.59)	(7.65)	(7.92)
60 M	0.33	1.47***	2.44***	4.44***	6.09***	5.76***
	(1.47)	(5.83)	(7.89)	(13.3)	(8.67)	(7.56)
Panel C: Full Sample						
24 M	0.37	0.88**	2.13***	4.61***	8.35***	7.98***
	(1.11)	(2.22)	(5.31)	(8.54)	(12.93)	(12.62)
60 M	0.29	1.24***	2.16***	4.65***	7.61***	7.32***
	(1.2)	(5.01)	(7.8)	(11.31)	(14.29)	(12.9)

Table A.6: Market Price of Idiosyncratic Volatility Risk

This table estimates the market price of idiosyncratic volatility risk. Following Fama and MacBeth (1973) and Cochrane (2005) (revised edition) (pages 245-251), we run a two-step Fama-MecBeth procedure to estimate the price of idiosyncratic volatility risk. First, we obtain time-varying betas from our time series regressions using residuals from the AR1 regression of monthly idiosyncratic volatility as firms' idiosyncratic volatility shocks and 24/60 months for our estimation window, consistent with our approach in Section 6.2 and Table 9. Second, we regress stock returns on their corresponding time-varying betas along with interaction between β_i^{IVOL} and demeaned idiosyncratic volatility σ_t^i to estimate the average price of idiosyncratic volatility risk, $\lambda_{\Delta IVOL}$. The regression equation is given by (52).

	(1) r_t^e	(2) r_t^e	(3) r_t^e	(4) r_t^e
$\lambda_{\Delta IVOL}$		-0.052***		-0.081***
		(-12.87)		(-13.66)
γ		0.061***		0.082***
		(14.71)		(16.34)
λ_{MKT}	0.142	0.077	0.027	-0.065
	(1.07)	(0.60)	(0.17)	(-0.42)
$\lambda_{\Delta TFP}$	-0.098	-0.077	-0.178	-0.112
	(-0.87)	(-0.75)	(-1.29)	(-0.88)
Observations	1820892	1809805	1663439	1652157
β_i^{IVOL} window	24 M	24 M	60 M	60 M
R-square	0.057	0.120	0.037	0.102

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

B Lessor Industries

To identify lessors, we follow Li and Tsou (2019) and employ a two-stage approach. First, we identify industries that engage in leasing activities as lessors and examine the business descriptions of SIC 4-digit industries. We conducted searches on the U.S. Census Bureau and SICCODE databases using a set of criteria based on keyword phrases such as "lease," "leasing," "lessor," "lessee," "rent," "rental," "renting," and "tenant." We consider an industry to be a lessor industry only if its business description contains at least one of these specified keyword phrases. This approach ensures the robustness of our results by minimizing the risk of false positives.

In the second stage of our approach, we narrow our focus to those firms classified in the identified lessor industries in the CRSP-Compustat merged universe, which spans the period from July 1978 to June 2017. We manually examine each firm's 10K financial statements to identify lessor firms. Specifically, by carefully reading item 1 in Part I of the financial statement, we obtain a detailed description of the firm's business operations and performance. This step enables us to precisely identify firms engaged in leasing activities. The resulting firm-level data are reported in Table B.1, in which we present firm-year observations of identified lessors across SIC 4-digit industries.

[Place Table B.1 about here]

Table B.1: SIC 4-Digit Code Combination for Lessor Industries

This table presents the SIC 4-digit code combination for leasing industries with corresponding the description of business across these industries as well as firm-year observations across these industries. The sample period is from 1978 to 2017.

SIC	Industry Name	Obs
1389	Oil and Gas Field Services, Not Elsewhere Classified	8
4119	Local Passenger Transportation, Not Elsewhere Classified	2
4213	Trucking, except Local	36
4222	Refrigerated Warehousing and Storage	22
4499	Water Transportation Services, Not Elsewhere Classified	14
4581	Airports, Flying Fields, and Airport Terminal Services	6
4724	Travel Agencies	8
4812	Radiotelephone Communications	23
4813	Telephone Communications, except Radiotelephone	70
6211	Security Brokers, Dealers, and Flotation Companies	84
6512	Operators of Nonresidential Buildings	112
6513	Operators of Apartment Buildings	14
6519	Lessors of Real Property, Not Elsewhere Classified	55
6531	Real Estate Agents and Managers	79
6792	Oil Royalty Traders	14
7213	Linen Supply	35
7353	Heavy Construction Equipment Rental and Leasing	7
7359	Equipment Rental and Leasing. Not Elsewhere Classified	184
7363	Help Supply Services	7
7374	Computer Processing and Data Preparation and Processing Services	76
7377	Computer Rental and Leasing	33
7381	Detective, Guard, and Armored Car Services	17
7513	Truck Rental and Leasing without Drivers	71
7514	Passenger Car Leasing	33
7819	Services Allied to Motion Picture Production	15
7922	Theatrical Producers and Miscellaneous Theatrical Services	12
7999	Amusement and Recreation Services, Not Elsewhere Classified	122
8231	Libraries	4